ADVERTIZEMENT.

The Institute is not, as a body, responsible for the statements and opinions advanced in the papers which may be read, nor in the discussions which may take place at the meetings of the Institute.

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Coronation of H.M. King Edward VII. and H.M. Queen Alexandra, of the United Kingdom of Great Britain and Ireland and the Dominions thereto belonging, August 9th, 1902: The Humble and Dutiful Address of The North of England Institute of Mining and Mechanical Engineers

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Discussion of Mr. S. J. Pollitzer's paper on "The Underlay-table"
Discussion of Prof. A. Rateaus paper on "The Utilization of Exhaust-steam by the Combined Application of Steam-accumulators and Condensing Turbines"
"The Gypsum of the Eden Valley." By David Burns
Discussion
"The Occurrence of Gold in Great Britain and Ireland." By J. Malcolm Maclaren

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APPENDIX.
Annual Report of the Council and Accounts for the Year 1902-1903; List of Council, Officers and Members, for the Year 1903-1904; the Charter and Bye-laws; etc.
THE NORTH OF ENGLAND INSTITUTE
OF
MINING AND MECHANICAL ENGINEERS.

ANNUAL GENERAL MEETING,
HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
AUGUST 2ND, 1902.

MR. J. G. WEEKS, RETIRING PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on July 19th and that day, and of the Council of The Institution of Mining Engineers.

ELECTION OF OFFICERS, 1902-1903.
The CHAIRMAN (Mr. J. G. w eeks) appointed Messrs. L. Austin, J. Kirsopp, jun., Thomas Lowdon, N. B. Ridley, J. Southern and W. B. Wilson, jun., as scrutineers of the balloting-papers for the election of officers for the year 1902-1903. The scrutineers afterwards reported the result of the, ballot, as follows:-

PRESIDENT:
SIR LINDSAY WOOD, Bart.
Mr. John Simpson moved, and the Retiring President seconded, a vote of thanks to the scrutineers for their services, and it was cordially approved.

Mr. Thomas Douglas moved a vote of thanks to the Retiring President, Vice-Presidents and Councillors, and to the representatives of the Institute on the Council of The Institution of Mining Engineers, for their services during the past year. Their President (Mr. J. G. Weeks) had devoted a very large amount of time and attention to the affairs of the Institute, which had progressed materially during his term of office.

Mr. W. C. Blackett, in seconding the vote of thanks, remarked that the President had carried out his duties to the entire satisfaction of the members.

The vote of thanks was cordially approved.

The Retiring President (Mr. J. G. Weeks), in acknowledging the vote of thanks on his own behalf, and also on behalf of the members of the Council and of their representatives on the Council of The Institution of Mining Engineers, thanked the members for the kind manner in which they had appreciated what had been done during their term of office. Personally, he was very grateful for the honour which they had conferred upon him in electing him as their President; and it was interesting to note that four Presidents had been connected with the Bedlington collieries: namely, the late Mr. Nicholas Wood, Mr. John Daglish, Mr. Thomas Douglas and himself.

The Annual Report of the Council was read as follows.

ANNUAL REPORT OF THE COUNCIL, 1901-1902.

The North of England Institute of Mining and Mechanical Engineers was initiated on July 3rd, 1852, "at a meeting of colliery-owners, viewers and others interested in the coal-trade, for the purpose of forming a society, to meet at fixed periods and discuss the means for the ventilation of mines, for the prevention of accidents, and for general purposes connected with the winning and working of collieries;" under the title of "The North of England Society, for the Prevention of Accidents, and for other Purposes connected with Mining." Of the 44 gentlemen attending
that meeting, 7 survive, and 4 of them (Messrs. Charles William Anderson, Cuthbert Berkley, John Daglish and Thomas Douglas) are still members of the Institute.

The celebration of the Jubilee of the Institute will be held on September 16th next, and, at the invitation of the Council, The Institution of Mining Engineers will conjointly hold their annual meeting.

The following table shews the progress of the membership in successive decades:

<table>
<thead>
<tr>
<th>Year ending August 1st.</th>
<th>1862.</th>
<th>1872.</th>
<th>1882.</th>
<th>1892.</th>
<th>1901.</th>
<th>1902.</th>
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<td>24</td>
<td>22</td>
<td>24</td>
<td>28</td>
<td>25</td>
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<tr>
<td>Members</td>
<td>295</td>
<td>618</td>
<td>669</td>
<td>545</td>
<td>880</td>
<td>893</td>
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<td>Associate Members</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>35</td>
<td>122</td>
<td>109</td>
</tr>
<tr>
<td>Associates</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>34</td>
<td>116</td>
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<td>Students</td>
<td>—</td>
<td>64</td>
<td>115</td>
<td>35</td>
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<td>Subscribers</td>
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<tr>
<td>Totals</td>
<td>326</td>
<td>720</td>
<td>720</td>
<td>691</td>
<td>1,226</td>
<td>1,238</td>
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Although 93 gentlemen have been elected during the past year, there has only been a slight increase in membership, due to the exceptional number of members who have died, and also to the names of a considerable number of members, etc., having been removed from the register by the Council.

The Library has been maintained in an efficient condition during the past year, and the books are now more readily accessible by reference to the card-index. The additions by donation, exchange and purchase, include 314 bound volumes, 151 pamphlets, reports, etc., and the Library now contains about 8,943 volumes and 2,640 pamphlets.

Members would render valuable service to the profession by the donation of books, reports, plans, etc., to the Library, where they would be available for reference.

The Lecture-theatre is being altered and decorated, and will be ready for use during the Jubilee meeting.

The three years' course of lectures for colliery-engineers, engine-wrights, apprentice mechanics, etc., at the Durham College of Science has proved very successful. The lectures are delivered on Saturday afternoons, and the next course will commence in October next. The entire course is as follows: —


Several owners of collieries have paid the fees (£1 10s. per annum) and railway-expenses of pupils attending the classes from their collieries. During the past year, the lectures of
Michaelmas term on Theoretical Electricity and Electrical Engineering were attended by 111 and 110 students respectively: 77 sat for examination and 67 passed. During Epiphany term, the lectures on the Steam-engine and Haulage and Winding were attended by 91 students, of whom 68 sat for examination and 55 passed. Prizes have been awarded to Messrs. James Wray and Arthur Hepburn. Certificates have been awarded to the following students who have completed a three years' course: — Messrs. William Alderson, William Pinkney Armstrong, Alfred Clark, John George Crowder, William Cummings, Thomas Henderson, Arthur Hepburn, Ernest Horler, George William Maddison, James Oswald, William Wainwright and James Wray. Mr. James Wray has received the first prize during each year of his course.

General and Subject-matter Indices to volumes i. to xxxviii. of the Transactions have been published, and will facilitate references to papers.

A Subject-matter Index of Mining, Mechanical and Metallurgical Literature for the Year 1900, has been issued to the members, and will afford access to a large mass of technical literature.

By a mutually advantageous arrangement with the Literary and Philosophical Society of Newcastle-upon-Tyne, the members of either institution are permitted to refer to the books in the Library of the other. The members are also accorded free access to the Museum of the Natural History Society of Newcastle-upon-Tyne.

Mr. John Daglish continues to represent the Institute as a governor of the Durham College of Science, which was jointly founded in 1871 by the University of Durham and the North of England Institute of Mining and Mechanical Engineers. Mr. T. E. Forster represents the Institute on the Council of the Durham College of Science, and the President (Mr. John G. Weeks) is also an ex-officio member.

Mr. J. H. Merivale will again represent the Institute at the Conference of Corresponding Societies of the British Association for the Advancement of Science, to be held in Belfast in September, 1902. Prof. H. Louis is the representative of the Institute on the Science & Art and Scholarships Committees of the Northumberland County Council. Mr. W. Cochrane represents the Institute upon the board of directors of The Institute and Coal-trade Chambers Company, Limited.


The following additional exchanges of Transactions have been arranged during the year: —

- American Philosophical Society.
- Societe d'Encouragement pour l'Industrie Nationale.
- The Institution of Electrical Engineers.

Prizes of books have been awarded to the writers of the following papers, communicated to the members during the year 1900-1901: —
"The Solvent Action of Pyridine on Certain Coals." By Mr. T. Baker, B.Sc.
"Endless-rope Haulage at Axwell Park Colliery." By Mr. R. W. Glass, Stud.I.M.E.
"Some Silver-bearing Veins of Mexico." By Mr. Edward Halse, M.I.M.E.
"Dry and Wet Treatment of Copper-ores." By Capt. C. C. Longridge, M.I.M.E.
"The Employment of Iron Bars at the No. 6 Pit, Lens Colliery." By Mr. E. Reumaux.
"A Method of Boring Deposits out of Rising-main Pipes in Shafts." By Mr. Hugh Ross, M.I.M.E.
"A Flash of Lightning at the Lambton Colliery, D and Lady Ann Pits, on October 2nd, 1900." By Mr. Jacob Sharp, M.I.M.E.
"Safety-lamp Cabin at Heworth Colliery." By Mr. Thomas V. Simpson, Stud.I.M.E.
"Sinking through Swamp, Clay and Sand." By Mr. William Tattley, M.I.M.E.
"Endless-rope Haulage at Pelton Colliery." By Mr. Norman M. Thornton, Stud.I.M.E.

The papers printed in the Transactions during the year are as follows: —
"A Method of Socketing a Winding-rope, and its Attachment to a Gage without the Use of Ordinary Chains." By Mr. W. C. Blackett, M.I.M.E.
"Mechanical Undercutting in Cape Colony." By Mr. John Colley, M.I.M.E.
"Electric Pumping-plant at South Durham Collieries." By Mr. Fenwick Darling, M.I.M.E.
"Memoir of the late George Baker Forster." By Mr. R. H. Forster.
"Memoir of the late George Clementson Greenwell." By Mr. G. C. Greenwell, M.I.M.E.
"Some Silver-bearing Veins of Mexico." By Mr. Edward Halse, M.I.M.E.
"Apparatus for closing the Top of the Upcast-shaft at Woodhorn Colliery." By Mr. C. Liddell, Stud.I.M.E.
"Note on a Mineral Vein in Wearmouth Colliery." By Prof. Henry Louis, M.I.M.E.
"Standardization of Surveyors' Chains." By Prof. Henry Louis, M.I.M.E.
"Report of the Delegate to the Conference of Delegates of Corresponding Societies of the British Association for the Advancement of Science, Glasgow, 1901. By Mr. John H. Merviale, M.I.M.E.
"A Visit to the Simplon Tunnel: the Works and Workmen." By Dr. Thomas Oliver.
"The Carboniferous Limestone Quarries of Weardale." By Mr. A. L. Steavenson, M.I.M.E.
"Auriferous Gravels and Hydraulic Mining." By Mr. William S. Welton, M.I.M.E.
"Tapping Drowned Workings at Wheatley Hill Colliery." By Mr. W. B. Wilson, Jun., M.T.M.E.

Mr. James Stirling, government geologist and mining representative of Victoria, delivered an interesting lecture on "Mines and Mining in Victoria," illustrated by lantern-slides.

The award of the Greenwell medals will be made for approved papers communicated during the past year "recording the results of experience, and the deductions and practical suggestions of the writers for the avoidance of accidents."
As no papers have been received in competition for the prize offered by Mr. Clarence R. Claghorn for an approved essay on "The Action, Influence and Control of the Roof in Longwall Working," the Council will select another subject for papers in competition for this prize.

Excursions have been made to South Durham, Washington and Woodhorn collieries, and to the Parson Byres quarries, and the thanks of the members have been accorded to the owners of these collieries and works.

Members are desired to send copies of any unpublished sections of strata in the counties of Northumberland and Durham, in order that they may be incorporated in a supplementary volume to An Account of the Strata of Northumberland and Durham, as proved by Borings and Sinkings.

A committee has been appointed to investigate and report upon labour-saving machines and tools used in cutting and boring coal and rock.

The members are to be congratulated on the success that has attended the formation of The Institution of Mining Engineers, which has now completed its thirteenth year. Meetings have been held during the past year in the Glasgow district in September, 1901, and in London in May, 1902.

The Chairman (Mr. J. G. Weeks), in moving the adoption of the report of the Council, remarked that the number of papers read during the year was very satisfactory, the attendance at the meetings had been good, and altogether the members had got through a considerable amount of work.

Mr. Thomas Douglas seconded the resolution, which was unanimously agreed to.

The Report of the Finance Committee was read as follows:

---

REPORT OF THE FINANCE COMMITTEE.
The Finance Committee submit herewith a statement of accounts for the twelve months ending June 30th, 1902.
The total receipts during that period were £2,813 2s. 6d. Of this amount, £24 18s. 0d. was paid as balance of life-composition in lieu of annual subscriptions; £102 8s. represent subscriptions paid in advance, and £10 has been received from Mr. Clarence R. Claghorn as a prize to be offered for a paper; leaving £2,675 16s. 6d. as the ordinary income of the year, as compared with £2,582 11s. 7d. in the previous year.
The expenditure amounted to £2,443 9s. 4d. as compared with £2,115 10s. 10d., the ordinary expenditure for last year. This increase is principally due to expenditure incurred in connection with the publication of the General and Subject-matter Indices to the Transactions and the Subject-matter Index of Mining, Mechanical and Metallurgical Literature for the Year 1900, and the additional sum paid to The Institution of Mining Engineers on the increased membership. Deducting the total expenditure from the income for the year, leaves a balance of £369 13s. 2d.: and this added to the sum of £637 13s. 10d. brought from the previous year, gives a credit-balance of £1,007 7s. 0d.
During the year £180 10s. have been written off the amount of subscriptions and arrears. The amount of subscriptions for the year 1901-1902 still unpaid is £271 19s. and for previous years £47 4s.

The cost of the alterations to the Lecture-theatre, ordered by the Council, will come into the accounts for the year 1902-1903. There will also be in that year, considerable expenditure in connection with the Jubilee of the Institute, but the Committee hope to be able to provide the necessary funds out of the balance in hand and the surplus income for the coming year.

Thomas Douglas.

August 2nd, 1902.

[9]

General Statement, June 30th, 1902

LIABILITIES.

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<th>Description</th>
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<th>d.</th>
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<td>Subscriptions paid in advance during the current year</td>
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<td>106</td>
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<tr>
<td>The Institution of Mining Engineers</td>
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<td>Printing and Stationery</td>
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<td>George Clementson Greenwell Prize Fund</td>
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<td>Mr. Clarence R. Claghom: Prize for Essay</td>
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<td>Capital</td>
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<td>£12,419</td>
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ASSETS.

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<td>Balance of Account at Bankers</td>
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<tr>
<td>In Treasurers hands</td>
<td>56</td>
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<td>6</td>
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<td>Author's Excerpts</td>
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<td></td>
<td>1,007</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Arrears of Subscription</td>
<td>319</td>
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179 Shares in the Institute and Coal-trade Chambers Company, Limited (at cost) 4,100 0 0
Investment with the Institute and Coal-trade Chambers Company, Limited (Mortgage) 1,400 0 0

---------- 5,500 0 0

(Of the above amount, £1.013 148. is due to Life Subscriptions Account.)

Value of Transactions and other Publications, as per Stock Account 442 13 2
Books, Pictures, Maps, Furniture and Fittings 5,150 0 0

---------- £12,419 3 2

We, having examined the above account with the books, vouchers and securities relating thereto, certify that, in our opinion, it is correct. We have accepted the assets, books, pictures, maps, etc., and Transactions and other Publications as valued by your Officials.

JOHN G. BENSON AND SON,
CHARTERED ACCOUNTANTS.

Newcastle-upon-Tyne,
August 2nd, 1902.

[10]

The Treasurer in Account with The North of England Institute of Mining and Mechanical Engineers
For the year ending June 30th, 1902.

Dr.

June 30th. 1901. £ s. d. £ s. d.
To Balance at Bankers 593 6 10
" " in Treasurer's hands 44 7 0

---------- 637 13 10

To Dividend of 7½ per cent. on 179 Shares of £20 each in the Institute and Coal-trade Chambers Company, Limited, for the year ending June 30th, 1902 268 10 0.
Interest on Mortgage of £1,400 with the Institute and Coal-trade Chambers Company, Limited 49 0 0

---------- 317 10 0

To Sale of Transactions 77 0 6
To Subscriptions for 1901-1902 as follows :
706 Members @ £2 2s. 1,482 12 0
87 Associate Members @ £2 2s. 182 14 0
93 Associates @ £1 5s. 116 5 0
### Membership and Subscriptions

<table>
<thead>
<tr>
<th>Category</th>
<th>Fee</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>47 Students</td>
<td>£1 5s.</td>
<td>58 15 0</td>
</tr>
<tr>
<td>58 New Members</td>
<td>£2 2s.</td>
<td>121 16 0</td>
</tr>
<tr>
<td>2 New Members (not yet elected)</td>
<td>£2 2s.</td>
<td>4 4 0</td>
</tr>
<tr>
<td>7 New Associate Members</td>
<td>£2 2s.</td>
<td>14 14 0</td>
</tr>
<tr>
<td>13 New Associates</td>
<td>£1 5s.</td>
<td>16 5 0</td>
</tr>
<tr>
<td>20 New Students</td>
<td>£1 5s.</td>
<td>25 0</td>
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<tr>
<td>20 Subscribing Firms</td>
<td></td>
<td>2,022 5 11</td>
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<tr>
<td>To Life Composition:</td>
<td></td>
<td>2,110 9 0</td>
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<tr>
<td>1 New Member</td>
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<td>2,135 7 0</td>
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<tr>
<td>Less—Subscriptions for current year paid in advance at the end of last year</td>
<td></td>
<td>2,034 13 0</td>
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<tr>
<td>Add—Arrears received</td>
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<td>2,260 4 0</td>
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<tr>
<td>Add—Subscriptions paid in advance during the current year</td>
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<tr>
<td>To Technical Index</td>
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<td>46 0 0</td>
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<tr>
<td>To Mr. C. R. Claghorn for Prize</td>
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<td>10 0 0</td>
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<tr>
<td>Total</td>
<td></td>
<td>£3,450 16 4</td>
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</table>

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11
INSTITUTE OF MINING AND MECHANICAL ENGINEERS. JUNE 30TH, 1902.
Cr.

<table>
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<tr>
<th>Description</th>
<th>£</th>
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<td>June 30th, 1902.</td>
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<tr>
<td>By Annual Report</td>
<td>31</td>
<td>17</td>
<td>6</td>
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<tr>
<td>Banker's Charges</td>
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<td>British Association for the Advancement of Science:</td>
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<td>Expenses of Delegate</td>
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<td>Circulars, etc.</td>
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<td>1</td>
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<tr>
<td>Description</td>
<td>Amount</td>
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</tr>
<tr>
<td>-------------------------------------------------</td>
<td>----------</td>
<td></td>
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<tr>
<td>Cleaning Wood Memorial Hall, Offices, etc.</td>
<td>29 7 5</td>
<td></td>
<td></td>
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<tr>
<td>Electric Light and Gas</td>
<td>31 17 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expenses of General Meetings</td>
<td>6 15 6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fire Insurance</td>
<td>12 1 3</td>
<td></td>
<td></td>
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<tr>
<td>Fuel</td>
<td>16 9 5</td>
<td></td>
<td></td>
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<tr>
<td>Furniture and Repairs</td>
<td>62 4 6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Illustrations</td>
<td>6 17 4</td>
<td></td>
<td></td>
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<tr>
<td>Incidental Expenses</td>
<td>8 17 0</td>
<td></td>
<td></td>
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<tr>
<td>Index to Transactions</td>
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<td>Library—Books</td>
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<td>&quot; Binding</td>
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<tr>
<td>Petty Cash</td>
<td>8 19 9</td>
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<tr>
<td>Postages—Circulars</td>
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<tr>
<td>&quot; Correspondence</td>
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<tr>
<td>&quot; Publications</td>
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<td></td>
<td>106 7 1</td>
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<tr>
<td>Prizes for Papers</td>
<td>24 13 9</td>
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<td></td>
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<tr>
<td>Rates and Taxes</td>
<td>6 4 7</td>
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<td></td>
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<tr>
<td>Rent of Offices</td>
<td>24 9 2</td>
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<td></td>
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<tr>
<td>Reporting of General Meetings</td>
<td>13 2 6</td>
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<tr>
<td>Salaries. Wages, Auditing, etc.</td>
<td>471 13 7</td>
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<tr>
<td>Stationery, etc.</td>
<td>27 14 11</td>
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<td></td>
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<tr>
<td>Technical Index</td>
<td>3 17 3</td>
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<tr>
<td>Telephone Rent</td>
<td>2 17 0</td>
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<td>Travelling Expenses</td>
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<td>&quot; Water Rate</td>
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<td>Wood Memorial Hall: Alterations</td>
<td>49 13 0</td>
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<td>1,224 6 6</td>
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<tr>
<td>By The Institution of Mining Engineers</td>
<td>1,224 7 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less—Amounts paid by Authors for Excerpts</td>
<td>5 4 6</td>
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<td></td>
<td>1,219 2 10</td>
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<tr>
<td>By Balance at Bankers</td>
<td>949 17 6</td>
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<tr>
<td>&quot; in Treasurer's hands</td>
<td>56 8 6</td>
<td></td>
<td></td>
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<tr>
<td>&quot; Outstanding Amounts due for Authors' Excerpts</td>
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<tr>
<td></td>
<td>1,007 7 0</td>
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</tr>
<tr>
<td></td>
<td>2,413 9 4</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>£3,450 16 4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
We, having examined the above account with the books and vouchers relating thereto, certify that, in our opinion, it is correct.

JOHN G. BENSON AND SON.
Chartered Accountants.

Newcastle-upon-Tyne,
August 2nd, 1902.

[12]

Dr.
The Treasurer in Account with Subscriptions, 1901 – 1902

<table>
<thead>
<tr>
<th>To 880 Members.</th>
<th>£  s. d.</th>
<th>£  s. d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>49 of whom have paid Life Compositions.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>831</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Member paid Life Composition</td>
<td>24 18 0</td>
<td></td>
</tr>
<tr>
<td>830</td>
<td></td>
<td></td>
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<tr>
<td>4 not included in printed list</td>
<td>@ £2 2s.</td>
<td>1,751 8 0</td>
</tr>
<tr>
<td>To 122 Associate Members.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 of whom have paid Life Compositions.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>114</td>
<td>@ £2 2s.</td>
<td>239 8 0</td>
</tr>
<tr>
<td>To 116 Associates,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 of whom have paid as New Members.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>111 Associates</td>
<td>@ £1 5s.</td>
<td>138 15 0</td>
</tr>
<tr>
<td>To 57 Students</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 of whom have paid as New Members.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>55</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 of whom has paid Life Composition.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>54 Students</td>
<td>@ £1 5s.</td>
<td>67 10 0</td>
</tr>
<tr>
<td>To 23 Subscribing Firms</td>
<td></td>
<td>96 12 0</td>
</tr>
<tr>
<td>To 58 New Members</td>
<td>@ £2 2s.</td>
<td>121 16 0</td>
</tr>
<tr>
<td>To 2 New Members, not yet elected.</td>
<td>@ £2 2s.</td>
<td>4 4 0</td>
</tr>
<tr>
<td>60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>To 7 New Associate Members</td>
<td>@ £2 2s.</td>
<td>14 14 0</td>
</tr>
<tr>
<td>To 13 New Associates</td>
<td>@ £1 5s.</td>
<td>16 5 0</td>
</tr>
<tr>
<td>To 20 New Students</td>
<td>@ £1 5s.</td>
<td>25 0 0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2,500 10 0</td>
</tr>
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To Arrears, as per balance sheet 1900-1901 | 297 0 0 |

Add—Arrears considered irrecoverable, but since paid | 63 1 0 |
<table>
<thead>
<tr>
<th>Description</th>
<th>Paid</th>
<th>Unpaid</th>
<th>Struck off list</th>
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<tbody>
<tr>
<td>By 706 Members, paid</td>
<td>£2 2s.</td>
<td>1,482 12 0</td>
<td></td>
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<tr>
<td>By 96 &quot; unpaid</td>
<td>£2 2s.</td>
<td>201 12 0</td>
<td></td>
</tr>
<tr>
<td>By 8 &quot; dead</td>
<td>£2 2s.</td>
<td>16 16 0</td>
<td></td>
</tr>
<tr>
<td>By 24 &quot; struck off list</td>
<td>£2 2s.</td>
<td>50 8 0</td>
<td></td>
</tr>
<tr>
<td>By 1 Member, paid Life Composition</td>
<td></td>
<td>24 18 0</td>
<td></td>
</tr>
<tr>
<td>By 87 Associate Members, paid</td>
<td>£2 2s.</td>
<td>182 14 0</td>
<td></td>
</tr>
<tr>
<td>By 17 &quot; unpaid</td>
<td>£2 2s.</td>
<td>35 14 0</td>
<td></td>
</tr>
<tr>
<td>By 1 &quot; dead</td>
<td>£2 2s.</td>
<td>2 2 0</td>
<td></td>
</tr>
<tr>
<td>By 9 &quot; struck off list</td>
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<td>18 18 0</td>
<td></td>
</tr>
<tr>
<td>By 93 Associates, paid</td>
<td>£1 5s.</td>
<td>116 5 0</td>
<td></td>
</tr>
<tr>
<td>By 15 &quot; unpaid</td>
<td>£1 5s.</td>
<td>18 15 0</td>
<td></td>
</tr>
<tr>
<td>By 3 &quot; struck off list</td>
<td>£1 5s.</td>
<td>3 15 0</td>
<td></td>
</tr>
<tr>
<td>By 47 Students, paid</td>
<td>£1 5s.</td>
<td>58 15 0</td>
<td></td>
</tr>
<tr>
<td>By 6 &quot; unpaid</td>
<td>£1 5s.</td>
<td>7 10 0</td>
<td></td>
</tr>
<tr>
<td>By 1 &quot; struck off list</td>
<td>£1 5s.</td>
<td>1 5 0</td>
<td></td>
</tr>
<tr>
<td>By 20 Subscribing Firms, paid</td>
<td></td>
<td>88 4 0</td>
<td></td>
</tr>
<tr>
<td>By 3 &quot; unpaid</td>
<td></td>
<td>8 8 0</td>
<td></td>
</tr>
<tr>
<td>By 58 New Members, paid</td>
<td>£2 2s.</td>
<td>121 16 0</td>
<td></td>
</tr>
<tr>
<td>By 2 New Members, not yet elected.</td>
<td></td>
<td>4 4 0</td>
<td></td>
</tr>
<tr>
<td>By 7 New Associate Members, paid</td>
<td>£2 2s.</td>
<td>14 14 0</td>
<td></td>
</tr>
<tr>
<td>By 13 New Associates, paid</td>
<td>£1 5s.</td>
<td>16 5 0</td>
<td></td>
</tr>
<tr>
<td>By 20 New Students, paid</td>
<td>£1 5s.</td>
<td>25 0 0</td>
<td></td>
</tr>
</tbody>
</table>
The Chairman (Mr. J. G. Weeks), in moving the adoption of the report of the Finance Committee, said it was satisfactory to know that there was a considerable credit-balance. The alterations to the Lecture-theatre would cost about £1,000, and when these were completed he thought that the comfort and convenience of the members would be materially increased. The architect had promised that the alterations should be completed in time for the Jubilee Meeting in September next.

Mr. Thomas Douglas seconded the resolution, which was unanimously agreed to.

REPRESENTATIVES ON THE COUNCIL OF THE INSTITUTION OF MINING ENGINEERS.

Mr. Thomas Douglas moved, and Mr. W. C. Blackett seconded a resolution, that the following gentlemen be elected as the representatives of the Institute on the Council of The Institution of Mining Engineers for the year 1902-1903:

Mr. William Armstrong        Mr. T. E. Forster.        Mr. John Morison.
Mr. Jon Batey.                Mr. William Galloway.     Mr. M. W. Parrington.
Sir Lowthian Bell, Bart.      Mr. John Gerrard.         Prof. R. A. S. Redmayne.
Mr. T. W. Benson.             Mr. Reginald Guthrie.  Mr. A. R. Sawyer.
Mr. Bennett H. Brough.        Mr. Philip Kirkup.        Mr. J. B. Simpson.
Mr. A. G. Charleton.          Mr. C. C. Leach.         Mr. John G. Weeks.
Mr. John Daglish.             Prof. Henry Louis.        Sir Lindsay Wood, Bart.
Sir David Dale, Bart.         Mr. George May.         Mr. W. O. Wood.

The resolution was agreed to.

The following gentlemen were elected, having been previously nominated: —
Members—
Mr. Arthur Andrews, Electrical Engineer, 20, Carlyon Street, Sunderland.
Mr. John Frank Bledsoe, Mining Engineer, 309-310, Washington Block, Seattle, Washington, United States of America.
Mr. Thomas William Davies, Mining Engineer. Vereeniging Estates, Vereeniging, Transvaal.
Mr. George Eltringham, Colliery Manager, Eltringham Colliery, Ovingham-upon-Tyne, Northumberland.
Mr. Antonio Gascon y Miramon, Mining Prospector, etc., 36, Serrano, Madrid, Spain.
Mr. Gustave Gillman, Civil Engineer, Aguilas, Provincia de Murcia, Spain.

Mr. John Dampier Green, Engineer, P.O. Box 340, Johannesburg, Transvaal.
Mr. Reginald Thomas Hooper, Mining Engineer, Derwent Villa, St. Agnes, Cornwall.
Mr. John William Jamieson, Mining Engineer, Medomsley, R.S.O., County Durham.
Prof. Auguste Rateau, Ingenieur an Corps des Mines, 105, Quai d'Orsay, Paris, France.
Mr. Wardle Asquith Swallow, Mining Engineer, Tanfield Lea Colliery, Tantobie, R.S.O., County Durham.
Mr. Earle W. Jenks Trevor, Mining Engineer, 78, Palace Chambers, 9, Bridge Street, Westminster, London, S.W.
Mr. Robert Turnbull, Mechanical Engineer, Usworth Colliery, Washington, R.S.O., County Durham.
Mr. Michael Watson, Mechanical Engineer, 4, St. Nicholas Buildings, Newcastle-upon-Tyne.
Mr. Griffith John Williams, H.M. Inspector of Mines, Bangor, North Wales.

Associate Members—
Mr. Frederic Barrie Jack, 32, Grainger Street West, Newcastle-upon-Tyne.
Mr. Thomas Lambert, Town-hall Buildings, Gateshead-upon-Tyne.
Mr. Edward Arthur Langslow-Cock, 22, Elsham Road, Kensington, London, W.

Associates—
Mr. Robert Blair, Mining Surveyor, 6, Hamilton Terrace, Whitehaven, Cumberland.
Mr. John Cummings, Colliery Under-manager, Rowlands Gill Colliery, Newcastle-upon-Tyne.
Mr. Thomas Ford, Overman, Washington, R.S.O., Co. Durham.
Mr. Joseph Cresswall Roscamp, Colliery Manager's Assistant, Ravensworth Colliery, Low Fell, Gateshead-upon-Tyne.
Mr. Thomas Carlton Stobart, Under-manager, Ushaw Moor Colliery, County Durham.

Students—
Mr. Harold Percy Bell, Mining Student, Clyvedon, Cleadon, Sunderland.
Mr. George Cook, Mining Student, Binchester Hall, Bishop Auckland.
Mr. Benjamin Starks Field, Mining Engineering Apprentice, 8, Esplanade, Whitley, R.S.O., Northumberland.
Mr. Robert Norman Fowler, Surveyor. Usworth Villa, Great Usworth, Washington, R.S.O., County Durham.
Mr. John Norman Humble, Mining Student, West Pelton House, Beamish, R.S.O., County Durham.
Mr. George Adamson Strong, Mining Student, Byron House, Ouston, Chester-le-Street, County Durham.
Mr. William Wilson, Mining Student, Usworth Colliery, Washington, R.S.O., Comity Durham.

[16]

THE GASES ENCLOSED IN COAL.*

By DR. BROOCKMANN.†

'I the first work on this subject was done by Prof. Ernst von Meyer‡ in 1870, his method being as follows:-

Pieces of coal of the size of a nut were boiled in a flask, filled with boiling (air-free) water, and closed with an indiarubber-stopper, through which a glass tube led the escaping gases, which were collected over boiling water. In order to obtain the gas in the pure state, it is necessary to keep the water boiling gently. When vigorous ebullition takes place, air diffuses into the flask, however good the indiarubber-stopper may be.

Prof. E. von Meyer obtained from British and Westphalian coals, heated to 100° Cent., from 4 to 238 cubic centimetres of gas per 100 grammes of coal. The gases were of variable composition: all contained nitrogen, oxygen, carbonic acid and marsh-gas; and coals from Zwickau gave off higher hydrocarbons in addition to the above-named gases.

In 1875, Mr. W. J. Thomas§ extracted the gases by heating to 100° Cent. and afterwards exhausting the gases by means of a Sprengel air-pump. He thus obtained from 30 to 600 cubic centimetres of gas per 100 gramme of dry South Wales coal, the gas having the same composition as that given by Prof. E. von Meyer. Some cannel coals and jet, however, gave only carbonic acid and nitrogen, others carbonic acid, nitrogen, marsh-gas and higher hydrocarbons. Mr. Thomas used indiarubber-tubes for connecting his apparatus.

† Translated and somewhat condensed by Prof. Henry Louis.
§ Journal of the Chemical Society, 1876, vol. xxx., page 144.
Prof. Jeller experimented on coals from Rossitz by the Meyer method, and obtained per 100 grammes of coal heated to 100° Cent.:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>I.</td>
<td>54</td>
<td>56</td>
<td>3</td>
<td>16</td>
<td>23</td>
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<tr>
<td>I.</td>
<td>38</td>
<td>35</td>
<td>10</td>
<td>4</td>
<td>51</td>
</tr>
<tr>
<td>III.</td>
<td>60</td>
<td>36</td>
<td>25</td>
<td>7</td>
<td>32</td>
</tr>
</tbody>
</table>

The author investigated dust and coal from Rossitz, the coal, however, being old. He obtained somewhat different results from Prof. Jeller, and he is not quite certain whether higher hydrocarbons than ethane (C₂H₆) were not present. With this reservation, he found 50 cubic centimetres of gas containing 31 per cent. of carbonic acid, 30 per cent. of marsh-gas, 19 per cent. of ethane, and 20 per cent. of nitrogen.

Recently Dr. P. P. Bedson, of the Durham College of Science, Newcastle-upon-Tyne, has taken up the same subject. He used about the same method as that employed by Mr. Thomas. The coals were heated in a closed vessel to different temperatures, the glass vessel being closed by a perforated indiarubber-stopper and connected with an air-pump to draw off the escaping gases. In addition to other coals, Dr. Bedson investigated the coal of the Hutton seam of the Ryhope colliery, Durham, the dust of which coal is known to be dangerous. He examined the fresh coal, coal subsequently pulverized, and also coal-dust. From 100 grammes of fresh coal he obtained 818 cubic centimetres of gas, which, however, only contained 17 per cent. or combustible gases. From the pulverized coal, which he heated to 184° Cent., he obtained a gas containing 27 per cent. of oxygen.

Dr. Bedson probably was not aware of the labours of the Austrian Commission, or he would have referred to them. He lays down as quite new the existence of two types of coals: (1) those which contain higher hydrocarbons, and are dangerous, and (2) those which contain no higher hydrocarbons, and form a less dangerous dust.

As already pointed out, all the chemists in question have used indiarubber. This is an almost indispensable material for the chemist, but, unfortunately, it is unsuitable in many cases, especially when working with pressures varying from the normal,


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these, three chemists have collected and investigated not the pure gases occluded in coals, but atmospheric air, from which the heated coal has absorbed a greater or lesser quantity of oxygen, and which was more or less contaminated with the occluded gases and the products of the heating of the coal. The latter point will be referred to again.

The author doubts the accuracy of the results obtained by these chemists, more particularly those of Dr. Bedson, so far as concerns Westphalian coals:—(1) He had long ago obtained some gas by boiling coal under water, but had contented himself with proving that such gases were combustible gases, the quantity being too small for analysis. (2) He had examined 30 to 40 pure blowers in Westphalian collieries, which gave over 99 per cent. of marsh-gas, the remainder being carbonic acid, but no trace of nitrogen or oxygen. As the occluded gases are indubitably the sources of the blowers, the latter would obviously have to contain nitrogen and oxygen if these were contained in the occluded gases. Blowers from other coal-fields have often been found to contain almost pure marsh-gas. (3) He had certainly found, now and then, traces of hydrocarbons or of hydrogen itself in the air of Westphalian collieries; but he had long ago come to the conclusion that both of these gases were not originally contained in the gases escaping from the coal, and that they had found their way into the return-airways owing to decomposition, heating, or accidental admixture.

In order to obtain gases as pure as possible from coal, he had arranged a Sprengel air-pump, on which a glass vessel was blown, to act as the receiver for the coals. By this arrangement all possibility of leakage in the apparatus was excluded. In order to remove as far as possible adhering air from the inner surface of the glass and from the coal, he had allowed his apparatus to stand as long as three days, repeatedly renewing the vacuum; he had then heated the vessel containing the coal to 100° Cent. in a water-bath, drawn off the escaping gases, and collected them over mercury.

All who know how difficult it is to remove adhering air from solid bodies will understand the necessity for this precaution; it, nevertheless, involves a source of error, inasmuch as each renewal of the vacuum removes a certain amount of the gases escaping from the coal, namely, such as would escape at ordinary atmospheric temperature into a vacuum. This error will be greater in those coals which give off their enclosed gases readily than in others which hold them more firmly. It is impossible, therefore, in the Meyer method or in any other, to determine the total quantity of the enclosed gases. For instance, in the author's method, only that portion is obtained which is able to escape from pieces of the dimensions employed in vacuo at a temperature of 100° Cent., minus that portion which escapes while the vacuum is being produced. The quantities of gas obtained by the author must therefore be looked upon as minima. They are, however, comparable with each other, because he always used fragments of the same size (2 to 4 millimetres in diameter). It is obvious that the larger the fragments the more gas will be retained in the coal, while it can escape the more readily the smaller the particles are.

Table I. shows the results of his investigations; and, for convenience, the coke and gas obtainable in each experiment are given, calculated upon the pure coal. The quantity of coal employed was always 100 grammes. It was always heated to 100° Cent. in the water-bath, and the gases removed until completely exhausted, which often took several days.
The Austrian Commission, and also Dr. Bedson, have attempted to draw various conclusions from the gases occluded in coal. They have attempted to explain explosions of coal-dust as follows: —Owing to the heat of a blown-out shot, the occluded gases are supposed to be evolved from the coal-dust thrown up by the shot, and this gas should form with air an explosive mixture which may be fired by the flame of the shot. This explosion would then induce a subsequent true coal-dust explosion. The gas is supposed to be especially dangerous when higher hydrocarbons are present in the occluded gases. These form an explosive mixture with air, and are, moreover, easily inflammable.

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[Table I, showing amounts and compositions of gases from 12 coals, omitted.]

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It will probably be impossible to prove this explanation experimentally until we can get an explosive whose temperature of detonation is under 650° Cent., the ignition-temperature of marsh-gas, so that the temperature would only suffice to ignite the higher hydrocarbons. The explanation must, however, fail, for all coals the dust of which is known to be explosive, if these contain none of the higher hydrocarbons, as, for instance, No. 13 seam at Hibernia colliery, No. 8 seam at Pluto colliery, and No. 3 seam at Camphausen colliery.

In this explanation, the fact is also overlooked that when a shot is fired pressure is produced, so that the occluded gases are not allowed to escape as into a vacuum, but, on the contrary, are driven into the pores of the coal. If the explanation is a correct one, the author's results would support it far better, seeing that he has found in the occluded gases of the Hutton seam scarcely anything but combustible gases, while Dr. Bedson has found only 20 per cent. of such gases, so that in the former case an explosive mixture would far more readily be formed than in the latter. Further, no attention is paid to the fact that when coal is heated in the presence of air, which corresponds to the actual conditions, quite different products are obtained from those when the coal is heated in a vacuum. The question to be solved is: What gas is produced when coal is heated in the presence of air at low temperatures, up to 650° Cent.? Messrs. Varrentrapp and Richters have already given an answer to the above question, which may be read between the lines of their classical works. Nitrogen must be produced, because the oxygen is absorbed.* In order to get a more accurate idea of the nature of the gases left when coal was heated in air, the author had heated about ½ gramme of coal, in sealed glass-tubes, of a capacity of about 60 to 70 cubic centimetres, in an air-bath to temperatures of 160° to 200° Cent., and had then investigated the residual air. He always heated the coal to above 160° Cent., because he was certain that oxygen would be absorbed at that temperature. At 160° Cent., many coals (he cannot say with certainty all coals) absorbed oxygen with extreme energy. The results are shown in Table II., in which the numbers refer to the same coals as in Table 1.

Table II.

<table>
<thead>
<tr>
<th></th>
<th>IV.</th>
<th>XI.</th>
<th>VII.</th>
<th>VII.</th>
<th>VII</th>
<th>I.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen, N₂</td>
<td>98</td>
<td>96</td>
<td>95</td>
<td>94</td>
<td>94</td>
<td>93</td>
</tr>
<tr>
<td>Carbonic acid, CO₂</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Olefines, CₓHᵧ</td>
<td>trace</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Oxygen, O₂</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Totals</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
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</table>

CₓHᵧ represents a higher hydrocarbon, which may be determined by calculation from the phenomenon of combustion to be either C₂H₆ or C₃H₆. The author draws, however, definite attention to the circumstance that other products of heating are obtained (for example an acid [? acetic acid]), the gases from which are mixed with the air, are not absorbed by caustic potash, and are combustible. Dr. Bedson has obtained similar products by heating his coals to 184° Cent. in vacuum (as he imagines), and has obtained a residue of air which he has recorded as occluded gas. The composition of this residual gas is as follows:

<p>| | |</p>
<table>
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<tbody>
<tr>
<td>Nitrogen</td>
<td>62.6</td>
</tr>
<tr>
<td>Carbonic acid</td>
<td>5.8</td>
</tr>
<tr>
<td>Paraffins</td>
<td>4.6</td>
</tr>
<tr>
<td>Oxygen !</td>
<td>27.0</td>
</tr>
</tbody>
</table>

This result absolutely upsets everything known with regard to coal. Dr. Bedson does not, however, even once point out that he has discovered a new method of producing oxygen! The writer has already pointed out sufficiently how air found its way into his apparatus. How oxygen may have been obtained by heating to 184° Cent. may be explained through the air having been drawn of too quickly, so that it had not time to come into contact with the heated coal. How, however, he obtained 27 per cent. of oxygen is inexplicable.

With regard to Table II., it may be noted that the results refer only to the conditions there given. If a larger quantity of coal is heated in a tube of the above size (70 cubic centimetres), the oxygen contained therein does not suffice for complete oxidation, and some marsh-gas remains. In order to prove this experimentally, the author has heated in a tube of 70 cubic centimetres capacity 6, 4, 2, 1 and ½ gramme respectively of coal No. XI., and

[23]

has examined the residual air, with the results recorded in Table III.

Table III.

<table>
<thead>
<tr>
<th></th>
<th>6 grammes.</th>
<th>4 grammes.</th>
<th>2 grammes.</th>
<th>1 gramme.</th>
<th>½ gramme.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen, N₂</td>
<td>85</td>
<td>90</td>
<td>91</td>
<td>95</td>
<td>96</td>
</tr>
<tr>
<td>Carbonic acid, CO₂</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Marsh-gas, CH₄</td>
<td>14</td>
<td>9</td>
<td>7</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Olefines, CₓHᵧ</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Oxygen, O₂</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Totals</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>
With reference to Table III., it may be noted that the content of carbonic acid is remarkably small, less than might have been expected from the quantity of marsh-gas present, the reason being the above-mentioned, that when coal is heated in the presence of oxygen other products than carbonic acid are formed. In the first four analyses, the writer was unable to find these products in the gaseous form (the residual gas was pure marsh-gas), but he was able to prove the invariable formation of some strong acid soluble in water (acetic acid ?).

In Tables II. and III., the absence of oxygen is especially indicated, in order to accentuate the fact that it is impossible to find free oxygen in a closed vessel in which coal has been heated. Volumetrically this absorption of oxygen is very important. One part of coal by volume in the form of powder suffices to absorb 50 times its volume of oxygen between 160° and 200° Cent., and to render 250 times its volume of air incapable of explosion. In these results, however, time also plays a part, so that further insistence upon them would be unfruitful.

How then may a coal-dust explosion be explained? As long as we blast with explosives, whose temperature of detonation is above 650° Cent., and which show flame, we have in a blown-out shot a source of heat (not only a source of warmth) which can generate abundant quantities of gas from coal, and at the same time produce a flash, which is capable of firing the explosive gaseous mixture thus formed. One part of gas-coal gives about 300 times its volume of gas when all the latter is evolved. The crusts of coke, which cover everything in the pit after a coal-dust explosion, may be looked upon as coal from which about half of the gas has been set free. There is, therefore, in a coal-dust explosion evidently no want of combustible gas, though there may be of air. For this reason, the wave of explosion is propagated in the opposite direction to the intake air-current. On its way, it liberates further gas from coal-dust that is thrown up; it, therefore, constantly requires fresh air, and thus continues its course to the downcast-shaft, which it also frequently destroys. In coal-dust explosions, the large volume of air which the miner employs for the ventilation of the mine is a source not of safety but of destruction. The flash of a blown-out shot can cause the ignition of an explosive mixture of gas, but even its presence may be dispensed with, for the powerful pressure which a blown-out shot produces may cause the ignition-temperature of marsh-gas to be attained. Here, however, the conversion of mechanical work into heat does not play the principal part, but the properties of oxygen, which are affected by compression, inasmuch as compressed oxygen has a far more violent oxidizing action than it has under normal pressure.

It is, therefore, not a matter of indifference how a shot-hole is placed: whether the shot blows out straight along the centre of the road, whether it lies at an acute angle to the roof or the floor, or perpendicular to the solid mass of coal.

The main factor in a coal-dust explosion is, and remains, the fine state of division of the dust; the second condition is the heating of the dust; while the chemical properties of the coal only occupy the third place. All coals can produce dust-explosions, even coke, which is perfectly free from gas. Supposing that finely-divided coke were flung up by means of a blown-out shot, at a sufficiently high temperature, this would burn to carbon monoxide in the presence of sufficient coke, and produce an explosive mixture with air.

Some coals give off gas at lower, others at higher temperatures; some are dry, others moist; some produce a very finely divided, others a coarse-grained dust, etc. For the production of
coal-dust explosions the former conditions require a lighter, the latter a heavier charge of explosive.

Prof. P. P. Bedson read the following paper on "The Gases enclosed in Coal and Coal-dust":

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THE GASES ENCLOSED IN COAL AND COAL-DUST.

By P. PHILLIPS BEDSON

In the early part of the year 1899, a paper on the subject of the gases enclosed in coal appeared in Gluckauf* in which Dr. Broockmann gave an account of the results of his examination for "enclosed gases" of coals of the Westphalian coal-field; and, at the same time, detailed the results of his examination of the Hutton-seam coal, which he had obtained from Ryhope colliery. This coal was submitted to investigation, because Dr. Broockmann had reason to doubt the results obtained by the late Mr. McConnell and the author, which were described in a paper read before this Institute in February, 1894.t

After the perusal of this paper in Gluckauf, it appeared desirable to re-investigate the question rather than simply replying to the strictures of Dr. Broockmann, with the information then to hand. For this purpose, in November, 1899, the late Mr. McConnell collected samples of coal from the Hutton seam at Ryhope colliery, and the investigation, then commenced, has been continued until the present time. In the summer of 1900, Mr. McConnell was accidentally drowned, while boating off the Northumberland coast, consequently the author has not had the benefit of his assistance; and for information on the work which formed the basis of the conjoint paper already referred to, he has had to content himself with the laboratory-notes and journals left by his friend. This sad event, therefore, made the repetition of a portion of the previous enquiry all the more necessary.

Before describing the results of these recent experiments, it will be best to deal with some of the points raised by Dr. Broockmann in his criticism.

† Ibid., 1894, vol. vii., page 27.

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In the first place, Dr. Broockmann draws attention to the unsuitability of indiarubber, either in the form of tubing or stoppers, for work of this kind, pointing out that, it is "as permeable to gases as a sieve is to water." Although the writer readily acknowledges the justice of these strictures on the use of indiarubber, he is unable to agree in the application made by Dr. Broockmann in the description given of the method employed by the late Mr. McConnell and himself: for, in the paper published in the Transactions of The Institution of Mining Engineers in 1894, to which Dr. Broockmann gives a reference, it is stated that the coal used in the experiments was contained in flasks sealed on to an air-pump of the Geissler type. Further, it is stated in this paper that "the apparatus used in these and all subsequent experiments was
made entirely of glass, the several parts being fused together to prevent leakage."** The properties of indiarubber cannot, therefore, be made responsible, as Dr. Broockmann suggests, for the fact that in one instance as much as 818 cubic centimetres of gas was obtained from 100 grammes of freshly-hewn Ryhope coal; nor are the proportion of the gases of the atmosphere found in this gas and the relatively small amount of combustible gas to be explained in the same manner.

Surely, in a case of this kind, it is not unreasonable to expect that a critic should show an acquaintance with the details of the work under criticism: but, in the paper printed in Gluckauf, no mention is made of another experiment with the same coal, in which a much smaller volume of gas was obtained, and a gas which contained a relatively large proportion of combustible constituents, nor is any note made of the fact that this difference is specially emphasised. The writer is of the opinion that the large volume of gas obtained in the first instance is explained by the difficulties surrounding the removal of the air adhering to the glass and to the coal itself, difficulties increased by the close packing of the coal in the flask, whereas in the second experiment the coal was loosely filled into a tube, 1 1/8 inches in diameter. The amount of coal used in the first experiment, namely, 220 grammes, as against 90 grammes in the second, must also have contributed to the difficulty of removing completely the adherent air.

Dr. Broockmann, in his experiments, took 100 grammes of coal, contained in a vessel sealed direct on to a Sprengel pump.


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The coal was in a finely divided state, being in grains from 2 to 4 millimetres in diameter; and, after repeated exhaustions, the apparatus was allowed to stand for 3 or 4 days, before the heating with a water-bath was commenced. In this way, as Dr. Broockmann states, he obtained a minimum quantity of gas, and he claims that the gas so obtained is truly representative of the "enclosed gases," and is not contaminated by air adhering to the coal, or by those gases produced by the action of the air on the coal itself.

Experimenting with the Ryhope coal, Dr. Broockmann obtained 70 cubic centimetres of gas, which consisted of 97 per cent. of combustible gas, and 3 per cent. of carbon dioxide: that is, from 100 grammes of coal he obtained 67.9 cubic centimetres of combustible gas, and 2.1 cubic centimetres of carbon dioxide. Whereas, as will be seen by reference to the paper by the late Mr. McConnell and the author, they obtained from the same weight of coal 61.07 cubic centimetres of combustible gas, 4.2 cubic centimetres of carbon dioxide, 1.40 cubic centimetres of oxygen and 55.53 cubic centimetres of nitrogen, making a total of 122.2 cubic centimetres.

As the writer's object in studying the gases enclosed in the Ryhope coal was to obtain information which would throw some light on the nature of the combustible gases that he had previously found in the dust from the screening of this coal, the coal was not taken in small fragments, but in such fragments as would permit to some extent of the partial separation (by reason of the differences in rates of effusion) of the denser from the lighter hydrocarbons. Thus, a rough fractionation would be effected, and in the results of the analysis of the several fractions the presence of different paraffin hydrocarbons would be more clearly indicated.
To return to the use of indiarubber-stoppers in investigations of this kind: it is certainly true that in the experiments on the gases enclosed in coal-dust, the author employed indiarubber-stoppers, but with the precaution that these stoppers were covered by a layer of Faraday cement. In this connection it may be of interest to record the result of a recent experiment on the manner in which vessels closed in this way will maintain a vacuum over a lengthened period. A flask, of about 300 cubic centimetres capacity, was closed by a tightly fitting indiarubber-stopper through a hole in which was inserted a glass-tube by which the flask was sealed on to a Geissler pump. The cork was carefully covered with Faraday cement, and then the flask was exhausted and closed off from the pump. After standing some two months, the flask was again exhausted, and the gas obtained collected over mercury. A single bubble of gas was thus obtained, the volume of which proved to be approximately 0.2 cubic centimetre. As this experiment was made under conditions practically similar to those described by the author in his earlier papers, it may be concluded that, in these experiments, the disadvantages arising from the use of indiarubber-stoppers had been satisfactorily overcome.

A second point in Dr. Broockmann's criticism is the assumption that the author had overlooked the results obtained by the Austrian Fire-damp Commission in the examination of certain varieties of coal-dust. This is all the more surprising, since in the paper in the Transactions (to which, as had been already mentioned, Dr. Broockmann referred), and also in the account of the lecture given by the writer to the members of the National Association of Colliery Managers at Nottingham,† the work of the Austrian Fire-damp Commission is specially mentioned. That the writer should have regarded the experiments of the Austrian Fire-damp Commission as confirmatory of his own observations cannot appear strange or remarkable, as the author's first paper on the subject was read before this Institute in August, 1888, while the investigation by the Austrian Fire-damp Commission of the coal-dust question was made during the years 1889 to 1891. Further, the conclusion arrived at by the Commission, and cited by Dr. Broockmann, "that the content of dense, easily inflammable hydrocarbon gases increases both the sensitiveness and the dangerous character of a coal-dust," appeared in the Final Report of this Commission published in 1891. This will suffice to show the independence of the two sets of observations.

Another observation of the late Mr. McConnell and the author, selected for special criticism by Dr. Broockmann, was the composition of the gas obtained by heating the coal at 184° Cent. As Dr. Broockmann pointed out, this gas was remarkable for the large percentage of oxygen given in the analysis: but he, unfortunately,


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† Colliery Manager and Journal of Mining Engineering, 1895, vol. xi., pages 30 to 32.
had not troubled to state exactly the conditions under which the gas was produced, nor the volume of gas obtained under these conditions from 100 grammes of coal. Had this been done, the reader of Dr. Broockmann's paper would, in the first place, have been able to appreciate aright the bearing, on the point under discussion, of the experiments made by Dr. Broockmann to demonstrate the nature of the changes produced in air when it is heated in closed tubes with coal to a temperature of 160° Cent. In the second place, the reader would have been compelled to admire the ingenuity of Dr. Broockmann, who credits the writer with the discovery of a new method of preparing oxygen, and this because from 100 grammes of coal he had obtained 21 cubic centimetres of oxygen, or barely 3 parts by weight of oxygen from 100,000 parts by weight of coal.

In the paper read before this Institute in February, 1894, will be found a description of the experiment from which this result had been isolated.* And there it will be noted that a definite weight of coal was introduced into a tube, sealed off at one end and at the other end sealed on to an air-pump. After exhausting the air from the tube, the coal was heated for a certain period by passing steam through a jacket surrounding the tube which held the coal. The gas so produced was drawn off; then, after the coal had ceased to yield gas at this temperature, it was heated by passing the vapour of amyl alcohol through the jacket. When the coal no longer yielded any gas at this higher temperature, it was heated for some hours to a still higher temperature, by passing the vapour from boiling aniline through the jacket: and thus the further fraction of gas was obtained, which in this instance formed from 4 to 5 per cent. of the total volume of gas extracted from the coal.

A repetition of this experiment became necessary, in the light of the importance attached to the composition of the gas obtained by this extraction at 184° Cent., and the difficulty in finding an explanation of the proportion of oxygen which it was found to contain; a difficulty made the greater by Dr. Broockmann's statement that the gas was obtained in experimenting with fine coal, whereas it was produced from coal in pieces, and pieces certainly much larger than those he employed in his investigation. It is not inconceivable that, under the conditions of the experiment, the heating of the coal would cause a mechanical breaking-up of


[30]

the pieces (if coal, and thus favour the release of oxygen and other gases not already removed in the previous extractions. As to the proportion of oxygen to the other constituents, while the statement in volume per cent. may appear misleading, it should be stated that a careful scrutiny of the actual analytical data, from which these percentages were computed, had revealed an error in calculation. But, even when this correction is made, the proportion of oxygen to nitrogen is larger than the relative amount of these gases in the air. As to the contention that this observation is contradictory of all our knowledge of the mutual behaviour of air and coal at such temperatures, and its refutation by the experiments recorded by Dr. Broockmann, it will be sufficient to point out that the chemical relations of many bodies are altered by conditions of pressure, and that conclusions drawn from the experiments made under increased pressure are not applicable to explain the results of experiments made under greatly reduced pressures. The impossibility of explaining the presence of the constituent gases of the atmosphere in this gas in the manner suggested by Dr. Broockmann has already been referred to, and that oxygen and nitrogen are found in the gases extracted from coal
under these conditions is shown by the results of experiments Nos. IV. and V. described below.

Turning now to the results obtained in the recent investigation of the gases enclosed in the Hutton-seam coal, it will be sufficient to point out that the method of extracting the gases is that employed by Messrs. McConnell and Bedson, described in the paper already referred to.* In experiments Nos. I. to IV. the pump employed, to which the tube containing the coal was sealed on, was one of the Geissler type; whereas in No. V. the pump used was a form devised by Prof. Topler, without taps. After establishing a vacuum in the pump and tube containing the coal, the apparatus was allowed to stand at the ordinary temperature for some days, and then the gas produced in the interval was drawn off. The volume of the fraction of gas so obtained was measured and afterwards analysed. In order to obtain, if possible, a clearer idea of the nature of the combustible constituents, and to demonstrate as far as practicable the composition of these combustible gases, the coal was submitted to a prolonged extraction at the ordinary temperature, before heating with steam was resorted to, and in this way a series of fractions was obtained, each being separately analysed.

The writer's engagements have in many instances determined the lengthy duration of some of these operations; but some compensation for this delay may possibly be found in the information supplied by the results of the analyses of the several fractions of gases obtained from the coal under these circumstances.

In experiment No. IV., instead of removing the air from the tube holding the coal in the ordinary way, the coal was filled into a tube, in which it was held in position by plugs of glass-wool; the tube was next drawn out at both ends, and on to these narrow glass-tubes were sealed. By one of these narrow tubes, the tube was sealed on to the air-pump; while to the other, which was over 30 inches in length, a movable vessel containing mercury was attached by a stout indiarubber-tube. The wider section of the tube was surrounded by a second which formed a jacket for the passage of steam, etc. To expel the air from the tube, the tap of the pump was opened, and by raising the vessel containing mercury, the whole was filled with mercury up to the tap of the pump, which was then closed. The movable vessel was next lowered, the end of the glass-tube to which this vessel was attached stood in a vessel filled with mercury, and on removal of the indiarubber-tube there was thus established a rough barometric column, with the coal standing in a partial vacuum. The height of the mercury was found to be approximately 710 millimetres. After standing overnight, the exhaustion was completed in the ordinary way; and after remaining in this condition for 9 days, the gas given off in the interval was drawn off. Thus it will be seen that the coal was sealed off from the air, not by closing the tube by fusion of the glass, but by a barometric column of mercury. This method of exhaustion was practised in experiment No. V., and afforded a quicker means of removing the air from the tube than by the ordinary method of repeated pumpings, and one which consequently yielded a larger amount of combustible gas per given weight of coal.

Below are given in tabulated form the results of the measurements and analyses of the several fractions of the gases extracted from the coal in the manner indicated. The results of experiments Nos. I. and II. are not stated in detail, as the analyses of

the several fractions were not completed. In stating the result, it has been deemed desirable to give not only the percentage composition of the several fractions, but also the absolute volumes of each gas yielded, calculated upon 100 gramme of coal. As previous experience has shown the combustible constituents to be almost entirely members of the paraffin series of hydrocarbons; and as carbon monoxide and olefines have been proved to be absent, or present only in minimum quantities, these gases have been omitted in the statement given below.

Table 1.—Weights of Coal taken, and Total Volumes of Gas evolved in vacuo at ordinary Temperature and at 100° Cent.

*Volumes of gas given are in all cases expressed in cubic centimetres at 0° Cent., and a pressure of 760 millimetres of mercury.

[Table omitted.]

Since the results of the estimation of the paraffin hydrocarbons do not suffice to allow of a definite statement of the nature of the constituents of the mixture, instead of returning these in terms of a value for \( n \) in the general formula \( C_nH_{2n+2} \) it has been thought better to interpret the results in terms of a possible mixture of marsh-gas \( (CH_4) \) and ethane \( (C_2H_6) \) or ethane und propane \( (C_3H_8) \) according as the analytical data appeared to warrant. All that is attempted to indicate by this form of statement is simply that the combustible gases are not pure marsh-gas, but that other gaseous members of this series of hydrocarbons are present in the gases. In the majority of cases these numbers are based upon the mean of two or more concordant sets of determinations.

The proportion of such hydrocarbon constituents is determined by taking a measured volume of gas from which oxygen, etc., have been absorbed, mixing it with a measured volume of oxygen and exploding, then by a series of operations determining the amount of the contraction and of carbon dioxide resulting, also the amount

[33]

Table II.—Detailed Results of Analyses of the Several Fractions of Gases evolved in vacuo under Stated Conditions.

[Table omitted.]
of oxygen which has been used in the combustion. From these data, the information desired can be obtained, but owing to the difficulties surrounding the exact determination of the oxygen, the writer has in computing the results, neglected the values found for the oxygen used. This mode of interpreting the results appears to be better than that used in the previous paper, since the amount of contraction and the proportion of carbon dioxide are data capable of more exact estimation, than is the determination of the amount of oxygen used; so the influence of experimental errors in making this last estimate is avoided. If this mode of calculation be applied to the analytical data obtained in the previous investigation, the proportion of combustible gas would then appear somewhat higher.

Table II. contains a statement of the results of the examination of the gases obtained in the several experiments, and from these a series of averages have been calculated, based upon the results of experiments Nos. III., IV. and V., and are contained in Table III. In the first column of figures are given the volumes in cubic centimetres of the several gases obtained from 100 grammes of coal; in the second column the composition of the gas is expressed in volumes per cent.; while in the third column of figures the analyses have been calculated on the assumption that the oxygen existed as air.

These numbers call for one or two remarks. In the first place, the total volume of gas per 100 grammes of coal obtained at 100° Cent. is not very different from that given in the paper of the late Mr. McConnell and the writer. In experiments Nos. III. and IV. (Table II.), it will be noted that the gas expelled by steam-heating was free from oxygen, and in one instance consisted entirely of combustible gas. In experiment No. IV., whereas the last extract at 100° Cent. was free from oxygen, the next extract at a higher temperature contained oxygen. The improbability of this being derived from the outside air (which would necessitate the assumption of a leakage from the tap) is rendered all the greater in the light of the results in experiment No. V., in which similar results were observed; and, as has been a ready pointed out, in this experiment a pump was employed without taps.

The composition of the gas obtained in the first extraction of experiment No. V. is worthy of special attention, as, in addition

Table III.—Average Results of Experiments Nos. III., IV. and V.
A.—Gases extracted at Ordinary Temperatures and at 100 Cent.

B.—Gases extracted at 100° Cent., and Included in A.

C.—Gases extracted at 130° Cent.

D.—Gases extracted at 180° Cent.
to carbon dioxide, it contains a considerable proportion of oxygen, and an amount in relation to the nitrogen in excess of that in which these gases occur in air. The coal used in this case was taken from a sample which had been kept in an open tube in the laboratory for several months, and this exposure to the air suggested itself as the explanation of the proportion of oxygen: for the coal-substance would not only lose gas, but would absorb gases from the air—and preferentially oxygen rather than nitrogen. The explanation was submitted to a direct test, and for this purpose a tube about 1 inch in diameter was sealed on to the Topler pump, the open end dipping under mercury. By exhausting the air from this, a barometric column was established, and into the space above pieces of coal were introduced by immersing them under the mercury in the cistern and allowing them to rise through the column of mercury. After the coal had remained some days in the exhausted space, the gas was drawn off and analysed.

From freshly-hewn coal, the gas obtained in live days (18 cubic centimetres) was found to have the following percentage composition: —

<table>
<thead>
<tr>
<th></th>
<th>Volumes.</th>
<th>Volumes.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon dioxide (CO₂)</td>
<td>1.63</td>
<td>1.65</td>
</tr>
<tr>
<td>Oxygen (O₂)</td>
<td>8.99</td>
<td>—</td>
</tr>
<tr>
<td>Marsh-gas (CH₄)</td>
<td>44.60</td>
<td>44.60</td>
</tr>
<tr>
<td>Nitrogen (N₂)</td>
<td>44.76</td>
<td>10.73</td>
</tr>
<tr>
<td>Air</td>
<td>—</td>
<td>43.02</td>
</tr>
</tbody>
</table>

From coal of the same origin, which had been exposed to the air of the laboratory for several months, a volume equivalent to 14.5 cubic centimetres was obtained in 17 days, which was found to have the following composition: —

<table>
<thead>
<tr>
<th></th>
<th>Volumes.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon dioxide (CO₂)</td>
<td>1.18</td>
</tr>
<tr>
<td>Oxygen (O₂)</td>
<td>23.80</td>
</tr>
<tr>
<td>Marsh-gas (CH₄)</td>
<td>3.58</td>
</tr>
<tr>
<td>Nitrogen (N₂)</td>
<td>71.44</td>
</tr>
</tbody>
</table>

On standing over mercury for a month a further quantity of gas was given off, measuring 16’2 cubic centimetres, and composed as follows: —

<table>
<thead>
<tr>
<th></th>
<th>Volumes.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon dioxide (CO₂)</td>
<td>0.64</td>
</tr>
</tbody>
</table>
Oxygen (O₂) 20.91
Marsh-gas (CH₄) 4.52
Nitrogen (N₂) 73.93

These results support the explanation given of the proportion of oxygen found in the first fraction of gas obtained in experiment No. V., and show, in addition to the readiness with which the coal loses marsh-gas, that it absorbs oxygen from the air more readily than the nitrogen. This suggests that the interpretation of the oxygen found in the enclosed gases as representing a corresponding proportion of air must be accepted with a certain amount of reserve. Nevertheless, this assumption has been made in stating the results in the foregoing tables, and may be permitted, as in almost every case there is sufficient nitrogen to mix with the oxygen.

The proportions of the combustible gases found and their nature sufficiently well support the writer's views expressed on a former occasion as to the manner in which the denser hydrocarbons are retained by the coal, and support the explanation given of their existence in the gases enclosed in the dust formed in screening this coal. It should be noted that in experiment No. III., the combustible gas extracted at the ordinary temperature is not entirely marsh-gas.

As to the application of the existence of these hydrocarbon gases enclosed in the coal-dust to explain the part played by coal-dust in an explosion, it has never been maintained that they are the only factors determining the sensibility to ignition of the dust, nor as pre-eminently more important in this regard than the fineness of subdivision or the dryness of the dust. Still, the practical experience with this dust at the colliery, which first suggested the investigation, sufficiently demonstrates the ready inflammability of this coal-dust; and these facts, taken together with the results of the examination of the enclosed gases of other coal-dusts, justify the conclusion advanced in previous publications.

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The Chairman" (Mr. J. (G. Weeks), in moving a vote of thanks to Prof. Bedson, who had dealt with the question most exhaustively, thought that there would be no doubt that he had refuted the arguments of Dr. Broockmann. Mr. C. C. Leach, in seconding the vote of thanks, said he had noticed that his firemen preferred to use coal taken from the small-coal heap; and Prof. Bedson's explanation of the facility with which coal exposed for some time to air would absorb oxygen probably accounted for their preference.

The vote of thanks was cordially adopted.

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Mr. Edward Halse's paper on "Some Silver-bearing Veins of Mexico" was read as follows: —

[SOM] SOME SILVER-BEARING VEINS OF MEXICO.
By EDWARD HALSE.

Zacatecas.

The classic region of Zacatecas, in the state of the same name, was discovered by Juan de Tolosa, in 1546, since which date it has produced immense quantities of the white metal. It has an extension from north to south of about 9 ¼ miles, and 7 ½ miles from east to west. The city itself is situated in the southern portion of the district on the slopes of the Grillo, Bufa and Bolsa hills, at an elevation of 8,178 feet above the sea.

Zacatecas may be described as a group of mountains separated by plains of varying elevations, the whole really forming a portion of the central plateau of the republic. The mountains seldom rise far above the plains, and their flanks have, as a rule, a comparatively gentle slope.

The principal country-rock of the district was formerly regarded by Mr. Laur† as a grauwacke (vacia gris), although Dr. Burkart‡ and most Mexican geologists considered it to be a diorite. Later researches have shown that the formation is a green rhyolitic tuff, associated with a rock—probably an altered andesite—similar to that of the famous La Luz district of Guanajuato.§ Besides the above there is a sedimentary rock—a black slate, frequently siliceous—which passes by insensible degrees into the volcanic tuff and andesite (?) and diorite proper, which in places is metamorphosed into chloritic schist. At a depth, varying from 800 to 1,000 feet, the favourable country (rhyolitic tuff and

‡ Aufenhalt und reise in Mexico in den Jahren 1825 bis 1834, Stuttgart, 1836.

andesite (?) or diorite) passes insensibly into black argillaceous schist* with kidneys of milky quartz, in which the veins rapidly become impoverished.

Dykes of diorite (feldstein of Dr. Burkart) traverse the region, and, among other rocks, mention may be made of trachyte, rhyolite and quartz-porphyrite (bird's-eye porphyry), limestone of Cretaceous age, and conglomerates of two ages, the more recent of a red colour containing fragments of the above-mentioned rocks in a paste of clay, the older one being purple in colour,† and composed, in addition to fragments of the same rocks in a felspathic cement, of large masses or boulders of decomposed granite, abounding in mica and pegmatite, formed of crystals of quartz, felspar and very little mica.

The slates of Catorce are, for the most part, of Jurassic age, but the age of the clay-slate or amphiolite (hoja de libro) met with in depth in Zacatecas and Guanajuato has not yet been determined. The red conglomerates of both districts belong to the Upper Tertiary (Pliocene),
and there is reason to believe that the majority of the veins were formed after the consolidation of that rock.

The veins of Zacatecas have a general north-west to southeast strike, the prevailing dip being southerly. There are, however, many exceptions to this rule. The principal ones, like the Veta Madre (mother-lode) of Guanajuato, are apt to be split up into branches separated by more or less altered country-rock. As in the Veta Madre, three branches are frequently distinguishable, known as the hanging- (cuerpo de alto), centre- (cuerpo del enmedio) and foot-branch (cuerpo de bajo). However, Dr. E. Tilmann pointed out that,‡ in the case of the Veta Madre, a distinct tripartite arrangement of the lode is very improbable, and, as a matter of fact, the latter is frequently split up into more than three branches, especially on the lying side, and the same is probably the case in Zacatecas.

It has already been shown§ that the large veins of the Taviches

* This must not be confounded with the black slate found near the surface, in which the veins are frequently profitable (e.g., at the Bote mine).
† At the San Rafael mine, there is purple conglomerate at the surface and diorite below. The richer, which go down only about 400 feet, are continuous in length while in the conglomerate.
‡ Der Bergbau con Guanajuato, 1866, page 19.

district of Oaxaca are in places split up into several branches, and by referring to Fig. 3 (Plate XVIII.)* it will be seen that these are mainly on the lying (or eastern) side of the lode, as in Guanajuato.

Francisco de P. Zarate says† that the ores of these so-called branches vary considerably in structure. Thus, in the veins of Malanoche, Veta Grande and La Plata, the ore on the hanging-branch is of a banded structure, being formed of layers or ribs of silver ores separated by country. This ore is usually the best. The middle-branch also has a ribboned structure—the silver-ores are however, symmetrically arranged in quartz or calcite. The footwall-branch is composed of iron-pyrites, galena and blende scattered with native silver,‡ black sulphide of silver, and complex sulphides (ruby silver, etc.), so intermingled as to constitute a pinta revuelta. These ores are sometimes arranged concentrically, forming nodules (en boleo), and, no doubt, coating fragments of country-rock, forming what Prof. F. Posepny terms "crusted kernels."§

The writer had no opportunity of studying the larger veins of this district, but he made a careful examination of a group of veins to the south of the city, which bear gold as well as silver.¶ Fig. 1 (Plate I.) is a sketch-plan of some of these veins. The strike varies from north 14 degrees west to north 28 degrees west,|| and the dip is easterly from 55 to 80 degrees.

† Apuntes sobre la Minería del Estado de Zacatecas, Zacatecas, 1884, 98 pages.
‡ The writer has suggested in another paper ("On Deep Mining in Mexico," Transactions of the Institution of Mining and Metallurgy, 1895, vol. iii., page 425) that where native silver is associated with iron-pyrites "its reduction is probably in some way connected with the
presence of that mineral." It is well known that a silver salt is readily precipitated by ferrous sulphate, and Mr. S. F. Emmons says, with an excess of ferrous sulphate present, as near the outcrop of ore deposits, this might account for the separation of native silver from silver salts, while on the other hand with an excess of ferric oxide the silver might be carried further down in solution." ("The Secondary Enrichment of Ore-deposits," Transactions of the American Institute of Mining Engineers, 1900, vol. xxx., page 213). As a matter of fact, native silver in Mexico is found (1) in gossan, with or without unaltered pyrites, (2) with iron-pyrites to some distance below the outcrop, and (3) in rare instances, as at Batopilas, Chihuahua, immediately below iron-pyrites (see Prof. C. B. Dahlgren's Historic Mines of Mexico).

¶ Several years ago, the writer endeavoured to show that a gold-bearing belt of considerable economic importance occurs south of Zacatecas city, Engineering and Mining Journal, 1894, vol. lviii., pages 78, 105-107 and 605-606.
ǁ Magnetic declination about east 8 ¼ degrees.

The No. 1 vein courses north 14 degrees west and dips eastward 80 degrees. It is small and compact, varying from 7 to 20 inches in thickness, in a dark-coloured slate-rock which appears to he chloritic schist (probably altered diorite) impregnated with iron-pyrites. The structure of the vein is shown in Figs. 2 and 3 (Plate I.). In Fig. 2 (Plate I.), the vein consists of quartz with ribbony streaks of sulphides, principally argentite (Ag₂S),* and fine native gold on either wall, separated by calcite, exhibiting rhombohedral structure here and there, which forms the centre of the vein. In Fig. 3, the quartz and calcite are in alternate layers, but in this instance calcite is on the hanging-wall and quartz on the foot-wall, while a layer of quartz occupies the centre of the vein. The rib of quartz on the foot-wall carries some streaks of sulphides and native gold on the side farthest from the wall. The colour of the quartz is white, pinkish or bluish (when impregnated with silver-sulphide), the calcite being white or pale green. In an arroyo, a little north of the hacienda, similar country is seen to course north-east to south-west and to dip southeastward, 35 degrees.

The No. 3 vein runs about north 30 degrees west and dips eastward 60 to 70 degrees. The workings in this vein were, in 1894, only about 90 feet in vertical depth, and had not reached water-level. The vein consists of solid bands of quartz, stained and ribboned by black sulphide of silver, etc., separated by bands and masses of calcite, the whole coloured a deep red by oxide of iron, in a schistose country-rock. The thickness of the vein varies from 3 to 5 ½ feet, the average being about 4 feet. Where the vein is wide, it is generally split up by horses of country-rock, although the average value of the vein-contents remains about the same. Figs. 4 and 5 (Plate I.) will give some idea of this structure. On the foot-wall side (Fig. 4), there is a selvage of white clay, 1 foot thick. The foot-wall joint is well defined and dips 60 degrees eastward.

The No. 4 vein strikes nearly north-and-south and dips eastward 75 degrees, meeting the No. 3 vein on the line of strike. The workings here were 160 feet deep, but water-level had not
been reached, although oxidation was only traceable to a vertical depth of 100 feet. The thickness varies from 3½ to 6 feet, the average being about 4½, feet. It would appear to be a contact-vein, for the hanging-wall consists of greenish diorite impregnated with iron-pyrites, while the foot-wall is a greyish schist. Figs. 6, 7 and 8 (Plate I.) exhibit the structure. The centre of the vein is sometimes occupied by country, 4 feet thick (Fig. 6): elsewhere (Fig. 7) the filling is solid quartz with sulphides of silver, etc., in streaks and spots. In the bottom workings, ribbony streaks of sulphides carrying finely-scattered native gold are distinguishable in the six bands of quartz, which are separated from each other by calcite (Fig. 8).

The No. 7 vein strikes north 20 degrees west, uniting with a north-and-south vein or branch about 80 feet from the shaft. The dip is 70 degrees eastward. The vein consists of bluish quartz ribboned with sulphides and some calcite, separated by bands and masses of the latter mineral. The walls are schist, trending east-north-east to west-south-west and dipping southward 50 to 70 degrees. The bedding-planes appear to roll a good deal. The width varies from 2 to 3 feet. Fig. 9 (Plate I.) shows the structure. Here a thick clay-selvage lines the hanging-wall.

The San Cristobal, a little north of the last, is a parallel vein running about north-north-west, and dipping 60 degrees eastward. The width varies from 4 to 12 feet. In a shallow working in the same vein, the structure illustrated in Fig. 10 (Plate I.) was seen. The vein in one place had been worked to a depth of upwards of 300 feet, and it would seem that the ore-body pitched at an angle of 66 degrees in the northerly direction of the strike. The hanging-wall, near the surface, has a day-selvage with slickensides. When the calcite has an opaque white-and-pink mottled (or altered) appearance, and the quartz is flinty and streaked with sulphide of silver, the ore is generally of good grade.

The banded structure of these veins is seldom, strictly speaking, symmetrical, and the writer believes that it has been produced partly by the substitution and partly by the re-opening of the original country. The calcite appears, generally, to be of more recent date than the quartz, nevertheless some quartz has been deposited since the former, for in the No. 7 vein several cavities in the calcite were seen to be lined with crystals of quartz, and here and there the quartz and calcite are so intermixed that they would appear to have been deposited contemporaneously.

The sulphide of silver has been deposited by preference on the quartz, although here and there it is said to occur in calcite, or to have crystallized out between the two minerals. Another noteworthy fact is that the calcite shows a tendency to disappear in depth. This would almost seem to indicate that this mineral is the result of surface-decomposition produced by
A little to the south of the above-described group of veins is a large outcrop of trachytic rock known as La Mesa del Cerillo. This rock cuts off all the veins in that direction,† so it is most probably of later origin.

The schistose country has been considerably altered close to the contact—the rock has a mottled red-and-purple colour, and the schistose structure is more or less obliterated. One of the veins, which is traceable almost up to the line of contact, consists mainly of quartz showing some ribbons of argentite, but the vein is considerably bent and ramified, and contains many lenticular inclusions of country-rock.

The veins carry from 6 to 38 ounces of silver, and from 10 to 60 dwts. of gold to the ton. The ratio of gold to silver varies considerably in the different veins, and in different parts of the same vein, but the average may be taken as 1 to 10 in weight, and

† In the mining districts of Tatatila and Zomelchuaca (State of Jalisco ?) silver-veins occur in limestone, and never penetrate trachyte, against which they terminate abruptly (Prof. Von Grodeck).

[45]

as 4 to 1 in value (taking silver at 2s. 1d. or 50 cents per ounce troy).

The caracol structure, already described* is sometimes met with in these veins. The gold is associated here and there with chlorobromide of silver or embolite (plata verde†) and brown ochreous iron.

The following additional notes on this district have been gathered from various sources: —

The Veta de la Cantera, one of the largest veins of Zacatecas, can be traced some miles east-south-east of the city. It has a general north-west to south-east strike, but, where it sweeps round the northern edge of the hill of grey trachyte, known as La Bufa,‡ it has been bent considerably out of its normal course.

About 1 ¼ miles west of the city, or in the region of the Bote mine, the lode is divided up into several more or less parallel branches or veins, similarly to the Veta Grande between Panuco and Zacatecas, and here it once more assumes a general northwest to south-east course. The dip of the main vein is southerly.

La Cantera vein, where formerly worked in its eastern portion, trends north 70 to 75 degrees west and south 70 to 75 degrees east, dips southward 48 degrees and is from 16 ½ to 98 ½ feet thick. According to Mr. F. Sescosse, the vein itself is almost sterile, but here and there it is enriched by transverse veins which are themselves poor. They may be called branches, as
they go from the body of the vein in a north-easterly direction, but do not pass to the south. Nevertheless the foot-wall portion of the vein bears traces only of complex ores containing lead and zinc, the rich and docile ores being confined to the hanging-wall for a width of 6 ½ to 19 ½ feet.

At the Bote mine, the ores of this and parallel veins consist of argentite, with some ruby silver and other high-grade ores, and free gold associated with iron-pyrites (not abundant). In the upper levels, silver occurs both native and as chloride and bromide. At this mine, a distinction is drawn between silver-

† At Catorce, plata verde is bromyrite, a mixture of bromide and iodide of silver.
‡ Bufa in Mexico is the name given to a narrow ridge of rock standing above the general surface, the sides being steep.— The bufas a little south of Guanajuato city are formed of a greenish porphyritic rock (? trachyte).

[46]

bearing veins proper and those carrying gold as well. According to Mr. Enrique Wiust, the former run north 49 degrees west and dip southward 75 degrees, and the latter north 58 degrees west, the dip being 64 degrees in the same direction—hence they meet both horizontally and vertically.

A few veins in this district course about east and west, and dip northward in black slate. The ores are galena, pyrites, blende (abundant), and pyrargyrite (rosicler oscuro). To the south of Malanoche, the San Clemente vein has a similar trend and dip: the ores, native silver, chloride of silver (plata azul*) and argentiferous pyrites, occur in rich bunches or shoots (ojos or tramos). To the east of Malanoche is the mineral of San Bernabe, in which, according to tradition, the first mines worked by the conquistadores are situated.

The San Miguel and San Luis veins have no well-defined walls or selvages, and in places the silver-ore is disseminated in the rock, but following a certain direction (Dr. F. de P. Zarate). At the Mina de los Clerigos—ore, sulphide of silver, native silver and ruby silver—the walls of the vein (strike ninth 47 degrees west, dip northward 49 degrees) are said to be a kind of conglomerate, and the riches occur between 328 and 559 feet (Mr. E. Wiust).

If the country-rock be identical with the red conglomerates, it proves that the vein which courses through it was formed, like the Veta Madre, after the consolidation of that rock, and fixes the age of the vein as later Pliocene or Post-Pliocene.

GUANAJUATO.

The city of Guanajuato, in the state of the same name, is situated about midway between the Pacific Ocean and the Gulf of Mexico, in 24 degrees north latitude and 108 degrees west longitude. It lies at an elevation of 6,724 feet above sea-level on the south-western slope of a range of mountains, known as the Sierra de Guanajuato, which trends north-west and south-east, dividing the central plateau of Mexico into two unequal portions,
At Zacatecas, plata azul plomillosa is argentite (the plata azull of Tlapujahua). Plata azul acriada is polybasite; plata azul de Catorce is selzite or carbonate of silver. Dr. Del Rio, the geologist, gives the name plata azul to a silver-bearing copper-ore.

The eastern plains, or those nearest the gulf, having less lateral extent, and being of somewhat higher altitude than the western plains. The Sierra itself rises to a maximum height of about 9,500 feet above sea-level. The hills in the neighbourhood of Guanajuato city range from about 6,888 to 7,954 feet (the height of the Sirena mountain), while the lowest working on the Veta Madre or mother-lode in the deep Valenciana mine is still 4,484 feet above sea-level.

The surface-geology of the Guanajuato district, which extends about 12 miles from north-west to south-east, and 9 miles from north-east to south-west bears some resemblance to that of Zacatecas, although it is, if possible, still more complex. An older sedimentary formation, consisting of clay-slate, calc-schist, running here and there into pure calcareous layers, and grauwacke, with some beds of rather fine conglomerate, of unknown thickness and of undetermined age,* extends for some distance to the east of the city and for a considerable distance to the north of it, striking in a general north-westerly to south-easterly direction and dipping south-westward from 40 to 50 degrees, while the predominating rock around the city itself, and right away to the alluvial (Quaternary) plains to the west, is a red conglomerate, or rather breccia, of Pliocene age,† with a similar strike, but dipping eastward. The breccia is at least 2,000 feet thick.

Some distance north-west of the city, the Luz group of veins occurs in a greatly altered eruptive, which has been termed "diorite," as well as other classes of greenstone (roca verde)—probably altered andesites and rhyolites.

Just south of the city is a large outcrop of recent argillaceous

* Formerly regarded as Silurian or Devonian, but no rocks of these ages have yet been identified in Mexico. Thin black layers of anthracite occur in the clay-slate. The older sedimentary rocks of this area are certainly pre-Cretaceous and may be Triassic, or possibly Carboniferous (corresponding perhaps to the Culm-measures of Great Britain).

† Of the same age as that occurring at Zacatecas (Trans. Inst. M.E., 1902, vol. xxiv. page 42) and in the neighbourhood of Tasco (Trans. Inst. M.E., 1901, vol. xxi., page 208). The red conglomerate of Guanajuato was formerly regarded as Triassic (New Red Sandstone). According to Prof. E. Tilmann, it is made up of more of less angular fragments of schist, grauvaclle, and various greenstones (diorite and porphyry predominating) in an argillaceous cement stained by red oxide of iron. The fragments are often upwards of 2½ feet (70 centimetres) thick.
sandstone called losero* and, beyond the clay-slate to the east, the Villapando and Santa Rosa group of veins is found in so-called "porphyry," an eruptive or prior date to the diorite of La Luz.

According to Prof. Tilmann, the clay-slate and grauwacke owe their present inclined position to the breaking-through of the porphyry, while the diorite supplied the material of the red conglomerate.

Besides the above rocks, there are numerous dykes and masses of hornblende, granites (syenites) of pre-Cretaceous age, more especially near the contact between the clay-slate and diorite, as well as recent emanations of trachyte, basalt, etc.

Among the metamorphic rocks of the area may be mentioned chloritic schist, hornblende-schist and serpentine. Here and there, the two latter, together with syenite, are found in sheets overlying the clay-slate.

A long series of eruptions must have taken place here during the Tertiary period. The order of eruption in this particular district appears to have been (1) andesite, (2) rhyolite, (3) trachyte and (4) basalt. The vein-fractures, especially those of the Veta Madre, were probably formed during the ejection of the trachyte. After the filling of this lode, there was considerable erosion of the eruptive, forming the sedimentary deposit known as losero, which covers a large portion of the outcrop south of the city. Finally, the hot springs now issuing in the neighbourhood of the basalt prove that deep subterranean disturbances are still in progress.

Fig. 13 (Plate II., after Prof. Tilmann) shows the surface-geology and the principal veins of the district. The general parallelism of these is much more marked than is the case at Zacatecas. They course, with few exceptions, from north-west to south-east, and dip south-westward.

The Veta Madre has an average strike of north 38 degrees west. At the Cardenas mine (depth 600 feet, and now abandoned)

* This rock also occurs at Tasco (Trans. Inst. M.E., 1901, vol. xxi., page 208). Baron A. von Humboldt (Essai Politique sur le Royaume de la Nouvelle-Espagne, 1811) describes the Guanajuato rock as a felspathic conglomerate composed of grains of quartz and small fragments of felspar in a ferruginous cement. Prof. St. Clair Duport (De la Production des Metaux Precieux au Mexique, 1843) calls it a grit containing fragments of felspar. Prof. E. Tilmann describes it as a very fine conglomerate lying almost horizontally on the red conglomerate in grey, blue, violet, red and yellow stripes. The new dam at Guanajuato (capacity 1,600,000 cubic metres) is made of this rock, known as cantera by the quarrymen.

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to the south, the strike is north 25 ½ degrees west; from the Cedro mine (depth 500 feet and now abandoned) to Sirena, it is north 34 ½ degrees west. Between Sirena and a little north of Valenciana, where the greatest wealth occurs, the lode takes a wide sweep, first westward (north 50 degrees west) and then eastward (north 33 degrees west), the average trend of this portion of the vein being north 47 ½ degrees west. From Valenciana to a little north of Santa Gertrudis, the vein courses north 31 ½ west. North of this point, the average strike is north 37 degrees west and the dip 45 degrees south-westward.

The Veta Madre was somewhat incorrectly termed a bedded vein by Prof. Von Grodeck.* It is true that both strike and dip correspond more or less with the schistose rocks, but it is undoubtedly a fissure-vein; and it is worthy of note that the richest portion of it corresponds
with the line of contact between the red conglomerate (hanging-wall) and the clay-slate (foot-wall), and that in the latter rock the vein is split up into several branches, most of which contain ore in payable quantities.

Prof. Von Groddeck pointed out that the Veta Madre must have shifted the beds of conglomerate about 13,120 feet (4,000 metres) laterally. Prof. Tilmann makes no mention of any such displacement as this. If such a shifting took place, it probably happened long before the Veta Madre was formed. This lode, for a portion of its course, may occupy an old line of fault, formed, perhaps, during the emission of the granitic rocks, for the line of least resistance from pre-Cretaceous times has been in a general north-westerly to south-easterly direction. When the fracture, or series of fractures, occurred in Tertiary times, this fault may, therefore, have been re-opened for a considerable portion of its length. The new fracture would appear to have been propagated from a north-westerly direction (the centre of the disturbance may have been in the neighbourhood of the Gigante mountain), for, on meeting the dense beds of conglomerate, it was deflected eastwards, following the line of contact between that rock and the clay-slate, and the forces of rupture, rebounding from the denser beds of conglomerate, tore open, as suggested by Prof. Tilmann, the fissile beds of clay-slate—hence the numerous branches on the lying side of the vein, where the conglomerate forms the hanging-wall, and which decrease in number, until they finally disappear

*Lehre von den Lagerstatten der Erze, 1879.

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farther south. On meeting the solid mass of conglomerate at Sirena, the fracture was deflected or refracted in an opposite direction, cutting through these beds perpendicularly, or, in other words, following the line of least resistance of that rock.

The principal veins of Villapando, San Nicolas and Santa Rosa run strictly parallel to the Veta Madre, as will be seen by referring to Fig. 13 (Plate II.) . The parallelism of the Luz system of veins is not so noticeable. The main vein (Plateros) has an average strike of north 56 degrees west. It was probably formed contemporaneously with the Veta Madre, but failed to penetrate the hard red conglomerate to the south. The direction of La Luz (north 15 degrees west) is exceptional—it appears to be a counter* vein to the Plateros. The Villapando and Santa Rosa veins are interesting, from the fact that they bear gold as well as silver. It is said that the old mines here produced ore yielding between 26 ½ and 68 dwts. of gold to the ton.

One vein, near Villapando, examined by the writer, strikes from north-north-west to north-west and dips southward from 55 to 65 degrees. It is about 3 feet in width, the structure of the vein being sometimes brecciated and sometimes banded. The ore contains from 10 to 12 ounces of silver, and from ½ to 1 ½ ounces of gold per ton—the average gold-contents being about 12 ½ dwts. The beds of country-rock trend north-north-eastward and are nearly perpendicular.

A vein near San Nicolas courses east and west, and dips 52 degrees southward, the thickness being upwards of 13 feet, with good streaks of ore on both walls. The structure is generally
brecciated; the country-rock is slate and "porphyry." The shoots of ore in this mine have a tendency to pitch westward.

Near Santa Rosa, one vein, now being worked, runs north-and-south and dips westward, while another courses north-west.

* In Cornwall, "a metalliferous vein 30 degrees to 60 degrees from east and west" (Mr. J. Carne); "a lode 40 degrees to 50 degrees from the general strike" (Mr. R. W. Fox); and "a lode making a considerable angle, not exceeding 45 degrees, with the normal lode of the district. If it exceeds 45 degrees it becomes a cross-lode" (Mr. Salmon). Caunter is generally derived from Latin contra (English counter), against, but Mr. Salmon thinks that it is allied to caunt or cant (to tilt over or incline).

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to south-east with a similar dip. About 124 feet of soft greenish country ("porphyry") separates the two at the point examined. The former vein is from 1 ½ to 3 feet and the latter from 3 ½ to 6 ½ feet thick. The north-and-south vein has a good leader (cinta) 6 inches thick, on the hanging-wall. The best ore from these veins contains about 55 ounces of silver, while the gold-content only amounts to 12 grains to the ton.

According to Prof. Tilmann, the Luz vein was denounced a short time after the conquest, but was not worked in a formal way until 1845 by Mr. Perez Galvez.

The Luz group of veins* is famous for having yielded several very rich bonanzas. Two very rich shoots of ore, about 200 feet in length, were followed to a depth of 1,312 feet in the northern portion of La Luz, and another, almost equally rich, was proved for a length of 164 feet and followed to a like depth, in the southern portion of the Plateros vein.

The two veins cross each other obliquely; at the junction they run together for a length of 656 feet. It is a remarkable fact that the north-western portion of the Plateros vein (strike north 60 degrees west and dip southward 60 degrees), and the southern portion of La Luz (strike north 15 degrees west, and dip westward 60 degrees) had not been wrought when Prof. Tilmann wrote his memoir, the riches having been discovered only on the eastern limbs of the cross, or those nearest to the Veta Madre.

All the veins shown in Fig. 13 (Plate II.), with the exception of Melladito, dip southward—the latter vein, which is from a mere parting up to 49 ¼ feet thick, dips north-eastward 45 degrees (termed contra natural by the miners), and therefore meets the Plateros vein on the dip. At the junction, there is a complete splitting up of both veins, as many as seven branches having been opened out, which separate farther south and become insignificant.

The filling of the La Luz vein (thickness 13.12 to 16.40 feet) is quartz and calcite with many beautiful druses. When the vein is productive, the chief filling consists of a dark green friable

* In the description of these veins, and of the Veta Madre, which follows in the text, the writer is largely indebted to Prof. E. Tilmann’s memoir, "Der Bergbau und das Amalgamations-verfahren in den Bergwerks-distrikte von Guanajuato in Mexico," 73 pages, 5 folding plates,
Munster, 1866. He is less chary of quoting from this work as it has been out of print for some years, and is now scarce.

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talcose mass, finely sprinkled with silver-ores, termed jabones.* The silver-ores consist of stephanite (brittle silver-ore), the whole range of silver-bearingblendes, and light and dark ruby-silver.† In the Plateros vein, the ruby-silver is very finely sprinkled in hard quartz, stephanite occurring as well where the gangue contains some calcite. The thickness of this vein varies considerably, from a mere salband to about 19 ½ feet—the average being about 9.80 feet. The small veins (thickness 2 ½ to 6 ½ feet) of this group contain black threads of silver-ore (ruby and brittle silver) in compact quartz.

The ores known as jabones are found also in the Veta Madre, but of a white colour, being more calcareous. They are probably the result of the decomposition of the original matrix by solutions containing silver-ores, forming here and there distinct shoots or columns. The silver-ores may have been brought into the veins long after they had been filled with veinstone (quartz and calcite); but, more probably, they were leached out of the veins themselves, and redeposited as sulphides in certain portions of them, forming what has been termed secondary enrichments.‡

The two ore-shoots of the La Luz vein produced silver to the value of £6,000,000 in 15 years, the average yield of the ores being 137 ounces to the ton—masses of jabon, besprinkled with ruby silver and stephanite, being in some places upwards of 39 ¼ feet thick. The ore-shoot of the Plateros vein produced silver worth about £1,000,000. Between the ore-shoots of the La Luz vein, the filling is quartz and calcite in beautiful crystals, said to be quite sterile. The average thickness of the vein is about 9.84 feet (3 metres), the country being a highly-altered green eruptive. For this reason the rock is extremely difficult to determine. According to Mr.

† According to Prof. Tilmann, a solid piece of light ruby-silver (prosuttite), 25 pounds in weight, was taken out of La Luz mine, and presented to the Emperor Maximilian.
‡ "The Secondary Enrichment of Ore-deposits," by Mr. S. F. Emmons, Transactions of the American Institute of Mining Engineers, 1900, vol. xxx., page 177. Mr. Emmons believes that secondary enrichment is generally produced by descending surface-waters, although he has a strong impression "that not infrequently the ascending currents have also produced migrations of already formed deposits and local enrichments under favouring conditions."

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Exequiel Ordonez,* certain specimens from this district, examined microscopically, were found to approximate to andesitic porphyries and hornblende-andesites.
The ore-bearing in these veins, as in all those of Guanajuato, begins at a depth of 262 feet (80 metres).

The Veta Madre, where it has conglomerate on the hanging-wall and clay-slate on the foot-wall, has an enormous thickness, for example:—in Valenciana, 492 feet; farther south in La Cata, 426 ¼ feet; and in Mellado, 328 feet. The conglomerate is impregnated with iron-pyrites and silver-ores, forming pockets here and there. The clay-slate is also sprinkled with iron-pyrites, and for the width already stated, contains numerous branches, leaders, bunches and spots of ore separated by more or less dead country-rock. The branches, in number up to 8 or 10, in thickness from 5 to 26 ¼ feet, run sometimes parallel, sometimes unite in strike as well as dip and again separate. Here and there solid masses of ore occur from 98½ to 131 ¼ feet thick. In the Mellado mine, one ore-body was as much as 197 feet in thickness.

Fig. 11 (Plate I., after Prof. Tilmann) will give some idea of the ore-occurrence. The section was taken in the Cata mine, at a depth of 385 feet. It will be seen that the branches of ore are separated from each other by country-rock—as much as 90 feet in thickness of clay-slate divides the lying-branches from those on the hanging-wall. The total thickness here is 165 feet.

The structure of the separate branches is sometimes banded (Fig. 12, Plate I., after Messrs. Aguilera and Ordonez), and sometimes brecciated, fragments of country-rock of all sizes occurring in the vein-filling. The amethyst, quartz and other minerals are sometimes aggregated in small particles and fragments; they sometimes occur in leaders or ribs, which are rarely continuous, sometimes parallel to the walls, and sometimes in curved or circular forms. The ores are seldom in solid masses, but more often occur as thin coatings on the veinstone or inclusions of country-rock, or are very finely scattered throughout.

So far as the writer is aware, very little information, other than statistical, has ever been published about this master-lode. It is to be hoped that the Geological Institute of Mexico will soon supply the deficiency, and indeed publish a monograph on

* “Bosquejo Geologico de Mexico,” Boletin del Instituto Geologico de Mexico, nums. 4, 5 y 6, page 260.

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this district that will compare favourably with the admirable one on Pachuca.*

The number of druses in the vein proves that there were many open spaces when the first filling took place—no doubt re-opening, substitution and local concentrations or enrichments have occurred from time to time since, gradually building up the complex lode as we see it today.

Amethyst and calcite, with larger and smaller irregular pieces of country-rock, form the chief filling. The mass of the vein, is composed, in addition, of ordinary quartz, brownspar, talc, dolomite and rhodonite, while gypsum, spathic iron-ore, fluor spar, apophyllite (in beautiful crystals), asbestos, mountain-leather and hyaline quartz are more or less rare.

The ores include native gold (generally very finely scattered, sometimes as a thin coating, and rarely in small solid particles), native silver (solid, scattered, as a thin coating, hair-shaped, arboriform, etc.), silver-glance (solid, crystalline, hair-shaped and filiform), among the rarer
ores, and nearly always dispersed, are stephanite, light and dark ruby-silver, fahlerz, galena and blende.

Copper-pyrites (bronze malo) and iron-pyrites (bronze bueno) are largely disseminated throughout the lode—the latter generally silver-bearing. There is a notable absence of hornsilver and heavy-spar in this lode.

At the Providencia mine (depth 71 feet), where the most northerly workings are situated, clay-slate forms both walls; the vein is from 6½ to 26½ feet thick and compact—in other words, it is not split up into several branches, as is the case in the Valenciana, Cata, Mellado and Rayas mines farther south. The prevailing matrix is amethyst, finely scattered with silver-ores. Between Rayas and Sirena, only one branch is known, from 6½ to 16½ feet thick. At Sirena, where the lode is once more powerful, it is being actively exploited by the Guanajuato Consolidated Mining and Milling Company. This mine has a depth of about 984 feet. South of the losero formation, where both walls are composed of conglomerate, the maximum thickness of the vein is only about one-half of what it is at Providencia.

Mr. Obregón, a Spaniard, began to work the Valenciana mine, in 1760, on borrowed capital. By 1766, he had reached the critical

* "El Mineral de Pachuca," Boletin del Instituto Geologico de Mexico, 1897, nums. 7, 8 y 9, 184 pages and 14 plates.

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depth of 262 ½ feet (80 metres). The following year he was joined by Mr. Otero, and, during the next forty years, this mine was worked 4,264 feet along the strike and 3,116 feet on the dip. From 1788 to 1824, Valenciana produced silver worth £6,872,663, the net profit during this period being £2,571,242. It is a remarkable fact that, during those 37 years, the mine only showed a loss in 1810, when the surface-plant was burnt down during the war of liberation.

The total depth of the mine is 1,968 feet. The main shaft is 36 feet in diameter and 1,771 feet deep. It is octagonal in shape, and lined with masonry to a depth of 328 feet. The above depth was attained by means of horse-whims only*—and the shaft had to be of colossal dimensions in order to employ as many of these as possible. The Valenciana mine has upwards of 10 miles of underground workings, and is still the deepest and the most extensive mine in the republic.

It is a mistake to suppose that the enormous lode wrought was full of rich ores: although rich patches undoubtedly occurred here and there, the average grade was not very high, and Baron A. von Humboldt is probably correct in stating that it was below 80 ounces of silver to the short ton. In 1865, the average of all ores won from the Veta Madre, according to Prof. Tilmann, amounted to 43.7 ounces of silver per short ton, and 30 grains of gold per mark (8 ounces) of silver. The ore in the bottom workings of Valenciana is said to be rebellious, containing much antimony and lead.

The town of Valenciana rapidly came into existence during the most nourishing period of this great mine. At times, the inhabitants numbered as much as 30,000. A handsome church was built, and luxuriously furnished by the owners, at a cost of £144,000.
It is melancholy to record that, after the expulsion of the Spaniards, the mine, the greater portion of which had been under water for a whole decade, was mismanaged by a British company for about 12 years. After 5 years' incessant pumping, the water was forked, by means of a badly-constructed steam-engine and numerous horse-whims, at the enormous cost of £184,000.

* The ore was raised from the various Plats in sacks made of the fibres of the agave or ox-hide, called manias; while the water was hoisted in large bags made of ox-hide, termed botas, each holding from 75 to 200 gallons of water.

Various lower levels were opened up, but the undertaking was finally abandoned in 1836 with a sum of £160,000 to their debit. Since that date, the lower levels have remained under water, although, from time to time, the mine has yielded a profit from ores obtained from the upper workings.

The Cata mine was first worked in 1700. In consequence of the great profits raised therefrom, the King of Spain made the principal owner Marquis of San Clemente. The depth is about 984 feet.

The Mellado mine (depth 1,312 feet) was worked as far back as the sixteenth century. This and the Rayas mine caused the building of the present city. For three centuries, the production of this mine was unbroken, but unfortunately the data of the former workings were lost in 1810. A British company worked the mine on contract from 1825 to 1837, losing about £20,000. Afterwards, the owners worked it again at a considerable profit. Lead- and antimony-ores predominate in the bottom-workings, as at Valenciana.

The Rayas mine has a main shaft 1,312 feet deep, measured vertically, and 39.36 feet (12 metres) in diameter. The gold- and silver-contents are unusually high, quartz, very finely scattered with gold, termed guijo de oro by the miners, being not uncommon. A British company also worked this mine on contract, and, notwithstanding the glaring incapacity of the officials, made a clear profit of £400,000, which was speedily squandered away in other undertakings.

Judging by the longitudinal section of the mines on the Veta Madre,* the ore-shoots have a tendency to pitch south-eastward.

* Prof. E. Tilmann's memoir, plate II., which is a plan and longitudinal section of the mine from Providencia to Mellado inclusive. The Engineering and Mining Journal, 1901, vol. lxxii., page 534, gives a longitudinal section, including a portion of the above, and carrying it farther south, so as to include the Rayas and Sirena mines. Several views of the Sirena surface- and underground-works are also given.
Addendum.

Prof William P. Blake describes the rocks from La Luz to Bernabe* as "metamorphic clay-slates, quartzites and conglomerates. In some places the rocks are dioritic, either from metamorphism or by reason of the intrusion of dykes. All the formations are uplifted, and are flexed and contorted, so that the dip is variable. There is abundant evidence of pyritic mineralization, the rocks being everywhere rusty and red at the surface."†

The east-and-west vein near San Nicholas‡ is evidently a cross-vein. There are actually many of these veins in the district, and, according to Prof. P. Aguilar, they probably follow the cleavage-planes of the clay-slate country-rock.

The country-rock referred to as "porphyry" in the text, is principally rhyolitic-porphyry, and all veins occurring in it carry high-grade gold-ore, containing, generally, free gold, but in exceptional cases selenides and tellurides, or gold contained in the iron-pyrites.

According to Prof. Blake "the chief veinstone or gangue of the veins of La Luz§ is a compact white quartz, with some calcite carrying argentite, pyrargyrite, stephanite, polybasite, miargyrite, and sometimes a little cinnabar. There is a considerable amount of disseminated iron-pyrites, and there are small quantities of galenite. At Bolenitos, the chief silver-mineral is the simple sulphide of silver (argentite)."ǁ In addition to the above, apophyllite may be added, which occurs in beautiful pink and white crystals in the Refugio mine.

Prof. Blake, referring to the Veta Madre,¶ says, "the vein is described as in three distinct parts, separated by country-rock or tepetate, and named blanco (24 metres); verde (15 metres), and negros (10 metres). Including the barren intervals, the aggregate width of the vein is 125 metres. The white (blanco) ores shown me consisted chiefly of quartz with disseminated silver sulphides; the black ores (negros) contained much iron-pyrites, sometimes

§ Ibid., page 53.
ǁ Transactions of the American Institute of Mining Engineers, 1901, vol. page

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carrying argentite in small particles, and distinct crystals of" argentite from the bottom of the shaft."**

The Chairman (Mr. J. G. Weeks), in moving a vote of thanks, said that the members were once more beholden to Mr. Halse for a valuable contribution to the Transactions.

Mr. M. Walton Brown seconded the resolution, which was cordially approved.
Mr. W. C. Blackett described an "Improved Offtake-socket for Coupling and Uncoupling Hauling-ropes;" as follows:


[Plate I and II, sections and maps illustrating “Silver-bearing veins in Mexico”.]  
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**IMPROVED OFFTAKE-SOCKET FOR COUPLING AND UNCOUPLING HAULING-HOPES.**  
******By W. C. BLACKETT.*******

The improved socketing contrivance for haulage purposes, which the writer had lately devised, was intended mostly for use underground. It was principally intended as an improvement upon the appliances now in use for the quick coupling and uncoupling of ropes at way-ends, but other uses would doubtless suggest themselves to the members.

[Fig. 1: Photograph of the socket system, parts A to J.]

Fig. 1 illustrates both the old arrangement (AB and CDE) and a variety of the new contrivance (F, G, H, I and J). In the old arrangement, A is the socket, similar in many respects to that already described by the writer,* in which the rope is held by means of a tapered copper plug; B and C are the offtake-key and slotted lock or box, used for ready detachment; D is a swivel for avoiding any "spin" that there may be in the rope; and E is the socket at the other end. Instead of this somewhat lengthy arrangement of links, the new device substitutes two sockets, both of which may be like F, with a connecting-piece, G, joined as shewn at J; or the connecting piece, G, instead of being rigid, may be linked. But it is, perhaps, preferable that an ordinary socket, H, should be attached to a socket, I, which again may be either rigidly joined or preferably have an interposed link.


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**THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.**  
******EXCURSION MEETING OF ASSOCIATES AND STUDENTS,**

Held at Newbottle Collieries, September 3rd, 1902.  
******
NEWBOTTLE COLLIERIES.
Margaret Pit.

The Margaret pit is one of a group of nine pits comprising the Newbottle collieries, belonging to the Lambton Collieries, Limited. It is situated in the parish of Newbottle, about 1 ½ miles southeast of Penshaw station.

There are two pits, both of which are downcasts, one being 12 feet and the other 8 feet in diameter. This latter pit was sunk in 1774, and has been drawing coals continuously since that date.

The ventilation is produced by a Waddle fan situated at a ventilating-pit, 1,500 feet from the colliery, and producing 160,000 cubic feet of air, with a water-gauge of 1 ¼ inches at 54 revolutions per minute.

Four seams are being worked at this colliery, namely: —

<table>
<thead>
<tr>
<th>Coal-seams.</th>
<th>Depth from Surface.</th>
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<tbody>
<tr>
<td>Main</td>
<td>474</td>
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<tr>
<td>Maudlin</td>
<td>564</td>
</tr>
<tr>
<td>Brass Thill</td>
<td>654</td>
</tr>
<tr>
<td>Hutton</td>
<td>690</td>
</tr>
</tbody>
</table>

The system of working in the Brass Thill seam is longwall, and in the other seams, bord-and-wall. The output is 800 tons per day.

There are 7 Lancashire boilers at this pit, each 8 feet in diameter, 30 feet long, and working at a pressure of 80 pounds per square inch. The boilers are fitted with Proctor mechanical stokers.

Electrically-driven Coal-cutters.—The generating-plant, which was not specially erected for driving the coal-cutting machines,

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has been in existence for several years for hauling, pumping and winding. It was installed in 1891, and except for the renewals of certain parts, it remains exactly to-day as it was at that time. The engines for driving the generating dynamos are of the Willans high-speed type, two in number, each being equal to 140 indicated horsepower, at a speed of 380 revolutions per minute. The steam-pressure is 80 pounds per square inch. Each engine has two cylinders, 17 inches in diameter, with a stroke of 8 inches. There are two generating dynamos, driven by means of link-leather belts, 18 inches wide, and each capable of giving out 80 amperes at a pressure of 780 volts, when running at a speed of 500 revolutions per minute: this is equal to an output of 84 horsepower.

The coal-cutters are of the diamond type of disc coal-cutter. Each cutter is driven by two series-wound motors at a pressure of 500 volts. The revolutions of the cutter-wheel are about 12 per minute. The diameter of the cutter-wheel, with cutters and boxes fixed, is 6 feet 4 inches. The average depth of the cut is usually a little over 5 feet, and the height of the cut is 4½ inches. The power required to work each coal-cutter is on an average about 15 horsepower. Each machine is controlled by a reversing-switch fitted with resistances. The machine is drawn
along the face, and kept up to its work by a rope-hauling arrangement, fixed to the end of the
machine and worked by ratchet-gear from the driving-shaft.
The Brass Thill seam, in which the coal-cutting machines are working, has not previously been
worked at these collieries, owing to the bands of stone which it contains. An average section
of the seam is as follows:—

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<th>Ft.</th>
<th>In.</th>
<th>Ft.</th>
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<tbody>
<tr>
<td>Coal</td>
<td>0</td>
<td>10 ½</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Band</td>
<td>0</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coal</td>
<td>0</td>
<td>11</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Band</td>
<td>0</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coal</td>
<td>1</td>
<td>0</td>
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<td>8 ½</td>
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Its inclination is about 1 in 36, dipping eastward. It is overlain by a roof of mild blue metal, and
it has a hard fire-clay floor. The seam is entirely free from water, and fire-damp has not been
found.
The coal-cutter kirves in the upper band, that is, above the level of the machine.

There are three coal-cutters at work in the scam, only two of which work at any one time, the
third machine being kept as a spare one in case of breakdown.

Houghton Pit
The chief feature of interest here is a Corliss valve-gear hauling-engine, situated on the
surface, supplied with steam at a pressure of 50 pounds per square inch. This type of hauling-
engine is somewhat of an innovation, and has given capital results.
The Waddle fan, 21 feet in diameter, produces 280,000 cubic feet of air per minute at a water-
gauge of 15 inches, and 100 revolutions per minute.

Philadelphia Engine-works.
The whole of the scrap-iron from the various collieries is collected at the forge, where it is used
again for new work. The forge is fitted with suitable cranes, and a 15 cwt. hammer (steam
being supplied from a boiler placed over the heating-furnace), and is capable of turning out forgings up to 3 tons in weight.
At the brass-foundry, the process of melting and moulding was shown, and also the method
of preparing moulds from patterns.
The pattern-store contains thousands of patterns of various kinds, for castings, weighing from
a few ounces to several tons.
The boiler-shop is fitted with drilling, shearing and punching machines, and a cold saw. A
jigging-screen and coal-belt was seen in course of erection: and also a new boiler for a tank-
locomotive.
The smiths' shop contains a tool-fettling and case-hardening furnace; and the work in progress included the manufacture of springs, pit-cages and chains. The general store is the distributing centre of materials to all the collieries. At the fitting, erecting and machinery shop, locomotives were seen in course of reconstruction, and a locomotive-tender, a steam-hoist, and a mechanical screening-plant ere being erected.

Herrington Pit.
Here are two high-speed Waddle fans, each 25 feet in diameter, and capable of producing 250,000 cubic feet of air per minute, with a water-gange of 2½ inches, at 100 revolutions ppr niinute. The fans are coupled to a twin-drift, fitted with steel butterfly-doors. The special feature of the arrangement of these fans is that there are two separate fans and two separate engines to drive them, instead of the usual arrangement of a spare engine and only one fan. The work of erecting these fans has just been completed, and they are now running satisfactorily.

Lambton Sanitary Pipe-works.
The process of pipe-making was traced from the dumping-ground for fire-clay, to the crushing-rolls, elevators, and pipe-machine; from the machine to the drying-sheds: thence to the kilns: and, lastly, the finished product was seen stored ready for market.
The show-room contains samples of various specialties, and the more highly-finished products are stored therein.

Chemical Laboratory.
The apparatus for testing gas coal was inspected, including the process of taking the illuminating-power by means of a photometer. The laboratory is used for the testing of gas coal, for the analysis of water, oils, steel, etc., and for the investigation of all chemical and quasi-chemical matters connected with colliery work. Some interesting microscopic specimens were shewn.

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To the King's Most Excellent Majesty
The Humble and Dutiful Address of
The North of England Institute of Mining and Mechanical Engineers

Most Gracious Sovereign,

The North of England Institute of Mining and Mechanical Engineers (Incorporated by Royal Charter in 1876) beg leave humbly to approach Your Majesty's Throne on the Occasion of the August Ceremony of the Coronation of Your Most Gracious Majesty and of our Most Gracious Queen Alexandra, and to tender Sincere and Heartfelt Congratulations on the Auspicious Event.
We desire to present our Ardent and Sincere Wishes for Your Majesty's Health and Welfare. We also Fervently Pray that Your Majesties may wear with Glory and Happiness the Crown of this Kingdom and Empire, and long continue to Reign over a Happy, Prosperous and United People.

Witness our Hands and Seal, the twenty-first day of June, 1902.

[Seal]

JOHN GEORGE WEEKS, President.

M. WALTON BROWN, Secretary.

[Royal Coat of Arms]

Home Office, Whitehall,

4th September, 1902

Sir,

I am commanded by the King to convey to you hereby His Majesty's "thanks for the Loyal and Dutiful Address of The North of England Institute of Mining and Mechanical Engineers on the occasion of Their Majesties' Coronation.

I am, Sir,

Your obedient Servant,

A. AKERS DOUGLAS.

The Secretary to The North of England Institute of Mining and Mechanical Engineers,

Newcastle-upon-Tyne.

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THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

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To Celebrate the Jubilee of the Formation of the Institute,

Held in the Wood Memorial Hall, Newcastle-upon-Tyne,

September 16th, 1902.

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Sir LINDSAY WOOD, Bart., President, in the Chair.

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The members and visitors were received by the President, Sir Lindsay Wood, Bart., who afterwards delivered the following address:

ADDRESS.

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By Sir LINDSAY WOOD, Bart.
I beg to thank you for the honour that you have conferred upon me in electing me for the second period your President. It is at all times a great honour to preside over so important and influential a body of gentlemen as compose the members of the North of England Institute of Mining and Mechanical Engineers, but it is a still greater honour to occupy that post on so memorable an occasion as the present one, which is the fiftieth anniversary or Jubilee of the formation of this Institute.

On an occasion such as this, I think it is my duty to review shortly the past history of the Institute, and to endeavour to shew whether or not, and to what extent, the objects of the founders have been carried out and whether the results they anticipated have been realized.

For some time previous to 1851, considerable loss of life had been and was taking place in working the coal-mines of Great Britain; and it was with an universal desire to stop or reduce to a minimum this loss of life, that in 1835, a Committee of the House of Commons was appointed to enquire into the causes of the accidents which were taking place; and they reported that

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regretted that the result of their enquiry had not enabled them to lay before the House any particular plan by which the accidents in question might be avoided with certainty; and consequently in question they made no decisive recommendation.

In 1839 (resulting from a serious explosion at St. Hilda's colliery South Shields), a Committee of South Shields gentlemen was appointed and sat for 3 years. They made a report of great value and came to several conclusions. Among other matters they reported that with regard to safety-lamps: "No mere safety-lamp, however ingenious in its construction, is able to secure fiery mines from explosion."

In 1845, Sir Henry de la Beche and Dr. Lyon Playfair were appointed by the Government to institute enquiry into the causes of accidents in mines and particularly as to inflammable gases. These gentlemen reported recommending the appointment of inspectors of mines, and the compulsory use of safety-lamps in all fiery mines.

In 1849, a Committee of the House of Lords was appointed. They reported the evidence that they had taken, and drew attention to that part of it regarding the appointment of inspectors of mines, and improvements in safety-lamps and of ventilation generally.

In the same year, Mr. Blackwell and Prof. Phillips were appointed to investigate and report on the ventilation of mines. They reported that they considered superior practical and scientific knowledge was required in some districts, and superior skill and unsleeping vigilance in the over-looker; which they thought "would be promoted by the establishment of provincial mining schools, and by systematic inspections under the authority of Government."

In 1850, an Act of Parliament was passed appointing inspectors of mines.

In 1851, a Committee of the House of Commons, with Mr. Cayley as chairman, was appointed, and made various suggestions, not generally of a practical character, but they reported recommending the use of the steam-jet as being the most powerful and at the same time, the least expensive method of ventilating mines.

Notwithstanding all these investigations and recommendations, the loss of life from accidents in mines did not decrease,
and it was under these circumstances that a meeting of mining engineers and gentlemen connected with the working of mines in the North of England, was held at the Coal Trade Office, Newcastle-upon-Tyne, on July 3rd, 1852, "for the purpose of forming a society, to meet at fixed periods and discuss the means for the ventilation of coal-mines, for the prevention of accidents, and for general purposes connected with the winning and working of collieries." Forty-four gentlemen attended that meeting, and it was unanimously resolved that "a society be formed of coal-owners, viewers, and others interested in collieries" for these purposes: and such was the commencement of the Institute which I now have the honour of addressing; and I regret to say that out of the 44 gentlemen attending that meeting only 7 are now living. Your first President, Mr. Nicholas Wood, in his inaugural address, set out very fully the reasons for the formation of the Institute, and the object for which it was formed, and I trust that it may not be considered inappropriate if I quote his own words on these subjects, for I firmly believe that the desire and hope of the promoters of this Institute, expressed by him in that address, have during the long period of 50 years which has elapsed since it was read, been carried out, and have met with the accomplishment of the belief then expressed. He stated, as the reasons for the formation of the Institute that: —

We may hope that . . . we are entering upon an undertaking which may be of essential utility to the important interests entrusted to our charge, and which may be the means of averting some at least of those dreadful and deplorable catastrophes which have too often been felt with such disastrous consequences to the district and to the sufferers by their occurrence: and that it may be the means of raising the, profession to a higher standard of intelligence in literature and science than it has hitherto attained.

* The object of the Institution is two-fold: Firstly, by a union or concentration of professional experience to endeavour, if possible, to devise measures which may avert or alleviate those dreadful calamities which have so frequently produced such destruction to life and property, and which are always attended with such misery and distress to the mining population of the district. Secondly, to establish a literary institution more particularly applicable to the theory, art and practice of mining than the institutions in the locality at present, or which are within the reach of the profession in this locality.

* We wish the principles of the Institution to be understood. It is an Institution of practical miners associated together to endeavour by a combination of practical knowledge, by an interchange of practical experience and by united, and combined effort to improve ourselves in the science of our profession, and by

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together as a body we may be the instruments of preventing as much as practicable the recurrence of those dreadful catastrophes . . . and at the same time to raise the art and science of mining to its highest practicable scale of perfection in safety, economy and efficiency.*
Having given you the reasons for the formation of the Institute and the objects which the founders had in view, I will now endeavour to shew how far during the last 50 years these have been carried into effect.

During the first year of the existence of the Institute, 143 members joined, and year by year they continued to increase for 25 years, when the total membership reached 971 (in 1877). For a short period after then, the numbers somewhat decreased, but after 1891 it rapidly increased, until this year, 1902, it reached 1238 members. Therefore, so far as membership is concerned, the Institute has undoubtedly prospered, and clearly shews that there is a widespread desire to obtain the information contained in the papers which have been read and from the discussions which have taken place on them.

The prosperity of an Institute such as this, does not, however, depend upon the number of its members, although financially this is perhaps important; but it is the character of the papers which are contributed by the members, and the discussions which take place on them, that create the value of the Institute, and I think that if we refer to the 51 volumes of our Proceedings, 38 of which were published before The Institution of Mining Engineers was formed, and 13 published in their Proceedings, we shall find an enormous mass of the most valuable information on almost every subject which is of use or interest to the mining profession. Geology, as might naturally be expected, has been a very fruitful subject on which papers have been contributed, mineralogy, chemical and physical investigations, surveying, mining technology (including as it does so many important subjects connected with mining), metallurgy, machinery, electric investigations, railway and transport, administration, statistics, and many other subjects have been dealt with.

In addition to these 51 volumes of Proceedings, the Library of the Institute contains 8,029 volumes and 2,189 pamphlets, all of which are valuable books of reference.


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I consider, therefore, that I am justified in claiming for this Institute that, in carrying out the objects set forth by its founders, the members have by an interchange of practical experience and by a united and combined effort to improve ourselves in the science of our profession, raised the art and science of mining engineering to a greatly higher state of efficiency than it was 50 years ago; and this progress of the utility of the Institute and the good work that it was doing was recognized by the Government, for in the year 1876 Her late Majesty Queen Victoria granted to us a Royal Charter.

Between the years 1869 and 1875, five similar institutions to this were formed in the different parts of the mining districts of Great Britain and carried on successfully, each reading their own papers and circulating them among their members, but many valuable papers did not obtain the widespread circulation which their value to the mining industry justified. It was, therefore, about 1887 that a scheme was devised for a federation of these institutes and matured in 1889. There are now six Institutions federated together under the title of The Institution of Mining Engineers. The scheme is undoubtedly a good one, for under it each local association still maintains its own individuality, reading and discussing its own papers, but
each member of the local associations receives the papers and discussions of the other local associations, which form the membership of The Institution of Mining Engineers, as well as the papers and discussions thereon which are read at the meetings of The Institution of Mining Engineers, held twice in each year. Thus, the information brought before the local and general Institutions is much more widely circulated than it would otherwise be.

There is one important matter which has been brought to the notice of mining-engineers since the formation of the Institute, to which I think I shall draw special attention. That is, the discovery of the very important part that coal-dust, or in fact dust of other materials than coal, plays in causing explosions in our mines, and in increasing the disastrous effect of them.

In March, 1876, Mr. William Galloway read a paper before the Royal Society giving a set of experiments which he had made on the subject. This, I think, was the commencement of investigations into the subject in Great Britain, although it had previous to that time been under the consideration of some French engineers. The result of Mr. Galloway's experiments went to shew that when a small percentage of gas was mixed with air, from 1 to 1 ½ per cent., so small as could not readily be detected and the air mixed with dust, when exposed to a sufficiently large volume of flame such as that from a blown-out shot, an explosion of a very violent character took place. After this, many experiments were made on the matter by members of this Institute, notably those made at Elswick colliery by Mr. W. Cochrane, forming the basis of a paper read on November 2nd, 1878, by Messrs. A. Freire Marreco and D. P. Morrison recording the results of these and other experiments made by them, and pointing out that certain descriptions of dust when mixed with air entirely free from gas and exposed to a flash of flame, produced an explosion. The discovery of this new source of danger explained the cause of many explosions which at the time they took place were quite inexplicable, although the greatest ability and perseverance had been exercised to discover the cause. Since attention had been called to the matter, many stringent rules have been put in force, to be observed in dry and dusty mines, and it is satisfactory to know that very few explosions are now caused from this source of danger.

In making this short, and, possibly, very imperfect review of the objects aimed at and the work done by this Institute during the last 50 years, it is incumbent on me to refer to the great part that it took in the establishment of the Durham College of Science.

Although the formation of such a College was not specifically referred to as one of the objects of the formation of the Institute, yet it was laid down that one of the first principles of the Institute should be to raise the mining profession to a higher standard of intelligence in literature and science, and this could hardly be done without the establishment of a College of Science. Consequently, within a year of the formation of the Institute, namely, April 1st, 1853, the President, Mr. Nicholas Wood, referred to the subject of the establishment of a School or College of Mines. A Committee of the Institute had previously been appointed in furtherance of the object, and he stated the result of his interview with Dr. Lyon Playfair, the Warden of the University of
Durham, a Committee of the Corporation of Newcastle, representatives of the coal-trade, lead-mining, and manufacturers of the district, and informed the Council that he had the pleasing duty to report to them that considerable progress had been made in discussing the plans and in arranging the general outline of the scheme.

On December 7th, 1854, the Council of the Institute was formed into a Committee to draw up a plan in detail of a Mining College giving the scheme or system of education to be pursued. This report was widely circulated and gave the matter a practical bearing which it had not hitherto attained, and had the result of bringing, on January 11th, 1856, from the then Duke of Northumberland, a munificent offer to contribute £5,000 if £15,000 could be raised for the endowment, or £10,000 if £30,000 could be raised. The Council took steps to make this offer generally known and used every endeavours to raise the necessary funds, but they were not very successful. They, however, did not allow the matter to drop, but continued their negotiations chiefly with the Warden and Senate of the University of Durham. The proceedings of the Institute shew how indefatigable were their endeavours year after year to overcome all obstacles and prejudices which presented themselves to the formation of the scheme. It was not, however, until July 5th, 1871, that the Council of the Institute were able to report that a scheme had been finally agreed upon. This was largely due to the very great assistance rendered by the late Dean Lake and by the large grant of money given by the University of Durham. Thus the present Durham College of Science was founded on October 24th, 1871, jointly by the University of Durham and the North of England Institute of Mining and Mechanical Engineers, and from that day to this it has continued to prosper in a most satisfactory manner, and is now one of the finest colleges of physical science in the United Kingdom. There are at present 490 students attending the regular courses of lectures, and in addition to these there are 1,170 students attending the evening and special classes. Surely this large attendance shews the great need that existed for such an Institution, and the great work which it is now doing, not only in the education of those connected with mining but of those who are employed and likely to be employed in the manufactories in this great commercial district.

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I think I may now investigate whether since the formation this Institute and the founding of the Durham College of Science there has been any reduction in the great loss of life which was previously taking place in our mines. I do not for a moment wish to infer that the reduction in the loss of life which, as I hope to shew, has taken place, is due to the proceedings of this Institute; but I do claim for it that it has most materially assisted in the education of its members and the elevation of the science and art of mining, and that this has been one, if not the chief, agency by which the better and safer working of our mines is being carried on.

On reference to the Mineral Statistics of the knifed Kingdom it will be seen how enormously the coal-trade has increased during the past 50 years.

In 1851, the year immediately preceding that in which this Institute was formed, the output of coal for the United Kingdom was 53,000,000 tons, whereas in 1900 - 50 years after - the output had reached the very large figure of 225,170,163 tons, or more than four-fold. Of course, this enormous increase could not be obtained without employing a very much larger number of persons than were employed in 1851. The number of persons employed underground at that date was 171,893 whereas in 1900 they amounted to 644,242, or an increase of 3.74 times the number employed 50 years ago.
Consequently, mining-engineers have at the present day to provide for the daily safety underground of at least 472,449 more men and boys than they had to do in 1851. The men employed on the surface have increased in almost the same proportion. In 1851, there were 44,424 employed and in 1900 there were 174,275 or 3.83 times as many. Such has been the great increase in the coal-mining industry since this Institute was formed.

The chief object, however, in the formation of this Institute was the prevention of accidents, and the saving of loss of life. In reviewing the results which have taken place, I think that it will show more accurately what has been done in this way if I take an average of 5 years at the commencement of the period under review and a 5 years’ average at the present time, rather than take the first year and last year only. I will, therefore, take the result, of the average of the years 1851 to 1855, and compare them with the average of the years 1896 to 1900 inclusive.

To have obtained a correct comparison of 50 years I ought to have taken a period of 5 years from 1847 to 1851 inclusive, to compare with 1896 to 1900, but previous to 1851 no reliable statistics were kept of accidents and deaths. I have, therefore, taken the period of 1851 to 1855.

At this early date, as perhaps at the present time, explosions in mines were always looked upon as being the cause of loss of life which should be the first and great object of the mining-engineer to prevent, although at that time as at the present, they were by no means the source of accidents which caused the greatest number of deaths.

The number of deaths which were caused by explosions on the average of 5 years from 1851 to 1855 was 231 per annum, whereas the average for the last 5 years was 64; but if we take into consideration the difference in the number of persons employed underground during the latter period, as compared with that employed during the first period, and if the same death-rate per person employed which was taking place in the first period had continued the same in the latter period from 1896 to 1900 there would have been 765 lives lost from this cause, or 701 more than actually took place.

The next class of accidents in mines is that produced from falls of roof and sides. In the first period under review, there was an average of 368 deaths per annum from this cause, whereas the average per annum during the latter period from 1896 to 1900 was 469, but if the same death-rate had continued during the latter period as was taking place in the first period there would have been 1,205 lives lost, thus shewing a saving of 736 lives per annum.

The death-rate of 75 per annum, although too high (and I should like to see it reduced), does not seem excessive when it is taken into consideration that some 600,000 persons descend and ascend the shafts of our mines some 230 times each year. This, I think, shews that great care is exercised by the management and also by the workmen themselves.
The other classes of accident such as those termed “miscellaneous,” comprising all accidents other than those I have stated and also those which take place on the surface, follow much more nearly the ratio of persons employed.

The total loss of life from all sources, on the average of the five years from 1851 to 1855, was 985 per annum, whereas the average for the five years from 1896 to 1900 was 1,001 per annum or 16 more than in the first period, although there were 525,297 more men and boys employed in and about the mines: but if the same death-rate had continued during the latter period as during the first, there would have been a loss of 3,146 lives instead of 1,001, thus shewing a reduction of 2,146 deaths.

I therefore venture to assert that the objects which the founders of the Institute had with regard to the preventing of accidents and saving of life have been very largely fulfilled, but by no means fully accomplished.

We as an Institute must not, however, rest satisfied with the progress which has been made during the last 50 years, but must continue to the utmost our exertions to raise still further the standard of attainment in literature and science and in the art of mining among our mine-managers. There is still a great deal to be done towards the reduction of accidents, and the loss of life occasioned by them. Although the loss of life from explosions in 1900 was only 44, caused by 24 accidents, yet if we analyse the causes by which they occurred, we find that 20 out of the 24 were caused by naked lights, and some of these occurred through officials using naked lights instead of safety-lamps while making the statutory inspection of the working-places. Surely, there is great room for improvement in the discipline and care by which these mines are worked, and this, if exercised, would prevent many accidents taking place from this cause.

In the following year, 1901, we find that the proportion of accidents from this cause, namely, naked lights, is not so great, though it accounts still for a large proportion, namely 12 out of 21 accidents.

The number of explosions caused by shot-firing does not seem so huge; there were only 2 in 1900, and 3 in 1901. Considering the vast number of shots fired every day, these must be considered small in number.

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The class of accident which causes the most deaths is that due to falls of roof and sides. Accidents from this cause are not nearly so much under the control of the management as these arising from many other causes. The nature of the work of mining necessarily requires the workmen to be left for several hours of the day without supervision, during which time they must exercise their own judgment as to the safety of the roof and sides. It is, therefore, to the skill and care of the workmen themselves that we must look for the reduction in the number of deaths from this cause; yet I am of opinion that, with a sufficient supply of material for propping always within easy access of the workmen, explicit instructions for its use, strict discipline and better lights, the number of deaths from falls of roof and sides would be considerably reduced.

I trust, therefore, that the members of the Institute will take this matter into their consideration and by united conference be able to devise means for the prevention of this class of accidents.
In a short address such as this, I have not considered it advisable to refer to the many other duties of the mining-engineer, although many are very important, yet not so important as that of the prevention of accidents. The economical working of our mines is, however, a very important matter, and affords ample scope for the communication of papers on the very various matters which affect the proper working of our collieries, so as to enable us to compete with other countries in the sale of the product of our mines.

In conclusion, I can only say that I hope that the good work which has hitherto been done by this Institution will continue, and that the results will in future be even greater than those which have been accomplished during the first 50 years of its existence.

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Mr. John Daglish said that, as the oldest surviving Past-President and as one of the original members of fifty years age, he had pleasure in moving a vote of thanks to Sir Lindsay Wood for his admirable address. He had had a very long professional connection with the President, and also with his father, the late Mr. Nicholas Wood, with whom he commenced his professional career and with whom he was associated for very many years. He congratulated Sir Lindsay Wood on his re-election to so important an office, and he was also glad to congratulate the Institute upon Sir Lindsay's accepting for the second period a position for which he was so highly fitted.

Mr. J. G. Weeks (Retiring-President), in seconding the vote of thanks, said that the members felt highly gratified in having Sir Lindsay Wood—a distinguished son of their first president—to preside over the Institute. They were equally gratified in hearing from him so able and excellent an address, in which he had shown how the aims of the founders of the Institute had been amply fulfilled.

The vote of thanks was carried with enthusiasm, and was briefly acknowledged by Sir Lindsay Wood.

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A conversazione was afterwards held, at the invitation of the President, in the Hancock Museum of the Natural History Society of Northumberland and Durham.

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THE MUSEUM OF THE NATURAL HISTORY SOCIETY OF NORTHUMBERLAND AND DURHAM.

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The following notes indicate the portions of the museum collections, which are likely to prove most interesting to geologists and mining-engineers.

The fossil-room, the third large room from the entrance, contains sets of fossils, which represent the life on the earth from the earliest period (Cambrian) of which any such record has been discovered. The contents of this room have been arranged in their present form comparatively recently, and are not yet finally labelled and mounted. Much of the case-room on the ground-floor is devoted to the Coal-measures and the Permian formation. Especially noteworthy are the fine series of Magnesian Limestone fossils collected by the late Mr. J. W. Kirkby and others: the Atthey collection of Coal-measure fishes and amphibians from the
shales above the Low Main seam at Newsham; and the Hutton collection of Coal-measure plants. The Hutton collection contains

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many of the original specimens figured in Messrs. Lindley and Hutton's Fossil Flora of Great Britain (1831-1887), a classical work which forms the basis of the modern knowledge and nomenclature of fossil botany. The collection was formerly the property of the North of England Institute of Mining and Mechanical Engineers, and was presented by them to the Natural History Society.

In the upper and lower western corridors will be found the collection of minerals, and in the wall-cases on the upper floor a series of rocks, the latter, so far, only roughly arranged. Amongst the rocks is a good set of the remarkable concretionary Magnesian Limestones of the Sunderland district.

In the lower eastern corridor, which contains objects too large to be placed in their proper systematic position, are some specimens of interest to practical geologists: for example, a section of the Brockwell seam, Coal-measure tree-stems, and some large polished slabs of Weardale "marbles" (Carboniferous Limestone crowded with corals).

Of the remainder of the Museum collections, the sections of chief general interest include the well-known Hancock collection of British birds occupying the central room, the gallery of wood-cuts and original drawings by Thomas Bewick, and the upper eastern corridor containing the ethnology collection.

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THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

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GENERAL MEETING.

Held in the Wood Memorial Hall, Newcastle-upon-Tyne,

October 11th, 1902.

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SIR LINDSAY WOOD, Bart., President, in the Chair.

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The Secretary read the Minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on August 16th, September 27th and that day.

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The Secretary also reported the proceedings of the Council of The Institution of Mining Engineers.

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The following gentlemen were elected, having been previously nominated: —

Members —

Mr. John Boland Atkinson, H.M. Inspector of Mines, 2, Devonshire Terrace, Newcastle-upon-Tyne.
Mr. Alfred Quintin Carnegie, Engineer, 21, Eldon Place, Newcastle-upon-Tyne.
Mr. Charles Crofton, Engineer, 17, Albany Gardens, Whitley, R.S.O., Northumberland.
Mr. Percy H. Jones, Colliery Manager, Snatchwood Park, Pontypool, Monmouthshire.
Mr. Robert Rutherford, Colliery Manager, Axwell Park Colliery, Swalwell, R.S.O., County Durham.
Mr. Herbert Kilburn Scott, Consulting Mining Engineer, Clun House, Surrey Street, Strand, London, W.C.; and Rio de Janeiro, Brazil.
Mr. Robert Rowell Simpson, Mining Engineer, The Geological Survey of India Offices, Calcutta, India.
Mr. John Whitfield Thomson, Mining Manager, General Manager, Ashanti Proprietary Gold-mines, Limited, c/o Messrs. A. Miller Brothers, Axim, Gold Coast, West Africa.

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Associate Members—
Mr. George Mattland Edwards, 24, De Vere Gardens, West Kensington, London.
Mr. Oswald W. Ellis, 31, Grosvenor Place, Newcastle-upon-Tyne.
Mr. Charles R. Pattinson, Burnaby Lodge, Ryton-upon-Tyne.

Assessors—
Mr. John Eskdale, Assistant Mechanical Engineer, Ashington Colliery, Morpeth, Northumberland.
Mr. William James Knight, Engineer's Draughtsman, 12, Wolmerhausen Street, Wheatley Hill Colliery, Thornley, R.S.O., County Durham.
Mr. George Bailey Morris, Back-overman and Surveyor, 7, Lloyd Street, Lemington-upon-Tyne.
Mr. Percy Edmund Smallwood, Back-overman, Chopwell Colliery, Lintz Green, R.S.O., County Durham.
Mr. James Wallace, Gold-miner, c/o West African Union Mines, Adjah Bippo, Tarkwa, via Sekondi, West Africa.

Student—
Mr. John Edward Ralph Herrison, Mechanical Engineering Apprentice, Ottawa, via Durban, Natal, South Africa.

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DISCUSSION OF MR. FRED C. KEIGHLEY'S PAPER ON "COKE-MAKING AT THE OLIVER COKE-WORKS."

Mr. A. L. Steavenson (Durham) said that the coke-ovens described were of the old type of bee-hive ovens similar to those working on the Quayside, Newcastle-upon-Tyne in 1765, and which he himself had described to the members of the Institute in 1860. Mr. T. Y. Greener† appeared to agree that the 12 ¼ feet coke-oven described by Mr. Keighley was an improvement on the practice in the North of England of erecting 11 feet ovens. He (Mr.
Steavenson) differed from Mr. Greener on that point, for if the ovens were 12 ¼ feet, and the drawers had to work with drawing-rakes sufficient to reach to the back of the oven, they became exceedingly heavy and awkward to move, and one of the first results would be that the workmen would demand an increase of 1d. or 2d. per oven. In his experience, a coke-oven 11 feet in diameter was about the best dimension to adopt. In building the ovens described by Mr. Keighley, no space appeared to have been left between them; and, consequently, there was no room for the expansion of the ovens, which would eventually mutually destroy each other. Mr. Greener pointed out that it was wrong

† Ibid., vol. xxiii., page 485.

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To use lime in the building of the ovens, but what was described in the paper was loam-mortar, and he (Mr. Steavenson) understood this to mean the use of loam instead of lime-mortar. The cost of manufacture was a little above that of this district, namely, 1s. 7 ¼ d. against 1s. 5d. to 1s. 6d. per ton; wages, however, were high, and he was not surprised at the cost being a little more. The paper described a seam of good coking coal, and under such conditions it was not surprising that the coke was obtained cheaply, and it was no fault of the managers of collieries here that they could not compete with them in price.

It was stated in the paper that no attempt had been made to utilize the waste-products, and in this respect America is very far behind this country. He (Mr. Steavenson) did not go so far as Prof. P. P. Bedson, who contended that they were bound to extract from the coal every product which it was capable of yielding. To put down a plant capable of extracting bye-products from 700 coke-ovens would involve an outlay of £90,000, or more than twice the cost of ordinary bee-hive coke-ovens. Before entering upon such a very large outlay, it was necessary to consider whether the bye-products would justify the expenditure, and it would be seen by referring to an article on “Coke-oven Residual” that some of these bye-products had a very limited market, and had recently experienced a very serious fall in prices. He had supplied blast-furnaces with coke from beehive coke-ovens for the last 50 years, and during that time he had been at least once a week to the furnaces, and therefore knew exactly what kind of coke they wanted. He found that if they used coke from retort coke-ovens, 2 cwts. more of such coke were required per ton of iron than of coke from beehive coke-ovens. Many engineers had experimented with a few retort coke-ovens, but they were generally very shy of giving their results; and merely contented themselves with stating that the coke was just as good.

With 28 beehive coke-ovens, they could boil, with a Lancashire boiler, 80 tons of water in 24 hours. Assuming that this quantity of water was boiled by coal, it would be found that this alone represented something like 1s. per ton of coal put into the oven, and this he contended was a very useful mode of utilizing what might be termed a bye-product. At three large collieries


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raising about 1,000 tons per day, they were using no coal whatever for their boilers, and he would defy anybody to come forward and say that retort-ovens were giving better results than this; taking into account, in the case of retort-ovens, the extra cost per oven for distilling the bye-products, and the great doubt there was as to the value of the material compared with the known, value of the gases used under the boilers.

Mr. F. R. Simpson suggested that in all papers of this kind it would be an advantage if the unit of weight was the ton of 2,240 pounds. The special feature in the plant of beehive coke-ovens described was the low cost of producing coke, due chiefly, as Mr. Steavenson had pointed out, to the low cost of the coal. Reducing the figures to the British ton, the total cost amounted to only 7s. per ton. Taking the yield of coke at 67 per cent., the coal put into ovens only cost about 3s. 3d. per ton, a very low figure. The cost of labour in converting the coal into coke, was about 1s. 9d., per ton, or slightly higher than the cost at many coke-yards in the North of England, and this was accounted for by the higher rate of wages paid to the men. The cost of materials was low, being about 0.80d. per ton of coke produced. The average coke-production per day from 300 ovens drawn was 675 to 700 short tons, or 603 to 625 long tons; and at the rate of three drawings of each oven per week, this gave 12 ½ tons per oven per week, a result which could only be obtained by regular working. Messrs. Oliver supplied the coke to their own blast-furnaces, and any small variations in the quality would be treated with greater leniency than in the open market. Over 9 per cent. of ash, on the average of the analyses, appeared high when the whole output was converted into coke, and many collieries in Durham could manufacture coke from small coal with the percentage of ash quite as low. The statement that the establishment of 700 beehive coke-ovens was until recently the second largest in the world, was rather sweeping, and might perhaps be modified into an expression of opinion.

Mr. J. C. B. Hendy (Etherley) said that all who had read Mr. Keighley's paper would agree that the writer had every reason to congratulate himself upon the nature and quality of the coal that he had to coke. A coal which could be thrown into

the ovens as it came out of the mine, without any cleaning, crushing or any treatment whatever, and yield 67 per cent. of coke which only contained about 9 per cent. of ash and 0.7 per cent. of sulphur, was very valuable, especially if it could be put into the coke-ovens at a cost of 4s. 4d. per ton. The Connellsville seam is naturally an excellent coking coal, but when we come to consider the manner in which it is treated and the construction of the coke-ovens described in the paper, there are several points which are open to discussion. Setting aside the question of the recovery of the bye-products, there is apparently at the Oliver coke-works no attempt whatever to utilize in any way the waste-gases from the ovens, either for raising steam or any other purpose. The ovens are burnt out of the top-eye. There may be some special reason for it, not explained in the paper, but it is rather surprising to find, in such a large plant and where so much money has been expended, that there is no arrangement of flues to the ovens. He (Mr. Hendy) thought that if a properly constructed main flue had been made between the rows of ovens, with branch flues from each oven into the main flue, and dampers so arranged in the branch flues that the coke-burner could regulate
the proper proportion of air-supply to each oven and shut off the oven from the main fine when necessary, a much better and more economical result would have been obtained.

The ovens appear to have been built (in the first instance) of ordinary fire-bricks, which after about 4 or 5 years have fallen in, partly owing, no doubt, to the poor quality of the bricks and partly to the construction of the oven. Mr. Keighley also appears to have used a brick made of flint-clay containing about 64 per cent. of silica and 26 per cent. of alumina, but he (Mr. Hendy) could not make out from the paper where these bricks had been used. The latter is evidently a mixed brick, or a brick made of a mixture of clays yielding together the above proportions of silica and alumina. Mr. Keighley is now, however, using a brick containing about 97 per cent. of silica. Such a brick, no doubt, is eminently suitable for very high temperatures, but he (Mr. Hendy) doubted whether it would stand the constant heating and cooling to which a coke-oven was subjected, and he believed that if the coke was slacked in the oven, the water and steam would have the effect of cracking this brick and causing it to splinter and fall into the oven in small pieces. He (Mr. Hendy) was of opinion that the best brick for use in building beehive coke-ovens contained about 70 per cent. of silica and 23 per cent. of alumina, and was made from a clay naturally yielding of itself these proportions of silica and alumina. He had known several instances of such a brick lasting in beehive coke-ovens for 20 to 25 years: of course-the back-eyes and door-jambs had been repaired during that time but the body of the coke-ovens had stood for that period.

He (Mr. Hendy) agreed with Mr. Steavenson that a diameter of 11 feet was the most convenient and useful size for a beehive coke-oven.

In the ovens at the Oliver works, the doors were only 2 feet 8 inches wide and 2 feet 8 inches high to the spring of the arch; he thought that this door was rather narrow for a 12 feet oven, and that the drawer might experience some difficulty in drawing out the coke from the sides of the ovens.

Further, it would be noticed that there was only one line of rails running along the centre, for loading both rows of ovens— an objection to only one line of rails was, of course, that the ovens could not be loaded so quickly as with two lines, and that if a stoppage or breakdown occurred on the only line, the loading was stopped on both rows of ovens. He preferred a line of rails running over each row of ovens, with a lighter and smaller locomotive and smaller coal-tubs.

A striking feature in this paper was the low cost of production compared with the rate of wages paid for coke-making. He noticed that chargers were paid 7s. 8d. per day; ash-carters, 6s. 8d.; track-cleaners, 6s. 3d.; car-shifters, 9s. 4d.; masons, 10s. 5d.; and labourers, 6s. 3d. The cost of the coal put into the ovens was low, but something more than this appeared to be necessary to account for the low total cost of coke-production, when the above rates of wages were considered; and it would be interesting to know the number of hours and amount of work done per day by the above workmen, and compare the same with those prevalent in this district.

Mr. Keighley had told the members that he had sold coke for 2s. 11d. per ton. They were accustomed to hear of startling things from America, and, certainly, the most extraordinary selling-price that he had heard of for blast-furnace coke was 2s. 11d. per ton.
Mr. W. C Blackett (Sacriston) thought that it was remarkable that so little account was taken, in comparing the different kinds of coal, of the temperatures at which the coal carbonized. One gentleman, who found his coal, carbonizing as it did at high temperature, to be best suited for a beehive coke-oven, would condemn another for using retort-ovens, although the latter might be better adapted to his particular class of coal, which coked at a lower temperature. A colliery-owner might be driven at last to work an inferior seam, and from bye-product ovens, he would obtain as good, and sometimes better, coke than he would obtain, perhaps, from the same coal burnt in bee-hive ovens. In bee-hive ovens, their fine Durham coal carbonized at a very high heat, and when they had a very high heat they got a deposit of carbon—similar to that in gas-retorts—upon the coke, giving it a fine silvery and hard looking appearance. Some of the inferior coal did not carbonize at that high heat, and they did not get the same fine crystalline appearance and the same hardness, and it was comparable with the black-looking coke, watered outside, produced at bye-product ovens.

Mr. W. O. Wood (South Hetton) wrote that, judging from the particulars given in Mr. Keighley's paper, coke-making was one of the things that could be done better in England. From a coal, containing 5.73 per cent. of ash, the resulting coke ought to contain 8.12 per cent of ash, and the 9.25 per cent. was no doubt due to the fact that "no cleaning or slate-picking is done." Iron-masters in this country would certainly not be satisfied with a coke containing so high a percentage of ash. The yield appeared to be fairly good, and the breeze was apparently wasted. Without knowing the country, it was difficult to judge, but unless the region was very arid, the supply of water necessary for cooling the ovens could have been collected in reservoirs at a very small proportion of the cost of the pipe-line, 12 miles in length, to say nothing of the cost of pumping the water.

The President (Sir Lindsay Wood, Bart.) said that Mr. Blackett had raised an important point respecting the temperatures at which coal was carbonized, and this would make a considerable difference in the results obtained from the ovens.

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DISCUSSION OF MR. E. REUMAUX'S PAPER ON THE "USE OF WASTE-GASES FROM BYE-PRODUCT COKE-OVEN IN EXPLOSION-MOTORS."

Mr. W. M. Parrington (Wearmouth colliery) wrote that he considered Mr. Reumaux's deductions as to the desirability of using the waste-gases from coke-ovens for power purposes were unanswerable. Mr. Reumaux clearly showed that at a large colliery, coking, say, half its output, as much power could be got by using the waste-gases in explosion-motors as would meet all the requirements of such a colliery under average conditions as to depth, water to be pumped, etc.

Mr. B. H. Thwaite (Westminster) wrote that Mr. Reumaux's paper was interesting and important, because it brought forward a subject that deserved the serious consideration of all owners of coke-ovens. If one were asked to provide an expression to signify in the briefest possible way the particular element that was supremely essential to a manufacturing nation,
no better reply could be given than is embodied in the sentence "cheap and abundant fuel-power." Therefore, the question of utilizing the waste effluent gases from coke-ovens for the purpose of securing directly or indirectly this supreme essential assumed at once a position of first-class importance.

The production of power for any modern electrical industry likely to be of permanent value, should be abundant. The fuel should be such as to permit of its being used for the production of power in large units, and it should be of such regular composition as to permit electric machinery to be driven by it. The effluent gases from coke-ovens, however, do not provide either condition satisfactorily. The hydrocarbon-constituents of coke-oven gas are extremely variable, and independently of their variability, they are too sensitive to combustion influences to permit of a satisfactory thermo-dynamic efficiency being obtained. Further, the power-potential as given by Mr. Reumaux, is not sufficiently large to permit of the laying-down of electric apparatus of sufficient magnitude to satisfy the creation of an electrical industry.

He (Mr. Thwaite) had two distinct methods of securing the most profitable use of the coke-oven effluent gas, and by these the objections raised were removed. One method was to dilute the effluent gas from the coke-ovens, with four times its volume


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of generator-gas, containing no appreciable proportion of hydrogen but having as its combustible constituent from 25 to 30 per cent. of carbonic oxide, such gas being generated from poor coke unsuitable for sale at a fair price. This method at once secured such a reduction in the proportion of the hydrocarbons, that the composite gas could be used for driving gas-engines of 1,000 horsepower and with satisfactory cyclical regularity. The indicated horsepower of the gaseous effluents issuing from each unit coke-oven, would be raised from Mr. Reumaux's factor of 15 to that of 63.75 indicated horsepower, so that a battery of 120 coke-ovens would have a power-potential of 7,650 indicated horsepower. This magnificent power-aggregate would only involve the putting on one side of 3.4 tons of poor coke, and this residue would be used to the best possible advantage.

Where coke-ovens were associated with blast-furnaces, his (Mr. Thwaite's) second method was the best. This included the employment of the coke-oven gases as directly as possible for the purpose of firing the hot-blast stoves, for the purpose of setting free blastfurnace-gas for the production of power in gas-engines. He had demonstrated that blastfurnace-gas was, as nearly as possible, ideal for power-production purposes, and the use of coke-oven gas in hot-blast stoves would enable a higher and more equitable stove-temperature to be maintained, because no lime or other incombustible matter would be introduced into the stove with the gas; and although blastfurnace-gas was so ideal for producing power, it was nevertheless inferior to coke-oven gas for heating purposes in which combustion was effected in fire-brick stoves or furnaces.

It would be noticed, on referring to the table of data supplied by Mr. Reumaux* that he gave the electrical horsepower ratio in No. 1 experiment as being equal to 16.42; this he (Mr. Thwaite) thought should be 15.33. In No. 2 experiment, Mr. Reumaux gives the figure as 17.10, but this he (Mr. Thwaite) also thought should be 16.85.† The variation in power would thus be (1685 — 1533 = ) 1.52 electric horsepower, resulting from the variable hydrocarbons
present in the gas. This constituted a very serious variation, and one that was quite inadmissible where the motive power had to be harnessed to electric generating machinery.  

† An electrical horsepower is 736 Watts in France, and 746 Watts in Great Britain. — Editor.

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DISCUSSION OF MR. G. P. LISHMAN’S PAPER ON “THE ANALYTICAL VALUATION OF GAS-COALS.”

Mr. W. C. Blackett expressed his appreciation of Mr. Lishman’s paper. He thought that analyses of gas-coal were often unfair and unreliable, and not unfrequently cargoes would be condemned because a few pounds, or it might be grains, of coal had given unsatisfactory results in the laboratory.

Mr. H. Dunford Smith (Newcastle-upon-Tyne) complimented Mr. Lishman upon the apparatus, which had been adopted at the Lambton collieries. He considered the plan of water-jacketing the condensers a very good one, and wished that it was universally adopted. From 60 to 90 minutes seemed to be rather a long time to be occupied in making a test: he thought that 45 to 50 minutes should be long enough, and he would like to know whether the additional time made any difference in the sperm-value.

Dr. H. S. Pattinson (Newcastle-upon-Tyne) wrote that this paper, dealing as it did with difficulties encountered in the testing of coal on a small laboratory scale to determine its value for gas-making purposes, was chiefly of interest to those whose business it was to make such tests. The value of these tests, of course, depended upon how they compared with the results obtained on the working scale in gas-works. If it was found by experience that the laboratory-test bore a definite ratio, within reasonable limits, to the result obtained when the coal was used in the gasworks, then the laboratory-test had a high value. Although there was some difference of opinion on the subject, yet he thought that it might be taken as generally conceded by gas-works managers and chemists that tests on a laboratory-scale of a coal formed useful guides as to the illuminating-value of the coal. It had been found by experience that the results given by a coal on a gas-manufacturing scale were inferior to those obtained from the coal in a coal-testing apparatus; but the difference between them had been found, within reasonable limits, to be fairly constant, so that a gas-works manager from his own experience might ascertain what deduction from the sperm-value of a coal given by the laboratory-test had to be made, to shew him what the coal would yield him industrially. Anything that would


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assist us to obtain regular results in laboratory-trials was of interest and value, and the members were indebted to Mr. Lishman for giving them the benefit of his experience.
The difficulties in the way of obtaining regular results he rightly points out to be due:—

(1) To variation of the heat of the distillation-retort, and (2) to the effects of the changes of temperature upon the condensable products of the gas in the tar-condensers and purifiers. He (Dr. Pattinson) had not found the first of these to offer great difficulty. A fair measure of the heat was the time required to expel all the gas, and by allowing a certain time for expelling say 10 to 10½ cubic feet from 2 ¼ pounds of coal, and adjusting the heat so as to drive off the gas in that time, the temperature of the retort might be taken to be fairly constant. With regard to the second point, he was surprised to learn that in Mr. Lishman's experience he still obtained very variable results, when the external heat around the cooling-pipes and purifiers and in the gas-holder was maintained constant by artificial means. Mr. Lishman offered no explanation of this and he could see no obvious one.

Mr. Lishman's remedy for all irregularities was to make a comparative test of each sample with a "standard coal" obtained from a "standard seam," and proportionately as the results-obtained with a standard coal varied from the normal, he made a correction upon the results given by the sample. He took no objection to the principle of correcting by a standard, but it was not every one who had a "standard coal" or a "standard seam" always available. And, he might be permitted perhaps to add, that knowing how the coal in most seams varied from time to time, he would feel very doubtful about his "standard seam" always being up to the standard. He feared that most people would have to do without their "standard seam" of coal.

He would point out in conclusion that the time mentioned by Mr. Lishman for distillation, namely, 60 to 90 minutes, indicated that he used an unusually low temperature in his retort, and, that the slow rate at which the gas passed over would tend to increase the effects in the cooling-pipes and purifiers due to variations of external temperature. The time which was aimed at in his firm's laboratory varied from 45 to 50 minutes.

Mr. James Stewart (Editor of the Gas World, London), wrote at if Mr. Lishman had made a cursory enquiry into the literature

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of gas-making he would not have introduced his paper with the statement that "there is an almost total absence in scientific journals of papers on the testing of gas-coal."* The Transactions of the different associations of gas-managers and the volumes of the journals specially devoted to gas-matters would have furnished him with numerous papers on the subject, to say nothing of the special treatises on gas-manufacture, from that of Clegg (published in 1840) onward. Then, after revealing his lack of acquaintance with what has been written on the subject of which he treats, Mr. Lishman asserts that "although coal-testing plants are attached to most gasworks now, they are usually of but limited use to the engineer, who still has to rely mainly on his working-scale results." It would be interesting to know what, if any, justification Mr. Lishman has for this statement. Of course, in a literal sense, the use of every separate apparatus is limited to the purpose which it subserves, and the ultimate and principal criterion of the value of a coal is found in its working results.

The object of the paper was to describe the apparatus in use at Lambton, to point out the difficulties which commonly beset the novice in coal-testing, and to explain the means ultimately employed by the author to remove those difficulties and to remedy the irregular results which had hitherto been obtained. The apparatus is of the usual type, for the distillation
of 0.001 ton. Mr. Lishman is well advised in heating his retort by gas, rather than by a coal or coke fire, as it is vastly more convenient of manipulation and more under control; and with a regulated gas-supply and occasional experiments with a Siemens pyrometer, the carbonizing temperature may be maintained as desired, within very narrow limits.

The illustration† shows a scrubber with a water-supply, but, from the paper itself, it is questionable whether it is employed. In fact, with an apparatus on so small a scale it is practically impossible (except with very great loss of illuminants) to wash the gas with thoroughness, or even to remove all condensable matter from it; and consequently Mr. Lishman has to confess that, to obtain steadily concordant results, he finds heavy condensation necessary. Without some scrubbing of the gas on

† Ibid., page 574, Plate XXVIII.

wetted surfaces, it is impossible to get the minute vesicles of liquid hydrocarbons, which are carried forward mechanically by the gas, to coalesce and fall out of it. Thus, while the temperature may be brought down to a fairly low degree, the gas, containing these traces of liquid hydrocarbons, which by the rougher treatment of the gas-works are removed, will possess a high and fallacious illuminating power. And this, he (the Editor) imagined, will help to explain how colliery-analysts obtain the high results that are never borne out in practice.

An interesting part of the paper is that in which the author shows the application of a standard coal as a criterion in testing others. The method is as follows: — Having at command a coal which can be relied upon to remain fairly constant in quality, its sperm-value under certain conditions being well established, he makes a test of this coal along with every other coal being tested; and as the sperm-value shown for the standard coal, under existing conditions, compares with that hitherto determined, so is the value obtained for the new coal corrected, up or down. The idea is not, of course, entirely original. Every expert in coal-testing has discovered the use of a coal of fairly uniform and known quality for checking the reliable working-of his apparatus before submitting to it some entirely new material. The systematic application of the idea, in the way recommended by Mr. Lishman, has not, however, been advocated before; and this proposal is distinctly to his credit.

There will probably always be differences of opinion and practice among gas-engineers in regard to coal-testing. The fact is, two different objects have to be served by a coal-testing plant. It is required, (1) to ascertain the comparative values to the gas-maker of different coals; and Mr. Lishman recognizes, with more justice and candour than some experimentalists have shown, that the true interest of both buyer and seller of gas-coals is served by aiming at results which approximate to what may be attained on the large scale in a well-conducted and properly equipped gas-works. The non-recognition of this principle by sellers of coal, or their analysts, has led, in the past, to much heartburning on the part of gas-managers; who, having bought on the strength of some hopeful analysis, have been justly indignant when corresponding results could not be obtained in practice.

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Then, (2) the object of a coal-testing plant in a gas-works is to check both the quality of the coals periodically received and the efficiency of the carbonizing plant and its supervision. For this latter purpose, the isolation of one or more of the ordinary working-retorts (providing, of course, the necessary separate condensing and purifying plant) is sometimes practised. And this method has its advantages, especially as it approximates closely to working-scale practice. On the other hand, the retort with its heating arrangements is not entirely under the control of the experimentalists; and the plant, as a whole, does not afford the same facilities as a smaller and self-contained one does for experimenting on improved methods of working. And in addition to furnishing a summary of actual working results, the coal-test should serve, at times, as an example of, and as a guide to, better working.

Mr. W. Doig Gibb (Newcastle-upon-Tyne) wrote that Mr. Lishman's paper dealt with a subject which was of equal interest to mining- and to gas-engineers, but the two branches of the profession would probably be inclined to judge the subject-matter of the paper from distinct sides, although in reality their interests were identical, in that it was of equal importance to both that they should be able quickly, and with a fair amount of accuracy, to determine the relative value of coals raised and used for gas-making purposes. The literature of gas-making did not include many reliable and accurate papers on the testing of coals, and, partly in consequence of that deficiency, the methods employed in testing coal at various gas-works were at present not uniform, but depended almost entirely upon the individual ideas of those in charge. Further, in comparatively few gas-works was a coal-testing plant used at all, and an apparatus could be very usefully introduced into many gas-works where at present they relied solely upon the appearance of the coal. In such works, they were apt to blame the raw material if good and uniform results were not obtained, and did not take into consideration that there was a considerable element of doubt introduced, in that the carbonization of the different samples might not have been carried on under exactly similar conditions. While the use of a testing-plant of the size named by Mr. Lishman was, of course, of great advantage to gas-works, it could only be regarded as one which

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would, in the best circumstances, give approximate results to those attained on a working scale; but it had the great advantage that the results were got quickly and economically. It was, of course, of no great use to a gas-maker in conducting experiments with different enriching agents, etc., and, for this latter purpose—as well as for obtaining more accurate results as to the carbonization of coal in bulk—it was very desirable for larger gas-works to possess, in addition to a laboratory-plant, a complete plant on a working scale. As regards laboratory-plant, most gas-engineers would agree with almost all Mr. Lishman's conclusions; and his practice of taking a certain seam of Lambton coal as a standard was, from his point of view, an excellent one. From a gas-engineer's point of view, the writer would prefer to assume a theoretically perfect gas-coal, giving it, say, an arbitrary value of 100, and then compare the tests of the different coals against this and give as their value a number which would bear the same proportion to 100 as their value did to the theoretically perfect coal.

He had no doubt that Mr. Lishman would be subject to criticism as regards his arrangements for condensation, etc., but in the present state of coal-testing it was impossible to do otherwise
than erect condensers, etc., of a size which seemed best to the designer and when those were erected (whether large or small) to endeavour to keep the whole apparatus in a room where an uniform temperature could be maintained. The arrangement might or might not give the best possible results (although experiments would tend towards getting the best) but at all events it might be counted upon to give with considerable accuracy comparative values. This (it seemed to the writer) was all that could be done, since he was afraid that no two engineers would, at the present time, agree upon what was the theoretically perfect amount of condensation required and how this condensation was to be effected.

Dr. W. Carrick Anderson (University of Glasgow) wrote that he had been much interested in Mr. Lishman's paper. Apart from the particular topic with which it dealt, it was valuable in helping to direct attention to the need there was for systematic examination and testing of coal, generally, in respect of its suitability for different purposes. In the case of gas-coals, Mr. Lishman stated clearly the difficulties that confronted the chemist in testing them for yield and quality of gas. These were of two kinds:

(1) Those that centre in the retort, and (2) those that are associated with the cooling and purifying apparatus. Those which he classified as being- due to the difference of results found in various gas-works were of course in themselves for the most part ultimately referable to one or other or both of the above groups.

Any and every coal would split up differently, according as the heat was raised more rapidly or more slowly upon it, and in practice no two firings of a retort would be identical in their effects upon the coal even with the most careful working. In an experimental retort he was afraid that, even with electrical heating, which would be more equable and more readily controlled than firing by combustion, satisfactory results could hardly be counted on, although this was a point which seemed to him (Dr. Anderson) to be worth investigating. With the condensing part of the apparatus, as Mr. Lishman's experiments showed, the same was true, and absolute constancy of result was impracticable.

They were, therefore, driven to refer their results to a standard as Mr. Lishman had done. He would suggest, however, that this standard should not be one chosen by each experimenter for himself, but that a standard gas-coal should be selected for the whole country. Such societies as the Institution of Mining Engineers and the Society of Chemical Industry might collaborate with advantage in a work of this kind.

**DISCUSSION OF MR. H. BIGG-WITHER'S "NOTES ON DETONATORS."

Mr. F. H. Edwards (Newcastle-upon-Tyne) wrote that Mr. Bigg-Wither appeared to place the responsibility of miss-fires with nitrate-of-ammonium explosives on the detonator, whereas it was a wellknown fact that explosives of the nitrate-of-ammonium class were difficult to detonate at any time, and more especially so if the explosive happened to absorb moisture, which it was certain to do if kept for any time in a store or magazine. No matter what high explosive is used, consumers could not be too careful in selecting the best quality of detonators, as this was a very important factor in blasting operations, whether in the mine or in the open.
Mr. A. C. Kayll (Gosforth) wrote that Mr. Bigg-Withers's practical and illustrative notes on detonators opened up an interesting and important discussion on the causes of miss-fires and incomplete detonation of explosives. It could readily be assumed that detonators would absorb moisture and be rendered useless, when packed in damp sawdust or even when the detonator was not entirely freed from sawdust before attaching it to the fuse or electric cable. In such instances, the onus of a miss-fire could, with justice, be put upon the detonator, as no sound would be heard, a clear proof that the detonator had not exploded. Miss-fires may, however, occur owing to the detonator becoming detached from the charge, when placed in position in the shot-hole or during the process of stemming, and then the detonator or the explosive would unjustly be blamed, as there are no means of ascertaining the true facts under actual mining conditions.

During the extensive series of experiments conducted by the Explosives Committee of the North of England Institute of Mining and Mechanical Engineers there were many instances of incomplete detonation of the charge caused by faulty explosives; miss-fires arising from the electric cable becoming short-circuited, when running the cannon into position; and only two instances occurred from the detonator being defective. These detonators were subsequently tried with other electric exploders, with non-effective results. Damp sawdust could not be assigned as a reason in these instances, as the detonators were of the enclosed type with attached wires.

The question, therefore, arose: Are all detonators regular in their action when fired? The experiments of the Explosives Committee showed that many detonators caused an ignition of an explosive mixture of gas and air, but some did not. He thought that Mr. Bigg-Withers's experiments with leaden blocks might do much to elucidate this question.

Mr. Harold Bonser (Leeds) wrote that the experiments which had been carried out and illustrated by Mr. Bigg-Wither very clearly demonstrated the ill-effects created by even the slightest trace of moisture on the fulminate of the detonator, greatly reducing its force and impairing its efficiency in blasting operations by causing partial detonation of the explosive. To this cause could be attributed many miss-fires, partial detonations, and ignitions of the charge of explosive without detonation,


too much attention, therefore, could not be paid to this subject, as so many of the modern safety-explosives depended on complete detonation for their safety. Electric detonator-fuses had of late been much improved in quality, and compared favourably with the old-time methods of firing shots by means of a length of time-fuse, as regards cost and expense. The adoption of electricity for the important mining operation of shot-firing, not only in fiery and
dusty mines, but in all other seams where blasting was a necessity, had reduced many of the chances of miss-fire. In the process of manufacture of electric fuses, the detonator is hermetically sealed on to the terminals of the wires, and this effectively excludes all moisture from the fulminate. He hoped that this paper might meet the eye of members who still pursued the ancient methods of shot-firing, and that it would induce them to give a trial to modern systems. Not only was moisture excluded in electric fuses, but, by their use, safety was assured to the workman who had to proceed to the place after a shot had been fired, and greater comfort to every person in the mine from the entire absence of fuse-smoke.

Mr. H. Bigg-Wither (Wigan) wrote that his "Notes on Detonators" had reference to detonators only, as an hitherto unsuspected cause of missed shots, and presupposed that the explosive itself, as well as the electric attachments to the detonator, were in proper working order, that the detonator did actually explode within the charge, and that, although the sound of the explosion was clearly heard, nevertheless, the charge was not detonated; the cause of the failure being that the detonator itself had become ineffective through absorbing damp, and, therefore, it did not set up a true detonating wave, which was essential in order to explode high explosives efficiently. Mr. Bonser very rightly pointed out that, in the absence of true detonation, the charge of explosive failed to perform its work, or even that the charge might be ignited and burn in the shot-hole. In this connection he had been making further experiments with detonators, fired on leaden plates, with a view to observing the relative body of flame given off by a good detonator (A, Fig. 5*) and a bad one (E, Fig. 6†). With the tester (Fig. 4‡) placed sideways, but not screened, a good detonator showed a bright

† Ibid., page 417.
‡ Ibid., page 443.

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flash extending about \(\frac{1}{2}\) inch beyond the edges of the tester, accompanied by sparks, which, doubtless, were incandescent particles of the copper tube. The flame was not solid, and in some parts was of a bluish tinge. A bad detonator, on the other hand, produced a solid body of bright white flame extending at least 6 inches on either side of the edges of the tester. These experiments were repeated with the tester screened, 4 inches on either side. A good detonator only showed sparks; whereas, bad ones showed the same bright flame, extending at least 2 inches beyond the screen.

DISCUSSION OF MR. W. E. GARFORTH'S PAPER ON AN "EXPERIMENTAL GALLERY FOR TESTING LIFE-SAVING APPARATUS."

Mr. W. H. Pickering (H.M. Inspector of Mines, Doncaster) wrote that in cases of colliery-explosions and fires, there was never a lack of volunteers, brave to recklessness, and ready to face any danger to save life, but a corps of trained men equipped with proper apparatus would have been invaluable in many cases. In his opinion, stations should be established in every mining district, where men could be trained in rescue-work and where all necessary appliances could be stored ready for use; where also explosives and safety-lamps could be tested. Such stations should not be initiated and maintained by private enterprise, but should
be supported by a small annual subscription from every colliery-owner, and the management of the stations might be entrusted to a representative committee, of a composition similar to the Boards for Examinations.

Mr. H. W. Halbaum (Gateshead) wrote that he was not anxious to throw cold water on any scheme the object of which was the saving of human life, and, speaking in the abstract, it was hardly necessary to say that he was in full sympathy with Mr. Garforth's work. He thought, however, that Mr. Garforth's method attempted to hustle them on to a stage more advanced than they were at present entitled to approach. Possibly the apparatus described by Mr. Garforth might be found useful when seal-mg-off a gob or other mine fire, especially when putting in the


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last stopping. But it could hardly be of any real service to a party exploring after an explosion with the object of rescue. The following reasons for this opinion might be stated in order: --

(1) Judging from Mr. Garforth's own description, the apparatus appeared to be faulty, whatever degree of excellence it might or might not attain in the future.

(2) The difficulty of obtaining pure oxygen, according to Mr. Haldane, appeared to be considerable; and if the impure oxygen, ordinarily obtainable, were employed, the use of the helmet, independently of the state of the external atmosphere in the mine, might easily bring about the very disaster that it was designed to avoid, namely, the suffocation of the wearer.

(3) While scarcely lessening the recognized danger of inhaling the irrespirable gases contained in the after-damp, the use of the apparatus accentuated and magnified the (at least equal) danger of accident due to the comparative inability of the wearer clearly to perceive his surroundings when creeping over the falls, and past the "side-wavers," and under the loosely overhanging rocks left by the passage of the blast.

(4) The benefit of the helmet was more apparent than real, as it deprived the wearer of exactly as much advantage as it gave. It might enable a man to penetrate farther into a deadly atmosphere, but, on the other hand, the man, being then farther removed from the fresh air, was put into so much greater peril when distress appeared: and, according to Mr. Garforth's account, distressing symptoms were liable to manifest themselves at any moment. Thus it clearly appeared that the measure of the helmeted explorer's penetration into the foul atmosphere was also the direct measure of his peril; and those two entities (the penetration and the peril) would remain in constant ratio, until an absolutely perfect apparatus was invented and adopted. As yet, however, there were no signs of such a perfect apparatus being put on the market.

(5) Such an apparatus as that described by Mr. Garforth, or even a perfect apparatus of the kind, would appear to be, except in the very rarest of rare circumstances, a wholly superfluous and unnecessary encumbrance in rescue-work. For, supposing that the appliance enabled the explorer to penetrate with safety to himself into the most deadly atmospheres, it would certainly never enable him to find living men in such atmospheres, and

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hence he could perform no rescue in the true sense of the word. It might be replied that the apparatus would allow the explorer to fix the ventilating-pipes more quickly; but ventilating-tubes should not be fixed too quickly, or further accidents might ensue. Large volumes of gas should be removed cautiously and slowly, and be diluted with still larger volumes of air, and the pipes could be extended quickly enough for this purpose by adhering to ordinary methods.

(6) If such an apparatus was to be of real service, it was the entombed person at the face who required it. It was he who, in order to escape to the shaft, must of necessity go through the noxious atmosphere. But, in that case, he must be in possession of it before the explosion occurred. And if that very obvious view were admitted, it was the logical inference that the apparatus should become an essential part of the daily outfit of every individual workman. And did anyone seriously imagine that the average workman would continually keep his apparatus in perfect working order, in view of a contingency so remote as a future explosion?

(7) If, however, they reverted to the practical possibilities of the case, and said that the apparatus was tor the use of the rescue-partly only, it was difficult to see what real want it supplied. The apparatus obscured their vision, impeded their movements, and increased their peril by temporarily concealing the state of the atmosphere. But, apart from the merits or demerits of the appliance, he contended that comparatively safe rescue-work could be effected without it. Rescue-work was not always conducted as safely as it might be: there was generally a little recklessness or impetuosity, which under the circumstances was excusable, but it was nevertheless a real element of danger. Imagine a string of rescuers traversing a passage of the exploded mine: the first man got into the after-damp and fell down; the second man ran to his aid, and was likewise stricken down by the deleterious gases, and in such a case possibly both men perished. If so, however, they perished through sheer recklessness—not solely their own, but that of the entire party. Such incidents, as a general rule, were not the necessary accompaniments of judicious exploring. He would suggest that many of those lamentable accidents might have been averted, by merely adopting the simple but time-worn and time-tried methods of the seaman and the mountaineer.

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A few years ago, at a large colliery in the county of Durham, a deputy for some reason or other ventured into a foul place, and was overpowered by the gas; a fellow-workman went to his assistance and shared a like fate; yet another man went to the rescue and he likewise, was stricken down; and all three men lost their lives. Now, had that deputy gone in with one end of a sufficient length of rope attached to his waist, and left a man outside in charge of the other end, he might, on falling, have been hauled out with little difficulty, absolutely without risk to his rescuer, and, the delay being reduced to a minimum, he himself might have been easily revived by the inducing of artificial respiration. In the majority of cases where the leading man of an exploring-party was knocked down, approximately, if not precisely, similar conditions prevailed: and in every exploring expedition through an exploded mine, the leading man, or the first couple of men, should be attached to their followers by a light but sufficiently strong rope, and at least two of the party behind should be expert at the process of inducing artificial respiration. By such means, exploring might be made comparatively safe, and in his opinion, the use of any helmet or other similar apparatus would tend to increased danger rather than increased safety. When the irreproachable atmosphere was found, it was folly to attempt to penetrate it, whether helmeted or otherwise. Such attempts to invade the undoubted
atmosphere of death might be heroic, or they might be foolhardy, but they could scarcely have any tangible useful result in the way of rescue-work.

He (Mr. Halbaum) would be glad to see ambulance-instruction more widespread before adopting Mr. Garforth's heroic scheme. Falls of stone were more numerous than explosions of gas; the former class of accident was always with them, and rescue-parties after the latter class of accident needed for their own safety and efficiency little more than a capable and cautious leader, a good rope, a thorough knowledge of the Sylvester method of inducing artificial respiration, and perhaps a stimulating drink. Where Mr. Garforth's helmeted explorer was called on once, the expert ambulance-man might be called on fifty times. They might, moreover, remember the axiom that when common-sense measures fail, heroic measures seldom succeed. It was much to be feared that, whatever the case might be elsewhere, ambulance propaganda was far too much neglected in the mining

villages of the North of England; and until such neglect had been effectively remedied, it would be premature to adopt in that locality any scheme such as that proposed by Mr. Garforth. Moreover, the inevitable effect of bestowing undue attention on fascinating but impracticable systems of that kind was naturally to induce one to relax one's efforts in extending those well-proved systems, which might indeed be less showy, but which, on the other hand, were infinitely more practicable, reliable and beneficent.

The President (Sir Lindsay Wood, Bart.) suggested that Mr. Garforth referred not so much to the erection of depots for the storing of life-saving apparatus, as to the desirability of erecting experimental galleries in which such apparatus could be tested.

Mr. T. E. Forster (Newcastle-upon-Tyne) referred to an accident at Killingworth colliery, in which the difficulty was not to rescue the men who were working in the mine at the time, but to save those who went down wearing the Fleuss apparatus.

Captain J. H. Thomson (H.M. Chief Inspector of Explosives, Whitehall) wrote that the establishment of an experimental gallery was, in his opinion, a very important step towards the working out of a thoroughly satisfactory apparatus which would enable men to enter places where the atmosphere was irrespirable. Mr. Garforth's paper did not give a detailed description of the apparatus used in the experiments, but he gathered that it was designed to absorb the expired carbonic acid, and to supply the deficiency of oxygen. He did not think that this was the best method of attacking the problem, and, as a matter of fact, it appeared that men wearing this apparatus could not perform hard work for any length of time. The apparatus should be, he thought, of so simple a character that it would be unlikely to get out of order, even if left unused for a considerable length of time. For this reason, indiarubber pipes and any fittings which were liable to deteriorate on keeping, should be avoided. He thought that the simplest way would be, as Dr. Nicholson and Dr. Markham had suggested, to supply air from steel cylinders and to exhale into the atmosphere. The average adult exhaled about 330 cubic feet per 24 hours, but a man when doing hard work might exhale as much as 850 cubic feet, or about 35 cubic feet.
per hour. If he were to carry on his back, two steel cylinders 4 inches in diameter and 2 feet long, these cylinders would hold at a pressure of 100 atmospheres, about 25 cubic feet of air, and would weigh, when empty, about 12 pounds each. They would hold, therefore, sufficient air to enable a man to perform hard work for nearly ¾ hour, and the supply would probably last longer than this, as the man would not be exerting himself the whole time. The cylinders might be fitted with a main valve, a reducing valve, and a regulating cock, by which latter the man could govern the supply of air at will. He also suggested that there should be a short length of helical-steel piping, passing over the man’s shoulder and fitted with a wooden mouthpiece, which could be held in the mouth by means of the teeth. Air could then be exhaled through the lips, and the nostrils could be closed with a clip or, better still, with soft wax. Of course, the air which was compressed would be previously purified, and a little excess of oxygen might be added. Care should also be taken to ascertain that there was no oily or other oxidizable material in the cylinder before compression. He imagined that an apparatus of this description might be kept at a mine or elsewhere for several years, and still be ready for use at any moment. He was recently asked to consider the possibility of a man carrying an apparatus by means of which the air that he breathed could be freed from carbonic oxide gas, and he was impressed by the very considerable difficulties attending any such attempt at purifying air as it was breathed.

DISCUSSION OF SIR HOWARD GRUBB’S AND MR. HENRY DAVIS’ PAPER ON “THE GRUBB SIGHT FOR SURVEYING-INSTRUMENTS.”

Mr. H. Jepson (Durham) said that the purpose of the instrument seemed to provide a permanent adjustment for parallax. The authors did not suggest that it should replace the telescope or the theodolite, and he understood that it was only useful as a substitute for the old-fashioned sight fitted with horse-hairs.

Prof. Henry Stroud (Durham College of Science) wrote that he agreed with the authors that it was impossible to focus simultaneously two or more objects at different planes. The Grubb sight appeared to be an important improvement, as it made the process of sighting at once accurate and simple. It should be, he thought, of especial service as an attachment to the miners’ dial.

Prof. Henry Louis (Durham College of Science) wrote that he had had an opportunity of examining the Grubb sight, and found that it gave fairly sharp definitions under the conditions of illumination prevailing underground, but was less satisfactory for surface-work. He found it very difficult to bring the image of the cross sharply enough upon a flagstaff standing up against the sky-line. He also noticed that the arms of the cross were rather too broad for accurate work in the instrument which he had examined; in this, he found that the width of the cross at the eye subtended an angle about equivalent to a chord of 1/100° so that an error equal to the thickness of a ranging-rod could occur in a sight less than 130 feet in length. He
would suggest that more accurate sighting could be done if the cross had a fine dark line along the centre of the luminous arms, or if these cross-arms did not quite meet in the centre and each terminated in a point.

He rather objected to the arrangement of the sights as adapted to the ordinary dial, because it was necessary, as now arranged, to turn the sights over on the trunnions between each fore-sight and back-sight; and there was always some risk of displacing the dial by thus handling it between two consecutive observations at the same station. It would probably be better if the sight were duplex, so that either end could be used as a fore- or a back-sight, as the case might require.

Sir Howard Grubb seemed to have overlooked the fact that in using his method of subtense measurements in plane-table work an error was introduced that might easily become serious; his instrument read off on the level-staff an intercept proportional to the hypothenuse of the vertical triangle of which the staff formed the perpendicular, the measurement really required being the base and not the hypothenuse. The distance read off would accordingly require correction by calculation, unless the ingenious appliance of Ljungstrom were used, as it is in some of the best Swedish plane-tables. In the Ljungstrom device, the alidade carries a telescope by means of which the subtense reading for distance is obtained. The alidade also carries the scale for plotting, but this scale is engraved on a strip of metal hinged to the fiducial edge: a pricker travels along the edge, the position of which is set off on the scale according to the subtense reading. By a simple mechanical arrangement, the scale is so connected with the telescope as to be parallel to the fiducial edge when the telescope is horizontal, and to be inclined to it in proportion as the telescope is inclined upwards or downwards; so that, while the length of the hypothenuse is set off on the scale, the distance traversed by the pricker along the fiducial edge of the alidade always gives the correct length corresponding with base, i.e., to the true horizontal distance. Such a device for automatically correcting the error of the subtense reading could easily be applied to the Grubb sight.

On cursory examination, it would seem that one of the most promising applications of the principle of the Grubb sight should be to the proposed modification of the prismatic compass, and he (Prof. H. Louis) hoped that this proposal would soon be worked out in a practical form.

Mr. Henry Davis (Derby) wrote that perhaps too much modesty was shewn by the inventor as to the capabilities and accuracy of the new sight. In his (Mr. Davis') opinion it would displace the telescope for colliery-surveys, both for underground and surface-work; and readings to 1 minute of arc could be made with a finely-marked sight, a degree of accuracy which was difficult to plot. A pocket monocular field-glass rendered the process easy and accurate. Doubtless, the theodolite and level would still be employed for extensive surface-surveys, but for underground work and general surface-surveys these instruments would be displaced by the Grubb sight. Referring to Prof. Henry Louis' statement that he had found a difficulty in observing the cross upon a flag-staff standing up against the sky-line: this could be overcome, in such positions, by artificially illuminating the sight, as a small electric lamp, candle, or even a match, would throw a brilliant cross upon the flagstaff. The arms of the cross could be made as fine as desired, the lines of the cross need not meet in the centre, and any other device to
suit the surveyor or the conditions could be provided. There would be no difficulty in providing a duplex sight, in place of a single sight turning on trunnions, but the latter form was convenient, and no unusual care need be observed in reversing its position.

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The paper, under consideration, had dealt only with the application of the Grubb sight to underground surveying: but it had several and important spheres of usefulness, in addition to its original application for sighting ordnance. Many small surveying instruments are now being fitted with the Grubb sight, such as clinometers, levels, prismatic compasses, pocket-sextants, optical squares, etc.; and, in fact, the Grubb sight may with advantage be applied to all instruments, by which levels and angles were previously measured by the eye-teasing processes of dividing the pupil and in endeavouring to focus two or more objects simultaneously, a further benefit being experienced therein that the observer need not keep his eye fixed, but may take his sight in the easiest position.

Sir Howard Grubb (Dublin) wrote (with reference to Prof. H. Louis' remark, that he had a difficulty in bringing the cross upon a flagstaff standing up against the sky-line) that the sight to which Prof. Louis refers was probably one made specially for mining work, in which, as a rule, the film of sulphide of lead was deposited very thinly: as the cross was always abundantly brilliant when illuminated even by a very poor artificial light; but for overground work this could be modified and the cross made as brilliant as desired. For overground work, however, he would recommend that one or two faintly-tinted glasses be supplied, which could be placed, if desired, in front of the sight, thus reducing the brilliancy of the object aimed at, and making the cross appear more brilliant by contrast. It should be remembered that the visibility of the cross as seen projected upon an object, depended not only upon the relative brilliancy of the cross and the object on which it was projected, but also upon the intrinsic brilliancy of the object itself; because, if the object aimed at was of a very brilliant character, as in the case cited by Prof. Louis, the pupil of the eye involuntarily contracted, and consequently the cross appeared less brilliant, not only by contrast with the background, but from the fact that the pupil of the eye itself was reduced in aperture. It was only in cases where the background was brilliant that there was a difficulty in seeing the cross, and there was no objection to reducing the brilliancy of that background by the introduction of neutral-tinted glass.

He (Sir Howard Grubb) would not touch upon the matter of

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the breadth of the arms of the cross, as Mr. Davis had replied to this point, except to state that one of the advantages claimed for this sight was that the ghost-image could he made of shapes and forms which would not be possible if it were a material object: that is to say, the lines may be broken lines, or dotted lines, or rings hanging apparently in space, forms which it would hardly possible to produce, except with a virtual image. Personally, he favoured the cross with a blank centre, which Prof. Louis had been kind enough to suggest, and which he had been using for some time with gun-sights.

With regard to the suggestion that an error was introduced in the measurements obtained by the plane-table, by reason of the instrument reading off "an intercept proportional to the
hypothenuse of the vertical triangle of which the staff forms the perpendicular, the measurement really required being the base and not the hypothenuse, this would be perfectly true and correct for many of the instruments which had been used for subtense work; but when Prof. Louis had an opportunity of inspecting one of his (Sir Howard Grubb's) instruments he would see that this matter had not been overlooked. It was true that a staff, held upon an eminence would subtend a smaller angle to the observer than if placed vertically under it in the horizontal plane: (1) Because it was placed at a greater distance, as the crow flies, and (2) because the staff was not at right angles to the direction in which it was viewed. But in his graphometer, so long as the plane-table was kept level, and the zero of the scale corresponded with the horizon (as it should do) that portion of the scale which was used to calibrate that staff subtended a less angle to the optical centre of the collimating-lens for the very same reasons, namely : (1) It was at a greater distance from the optical centre than the centre of the scale: and (2) it was inclined at an angle to the direction in which it was viewed, and this was in exactly the same proportion as the staff itself, consequently the result obtained was correct.

Of course, he (Sir Howard Grubb) was referring to moderate angles. If the angle at which the staff was to be viewed was very great, and the scale required to be so long that the end of it was sensibly out of focus with the collimating-lens, the above remarks would not be strictly true, and correct observations would not be possible except at the optical centre of the lens.

He (Sir Howard Grubb) would add that in making surveys with his graphometer, he did not propose that the subtense method should he used for all observations, at least where considerable accuracy was required. He would commence by chaining a line and laying down his large triangles from each end of that line, using the graphometer only as an angle-measurer; and then he would put in his secondary triangles and off-sets by the subtense method. By this means, fairly accurate surveys could be made and that very rapidly.

**DISCUSSION OF MR. W. R. COOPER'S PAPER ON "ELECTRIC TRACTION ON ROADS AND MINERAL RAILWAYS."**

Mr. John McLaren (Leeds) wrote that the question of electric traction at mines was very ably dealt with in the paper, but the use of electricity as a propelling agent for vehicles on common roads was hedged about with so many practical difficulties, that he was afraid it would be a long time before electric could come into serious competition with steam and petroleum-engines. The question of moving heavy loads on common roads by mechanical means had been engaging the attention of some of the best mechanical engineers in the country, and, although no absolutely satisfactory solution had yet been obtained, most of the practical difficulties had been overcome, and the matter was now in a fairly satisfactory position. Engineers were waiting for a good storage-battery; and as soon as this was discovered, there would no doubt be an immense development of electrically-driven road-motors, both for light and heavy work.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,
Held in the Wood Memorial Hall, Newcastle-upon-Tyne,
December 13th, 1902.

Sir LINDSAY WOOD, Bart., President, in the Chair.

THE LATE MR. G. F. BELL.

Mr. J. G. Weeks said that, since the last meeting, they had lost by death, Mr. G. F. Bell, H.M. inspector of mines. The deceased gentleman was a member of the Council, who in his work amongst them had been recognized as a friend in every sense of the word. It was with very great regret that the members had heard of his death, and he moved that a vote of condolence be sent to Mrs. Bell expressing their regret at her husband’s death, and conveying their sympathy with her and her family in their bereavement.

Mr. Henry Lawrence seconded the vote of condolence.

The vote of condolence was unanimously adopted.

The Secretary read the Minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on November 29th and that day

The following gentlemen were elected, having been previously nominated: —

Honorary Member—

Members —
Mr. Reginald Bell, Colliery Manager, The Equitable Coal Company, Limited, Jamooria Colliery, Raneegunge, Bengal, India.

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Mb. Herbert Wright Chapman, Mining Engineer, Tower Hill, Middleton St. George, R.S.O., County Durham.
Mr. Bourn Russell Chicken, Mechanical Engineer, 17, Kenilworth Road Newcastle-upon-Tyne.
Mr. John Curry, Mechanical Engineer, The Lyons, Hetton-le-Hole, R.S.O., County Durham.
Mr. William Davies, Colliery Manager, Llanhilleth House, Llanhilleth R.S.O., Monmouthshire.
Mr. Telesforo Garcia, Jun., Engineer, Santa Teresa, 2, and P.O. Box 463, City of Mexico, Mexico.
Mr. Joseph Green, Mining Contractor, Crag House, Ferryhill, County Durham.
Mr. Jonathan Edward Hodgkin, Electrical Engineer, Shelleys, Darlington.
Mr. Robert Hall Longbotham, Engineer, Ings Foundry, Wakefield.
Mr. Neil McLellan, Mechanical Engineer, Idsley House, Spennymoor, County Durham.
Mr. John Pettie MacTaggart, Electrical Engineer, 21, Grainger Street West, Newcastle-upon-Tyne.
Mr. Thomas Ventress Simpson, Under-manager, Throckley Colliery, Newburn, R.S.O., Northumberland.
Mr. Alfred Thompson, Colliery Manager, Talbot House, Birtley, R.S.O., County Durham.
Mr. Anthony Wilson, Mining Engineer, Thornthwaite, Keswick, Cumberland.
Mr. John Wishart Younger, Mechanical Engineer, Washington, R.S.O., County Durham.

Associate Members—
Mr. Peter Kirk, 13, Mosley Street, Newcastle-upon-Tyne.
Mr. Sidney Reid, 26, Claremont Place, Newcastle-upon-Tyne.
Mr. David Samuel, Albert Street, Llanelli, South Wales.
Mr. Peter Scholer, Royal School of Mines, South Kensington, London, S.W.
Mr. Alfred Francis Toovey, 33, Westgate Road, Newcastle-upon-Tyne.

Associates—
Mr. John Chipchase, Foreman, 23, St. Helen's Terrace, Coxhoe, R.S.O., County Durham.
Mr. Patrick Gallagher, Master-shifter, 15, James Street, Newfield, Chester-le-Street, County Durham.
Mr. Robert William Hall, Mine-surveyor, 1, Railway Street, Murton Colliery, Sunderland.
Mr. George William Hedley, Surveyor, Deafhill Colliery, Trimdon Grange, R.S.O., County Durham.
Mr. Thomas Patterson, Colliery Engineer, East Hetton, Coxhoe, R.S.O., County Durham.
Mr. William Pattison, Deputy-overman, 18, East Street, High Spen, Lintz Green, R.S.O., County Durham.
Mr. John William Robinson, Under-manager, Callerton, Kenton, Newcastle-upon-Tyne.
Mr. John William Wilkinson, Under-manager, Double Row, South Durham Colliery, Bishop Auckland.

Students---
Mr. Matthew Forster Cheesman, Mining Student, Throckley Colliery, Newburn, R.S.O., Northumberland.

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Mr Arthur Elliot, Mining Apprentice, 28, Burdon Terrace, Newcastle-upon-Tyne.
M John Galloway, Mining Student, Hebbum Colliery, Hebburn-upon-Tyne.
Mr John Bridges Bailey Hawkins, Student, Murton Colliery, via Sunderland.
Mr. Joseph Todd Swan, Mining Student, Throckley Colliery, Newburn, R.S.O., Northumberland.
Mr. George Teasdale, Jun., Mining Student, Garden House, Pelton, Chester de-Street, County Durham.
Mr. Thomas A. Thirlwell, Mining Student, Wallsend Colliery, Newcastle upon-Tyne.

Mr. Thomas Douglas (Past-president) referred in terms of satisfaction to the success which had attended the recent celebrations in connection with the Jubilee of the Institute. The success of the proceedings on that occasion was very largely due to the great interest and trouble which the President had taken in the matter, and he begged to propose that a very hearty vote of thanks be accorded to him.

Mr. J. G. Weeks (Past-president) seconded the resolution, which was very cordially adopted.

The President (Sir Lindsay Wood, Bart), in acknowledging the vote of thanks, said that the success of the meeting was sufficient recompense to him for any trouble that he had taken.

CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, BELFAST, 1902.

The report of the proceedings of the Corresponding Societies Committee of the British Association for the Advancement of Science, and also that of Mr. J. H. Merivale, the delegate representing the Institute, were read as follows:

Broomhill,
October 24th, 1902.

To the President and Council of the North of England Institute of Mining and Mechanical Engineers.

Gentlemen,
The meetings of delegates to the British Association for the Advancement of Science, appointed by local Societies, were held at the Queen's College on September 11th and 16th. I was present at both meetings, which were only moderately attended.

Erratic Blocks of England, Wales and Ireland.—The Committee, which has this matter in hand, would be very glad of assistance from any members interested in geology, as the information that they have received in regard to erratics in the counties of Northumberland and Durham is very scanty. Mr. P. F. Kendall, the honorary secretary to the Committee, states that the information required is as follows:

"The Committee desire local clubs to undertake the systematic examination of the areas covered by their operations. They should observe and record mainly, rocks which by their nature can be seen to have been transported from a distance; and
workers should not waste their energies in recording the occurrence of large blocks of local stones. The field in Northumberland and Durham is large, and comprizes almost virgin ground. Messrs. Lebour, Howse, Bulman, Dwerryhouse, and others have given some information, but only enough to whet our appetites. There are three pieces of evidence which the Committee and glacial geologists want to know:—(1) How far to the south and to the west the rocks from the Cheviot area descended into Northumberland and Durham; (2) how far south, west and east the Lake-district rocks were borne; and (3) how far inland such rocks as flints were borne from seawards. Observers should not limit their observations to large boulders, as many of the most significant erratic blocks occur solely as small stones, some not exceeding what might be called gravel. The attitude of boulders, that is to say of large boulders, when obviously in situ, is often of interest and importance, that is, the compass-bearing of their long axes."

Mr. Kendall will be pleased to render every assistance in his power to observers. He is willing to help by sending specimens of rocks of known origin, and also to identify, as far as he can, specimens submitted to him. The subject is interesting, and, unlike many other investigations, it can be carried out at a small expense, as the equipment required only costs a few shillings. I take this opportunity of inviting the assistance of members, and I will be very glad to receive the names of those willing to help, or perhaps a committee might be formed to take up the matter.

The following papers and reports read at the meeting of the sections are of special interest to the members: —

Presidential Address, by Prof. Dewar.
Report of the Committee on "Earthquake Phenomena."
Report of the Committee on the "Resistance of Road-vehicles to Traction."
Report of the Committee on the "Teaching of Elementary Mathematics."
Report of the Committee on the "Teaching of Science in Elementary Schools."
Report of the Committee on the "Training of Chemists employed in English Chemical Industries."
"Smokeless Combustion of Bituminous Fuels." By Mr. W. H. Booth.
"Solignac Boiler." By Mr. W. H. Booth.
"An Universal Language." By Sir Frederick Bramwell.
"All Stations Express." By Mr. J. Brown.
"An Elastic Wheel." By Mr. J. Brown.
"Regulation of Wages in Developed Industries." By Mr. S. J. Chapman.
"Undulations produced in a Road by the Use of Sledges." By Dr. Vaughan Cornish.
"Water-power in Ireland." By Mr. F. T. Dick.
"Science in Irish Secondary Schools." By Mr. T. P. Gill.
"Direct-reducing Levelling-staff." By Mr. George Henderson

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“Science Subjects in Schools.” By Dr. Kimmins.
“The Corrosion of Copper by Sea-water.” By Prof. Letts.
“World-shaking Earthquakes.” By Prof. J. Milne.
“Steam-turbines.” By Hon. C. A. Parsons
“The Prevention of Smoke.” By Mr. J. J. Rayworth
“The Teaching of Elementary Mathematics.” By Mr. A. W. Siddow.

I am, Gentlemen,
Yours truly,

JOHN H. MERIVALE.

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The President (Sir Lindsay Wood, Bart.), in moving a vote of thanks to Mr. Merivale for his report, said that he hoped the proposals with regard to the erratic blocks would be carried out by some of the members.

Mr. W. O. Wood seconded the vote of thanks, which was cordially approved.

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DISCUSSION OF PROF. H. LOUIS’ PAPER ON THE "STANDARDIZATION OF SURVEYORS’ CHAINS."

Mr. S. J. Pollitzer (Sydney, New South Wales) wrote that, with all due respect to its author, the paper by Prof. Henry Louis on the "Standardization of Surveyors' Chains" came as a surprise; as he did not think that in 1902 there were people in Great Britain, one of the most civilized countries of the world, who still used the antediluvian chain. And it was respectively suggested to the learned professor, to the members, and to all other professional engineers that they should exert their influence to have the chain abolished entirely as obsolete, and to have it replaced by the more modern steel-tape.

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Principal H. Palin Gurney read the following note on “The Crumlin Meteorite “: —


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THE CRUMLIN METEORITE.

By Principal H. PALIN GURNEY.

The writer is indebted for a cast of the Crumlin meteorite to the kindness of Mr. Lazarus Fletcher, F.R.S., the keeper of the Mineralogical Department, at the Natural History Museum South Kensington. It represents all that has been found of a sky-stone, which fell at 10.30 a.m. on September 18th, 1902, at Crumlin, about 12 miles west of Belfast. A loud noise was heard at the time, which may be attributed to the breaking of the meteorite, and the detonation was observed at places 30 miles apart. The fragment weighs 9.34 pounds (4,237.5 grammes). It is 7 ½ inches long, 6 ½ inches wide, and 3 ½ inches thick. The edges are rounded, and five of its faces are nearly smooth, and show clearly the characteristic pittings. The remaining four
or five surfaces are apparently due to fracture, and they exhibit distinct ridge-and-furrow markings. As Crumlin is only 3 ½ miles east of Lough Neagh, a lake extending over 13 miles by 7 miles, possibly the remaining pieces may be buried beneath its waters. The crack, represented on the model, was probably caused by impact on a larger stone in the earth, in which it buried itself to a depth of about 18 inches.

The meteorite is covered with the usual peculiar external layer. This crust or varnish is thinner on what are probably the surfaces produced by the breaking. It is mostly black or brown, the latter colour being possibly attributable to its contact with the soil, but on one part there is an iridescence, in which we may trace purple, pink and blue. On one of these surfaces, a flatfish bronze-coloured nodule of troilite is distinctly visible.

The meteorite belongs to the variety known as "aerolites." It consists mainly of stony matter, but it contains sufficient nickel-iron to affect a magnetized needle. Its exact composition is at the present time the subject of investigation by Mr. L. Fletcher.

This fragment is larger than any meteorite which has reached British soil since the fall at Wold Cottage, Scarborough, on December 13th, 1795, which weighed 44.84 pounds (20,111 grammes) It is the first sky-stone observed to fall in these islands since the Middlesbrough meteorite, which was found on March 14th, 1881, and weighed only 3.52 pounds (1,59.4 grammes).

Principal H Palin Gurney exhibited models of the Crumlin meteorite, together with an iron model prepared by Prof. A S Herschel to test the speed of fall of the original, and by which he had ascertained that the Middlesbrough meteorite struck the earth with a velocity of 412 feet per second.

The President (Sir Lindsay Wood, Bart.) moved a vote of thanks to Principal Gurney for his paper.

Mr. J. H. Merivale seconded the resolution, which was cordially approved.

Mr. A. H. Meysey-Thompson read the following paper on "Some of the Considerations affecting the Choice of Pumping Machinery," by Mr. H. Lupton and himself: —

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SOME OF THE CONSIDERATIONS AFFECTING THE CHOICE OF PUMPING MACHINERY.

By A. H. MEYSEY-THOMPSON and H. LUPTON.

Economy of fuel at collieries is a question which is rapidly becoming important. The old objection to the introduction of economical pumping-plant, that the boilers only burnt
unsaleable small coal, has been seldom heard of late years. The introduction of coal-cutting by machinery is tending to reduce the quantity of small coal; the manufacture of producer-gas on a large scale has opened out a lucrative market for inferior slack-coal; the growth of the briquette-fuel industry is eloquent testimony to the use that can be made of what was once considered almost valueless; and the washing of small coal and its conversion into coke have also greatly tended to reduce the supply of cheap boiler-fuel. It should also be remembered that each boiler saved represents a reduction of stokers' wages, of cost of insurance and of maintenance of boilers.

In a presidential address to The Institution of Mining Engineers, Mr. James S. Dixon stated that 7.39 per cent. of the output of a large group of Lanarkshire collieries was consumed at the pits, and he estimated that, at this rate, the consumption of the collieries of the United Kingdom was 16,186,852 tons.* He also expressed the opinion that a consumption of 10 pounds of fuel per indicated horsepower at collieries was very near the truth:†

Recently, Mr. A. M. Henshaw in a presidential address to the North Staffordshire Institute of Mining and Mechanical Engineers, stated that in their district they were wasting £106,800 a

† Ibid., page 373.

which might be saved by first-class steam-plant.* He said that actual tests at collieries had shown a consumption of 8.21 pounds of coal per horsepower; and it is worth noticing that, in the North Staffordshire district, the report of H.M. inspector of Mines shows that out of 755 boilers no less than 285 are of the old egg-ended type.

At many collieries, the weight of coal raised is far less than that of water pumped, and as pits become deeper the horsepower necessary to raise the water to the surface must be proportionately increased.

Speaking generally, it may be said that the heaviest pumping in the past has been done by a steam-engine on the surface, working pumps placed underground by means of rods. The old single-cylindered beam-engine, generally of the Cornish type, remains to this day one of the most economical of steam-engines, when the steam-pressure does not exceed about 40 pounds per square inch. For higher pressures, where circumstances admit of its use, an excellent type of pumping-engine is the vertical, compound Cornish-cycle engine. An engine of this kind fitted with the Davey differential gear, supplied to the Basset tin-mines, Cornwall, has been working for several years, yielding a duty of 80,000,000 foot-pounds on 1 cwt. of slack.† This duty is not so high as that reached by some of the old single-cylindered Cornish engines of the past, but they only obtained it by cutting-off steam at a very early period in the stroke, and in order to carry the piston to the end it was necessary to give an excessive initial velocity to the pump-rods. The strain on the rods was so great that they rapidly broke down, and, in practice, the early cut-off was abandoned, as it proved most economical to work with a duty of about 50,000,000 foot-pounds. The second cylinder is introduced in order to obtain a large degree of expansion of the steam, without the necessity of cutting-off so early in the stroke. The excessive speed of the rods is thus obviated, and the pit-work is not subjected to undue strains.
The large output of a modern colliery demands so much shaft-accommodation that room can rarely be found for a beam at the

† Ibid., 1900, vol. xix., page 157.

pit-top; and as the Cornish engine is only single-acting, its capital cost is considerably higher than that of a double-acting engine of the same power. The foundations and engine-house are also costly. Hence, double-acting horizontal engines, taking steam, on both sides of the piston, removed some way back from the shaft, and connected to quadrants or rockers, have been preferred: and these engines, being either triple-expansion or compound and condensing, enable high pressures of steam to be fully utilized.

The writers’ firm are now building a triple-expansion engine for a colliery in Durham, capable of working with a steam-pressure of 200 pounds per square inch; and, as the steam will be cut off early in the high-pressure cylinder, the resultant economy will no doubt be considerable. An objection is sometimes raised to the use of horizontal cylinders of large diameter on the ground of excessive wear, but this has hardly been borne out by facts.

Through the kindness of Mr. Edmund Howl, engineer and general manager to the South Staffordshire Mines Drainage Commissioners, the authors are enabled to quote the results obtained during the last 13 years from two large overground engines with shaft-pumps. The particulars during this time have been most carefully tabulated, and as no other engines (excepting small winding-engines used occasionally when examining pit, and capstan-engines for shaft-work) took steam from the same boilers, the results are more accurate than can be obtained at many collieries.

(1) The larger of the two engines, called the Bradley engine, has high- and low-pressure steam-cylinders, 52 and 90 inches in diameter respectively, with a stroke of 10 feet; and it works two plunger-pumps, each 27 inches in diameter, also with a stroke of 10 feet. This engine was put to work in April, 1885, but separate cost-accounts were not kept until the year ending June 30th, 1890. In the 13 years from that time until June 30th, 1902, the engine had raised 11,680,000,000 gallons of water from a depth of 384 feet, equivalent to an average continuous night-and-day horsepower, in the water lifted, of 199, and to an average continuous piston-speed of 69 feet per minute. The average annual cost of working the Bradley pumping-engine during the whole period has been as follows:

<table>
<thead>
<tr>
<th>Per Annum.</th>
<th>Per continuous Pump-horsepower per Annum.</th>
</tr>
</thead>
<tbody>
<tr>
<td>£</td>
<td>£  s. d.</td>
</tr>
</tbody>
</table>
Coal * 1,422  7 2 11  
Labour  873  4 7 10  
Stores, including oil and packing  99  0 10 0  
Repairs to engine and pumps  110  0 11 1  
Repairs to boilers  47  0 4 10  
Totals £2,551 £12 16 8

* The small slack coal used cost, on an average, 4s. 11 ¼ d. per ton of 23 cwt. delivered, and had an evaporative-capacity of 4 ½ pounds of water per 1 pound of coal.

(2) The smaller of the two engines, called the Moat engine, has high- and low-pressure cylinders, 44 and 76 inches in diameter respectively, with a stroke of 10 feet; and it works two ram-pumps, 19 inches in diameter, and below them a pair of bucket-pumps, 19 ½ inches in diameter, having a stroke of 10 feet, and with a total joint lift of 620 feet. This engine was put to work in 1885, but separate cost-accounts were not kept until the year ending June 30th, 1893. In the 10 years from that time up to June 30th, 1902, this engine has raised 7,391,525,000 gallons of water from a depth of 620 feet, equivalent to a continuous night-and-day horsepower of 264 in the water lifted and to an average continuous piston-speed of 115 feet per minute. The average cost of working the Moat pumping-engine during the whole period has been as follows:—

<table>
<thead>
<tr>
<th></th>
<th>Per Annum.</th>
<th>Per continuous Pump-horsepower per Annum.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal †</td>
<td>1,410</td>
<td>5 6 10</td>
</tr>
<tr>
<td>Labour</td>
<td>918</td>
<td>3 9 6</td>
</tr>
<tr>
<td>Stores, including oil and packing</td>
<td>98</td>
<td>0 7 5</td>
</tr>
<tr>
<td>Repairs to engine and pumps</td>
<td>150</td>
<td>0 11 5</td>
</tr>
<tr>
<td>Repairs to boilers</td>
<td>23</td>
<td>0 1 9</td>
</tr>
<tr>
<td>Totals</td>
<td>£2,599</td>
<td>£9 16 11</td>
</tr>
</tbody>
</table>

† The small slack coal used cost, on an average, 4s. 4 ½ d. per ton of 23 cwt. delivered, and had an evaporative-capacity of 41 pounds of water per 1 pound of coal.

It may be remarked that the cylinders and other parts of the Bradley and Moat pumping-engines are in excellent order, and that no important parts of either engines or pumps have at any time been replaced, with the exception of the pump clack-boxes—seven of which have been renewed.

As a standard of comparison it will be noted that taking the fuel-costs, half of the labour and stores, and the whole of the boiler-repairs, as belonging exclusively to the steam-plant; and, further, supposing that of the total power supplied to the
terminals of an electric motor 70 per cent. could be recovered in actual water lifted, current would have to be sold at 0.22d. per Board-of-Trade unit to be equivalent to the average of the above figures, as shewn in the following table: —

[Table omitted.]

In the case of pumps of large diameter, forcing against a heavy pressure, the writers have found that the old-fashioned practice of using large single valves is undesirable. When a large pump is provided with only one suction-valve and one delivery-valve very heavy shocks are often caused by the triggering-up of either valve through a wooden gag or other cause. In order to avoid this difficulty, multiple valves of small diameter have been substituted with beneficial results for one large valve. Several small valves in one large valve-box were found, however, to present difficulties when pumping a large quantity of water against a heavy head. The flanges of the valve-box must be made enormously thick, even more so than the rest of the casting. Consequently, unequal strains are set up in cooling after casting; and the box is weak, as a structure, from this cause, as well as from the fact that in large masses of metal, cavities are apt to form under the skin in casting, and are exceedingly hard to discover. Another disadvantage of grouping a number of small valves in one large box is that it is necessary to break a large joint and remove a heavy lid in order to examine or repair any of the valves.

Of late years, the writers' firm have adopted a standard pattern of valve-box, 6 inches in diameter—the number being varied according to the size of the pumps. Being comparatively small, they are less liable to undue strains in cooling after casting, and it is much more likely that each of these small boxes will be thoroughly sound than one large one. As these valve-boxes are made exactly alike to an accurate standard, a spare box can be kept, to be substituted for any one requiring repair. This operation can be speedily carried out by one man, and the damaged valve sent to the surface for repair in its valve-box. The pumps alone stand in the pit; the valve-boxes are placed in a recess, where they are easily attended to without interruption to the work in the pit; and the workman is also free from the risk of anything falling down the shaft on to him.

The engine is placed close to the boilers, so that it receives perfectly dry steam and can be kept under the constant superintendence of the management. If desired, the engine may be placed just below the surface, leaving the whole of the pit-top free for the operations of the mine.

In heavy pumping with long rods, it is desirable to have as few reciprocations as possible. The rods should start slowly from rest, accelerating in velocity as the stroke proceeds. The momentum, thus obtained, stores up energy, which is expended during the latter part of the stroke, and allows steam to be cut-off early, with a resultant economy of fuel. A pause between the strokes enables the valves to close quietly before the return stroke, and the fewer the reciprocations the less is the wear-and-tear of the valves. Bearing these facts in mind, it is evident that the longer the stroke, within reasonable limits, the better: and the writers are of opinion that the direct-acting engine without a flywheel is the most suitable for pumping. It is difficult to run a fly-wheel engine satisfactorily, and impossible to work it expansively at a slow speed. No pause is possible between the strokes; and in the event of a spear-rod breaking,
a pipe bursting, or of a valve failing to act and suddenly relieving the engine of its load, the
strain put on the fly-wheel is apt to cause a serious accident. Cases have occurred under
such circumstances of fly-wheels flying into fragments, which were thrown to considerable
distances. It is also much more costly to build a long stroke flywheel engine than a direct-
acting one.

Where low first cost is essential, an underground direct-acting steam-engine is no doubt the
cheapest to instal; but as

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regards economy in working, it is at a great disadvantage. The steam, has to be carried down
the pit in pipes which can with difficulty be kept properly clothed, especially in wet shafts; it
condenses in the pipes, and even if carefully drained, generally arrives at the engine in a more
or less wet condition. In a direct-acting engine of this class, little or no cut-off is practicable,
and the ordinary single cylinder or duplex steam-pump is a notoriously extravagant consumer
of steam.

A certain degree of economy can be obtained by adopting compound or triple-expansion
engines, but their best results compare unfavourably with those of the overground type. The
engine is often placed in an out-of-the-way corner, seldom visited by the management, and
the costs of installation and repairs are higher than when erected aboveground. Carrying
steam underground frequently damages the roof, and an inrush of water may drown the
engine.* A point in favour of underground engines is the height to which they can force water
in one lift.

At the Chamber colliery, Oldham, a compound condensing underground engine forces 100
gallons of water a minute a vertical height of 1,341 feet in one lift. Mr. W. W. Millington records
the results of a trial made by him, there being 59 indicated horsepower and 50 horsepower in
the water pumped, giving a mechanical efficiency of 84 per cent. The consumption of coal was
5.76 pounds per pump horsepower per hour.†

Where water has to be raised from dip-workings, hydraulic engines have been largely used,
taking their driving water from the main column of the pumps in the shaft, and returning it along
with the water pumped into the main sump. It is a very convenient system if the hydraulic
engine can be placed reasonably near to the main sump, and if the main pumping-engine can
be run a little faster to make up for the driving water supplied to the hydraulic engine. Hydraulic
engines being of simple construction, can be left to themselves, are quite safe, and require
little attention and few repairs, besides being cheap in first cost;

* One of the writers had occasion to visit a silver-mine in Mexico, where an underground
Chicago engine was within a few days of being started; the water gained on the existing pumps
and drowned them out, and they were only extracted, after an interval of a year, by an
overground engine from Great Britain.

and even when buried in water, they can be worked. In order to avoid shocks, it is important that the flow of power or driving water should not be interrupted; and the duplex is therefore preferable to the old single-cylinder type of engine. The great uniformity of flow, thus obtained, enables a smaller diameter of pipe to be used both for the power- and delivery-water. Where the hydraulic engine is placed, say, 2,500 feet from the main sump, the cost of power-pipes becomes a formidable item, and the friction of the water passing through them reduces the pressure, and consequently a larger quantity of water has to be used. In such cases, or where there is no main pumping-engine from whose rising column power-water can be drawn, the difficulty can be overcome by providing a steam-engine on the surface supplying water at, say, a pressure of 1,000 pounds per square inch and delivering it to the hydraulic engine placed in the mine. This method gives an efficiency of about 55 per cent.

In Westphalia, at mines from 1,500 to 2,000 feet below the surface, it was decided that rods were impracticable, owing to their great length; electricity was inadmissible, as giving too low an efficiency; and hydraulic pumping, by means of a steam-engine on the surface and hydraulic engines belowground, has been adopted in many cases. The water at the surface had a pressure of nearly 2 tons per square inch, and as much as 1,000 horsepower was thus transmitted. By adopting such a great pressure of the driving or power-water, the diameter of the pipe was kept small, and though practical difficulties due to the high pressure of the water were encountered, they were gradually overcome, and the system, when inspected by the authors last year, was working satisfactorily. A guaranteed efficiency of over 60 per cent. was obtained, but the first-cost of the plant was considerably higher per horsepower than that generally in use in this country, where the mines, as a rule, are not so deep, and cheaper systems can be adopted.

In the writers’ experience, where circumstances allow of it, the method of pumping by rods actuated by a compound or triple-expansion engine on the surface, and when required to do so, also driving hydraulic pumps for draining dip-workings, is the most economical for heavy pumping, both as regards consumption of fuel and of repairs.

Electricity, as a means of transmitting power for pumping purposes, has come into use of late years, and seems destined to play a larger part in the future. The lightness and portability of the cable as well as the small loss of power in conveying the current to a distance, are important points in its favour. A danger attendant on the employment of electricity is the liability to explosion, not only through the sparking of the dynamo, but also from the fact that an accident to the cable by a fall of roof or other cause may produce violent sparking.

Considering the great number of companies now commencing to supply electrical power on a large scale in this country, it seems probable that many collieries, especially the smaller ones, will be able to buy electric current cheaper than they can generate it for themselves. A mine-owner will do well to provide himself with a pump, which can do the whole of the work in a portion of the 24 hours; and if he can undertake not to use the current during the few hours that the maximum demand lasts, he will be in a good position to buy it at a low rate. Most of the electrically-driven pumps in this country are actuated by a motor running at a high speed,
geared down to give the pumps a velocity of little more than 40 revolutions a minute. But gearing is noisy, takes up space, and absorbs a considerable amount of power in friction; and a preferable plan would be to drive the pumps direct by a motor, running at, say, 100 revolutions per minute. In order to run pumps at this speed, it is necessary to provide ample waterway and a consequent small lift to the valves.

A disadvantage at present attendant on electric pumping-plant is its low efficiency. At a recent installation in the North of England, it appears that the consumption of coal per pump-horsepower per hour was 7.6 pounds, and the equivalent duty amounted to 29,000,000 foot-pounds. Mr. James S. Dixon recently stated that his compound condensing-engine, driving a dynamo, consumed 3.34 pounds of fuel per indicated horsepower per hour. * Reckoning the electric efficiency at 50 per cent., including the pump-gearing but exclusive of the pumps, and the efficiency of the pumps at 90 per cent., to obtain 1 actual or pump-horsepower, there is a combined efficiency of 45 per cent. or 7.4 pounds of coal per pump-horsepower per hour consumed by Mr. Dixon's engine.

Another disadvantage attendant on electric pumping is the liability to get out of order. In an address to the Engine, Boiler and Employers' Liability Insurance Company, Limited, the Chairman (Mr. R. B. Longridge) stated that "one out of every nine [electrical] machines insured by the company had broken down during the past year,** and that "even where trained electricians were in attendance, numerous breakdowns had occurred through lack of attention to cleanliness, which is so essential to the safety of electric machines."** If electrically-driven machines aboveground give so much trouble, it is hardly to be expected that the attention and cleanliness required by Mr. Longridge will be forthcoming to a greater degree at the bottom of a pit. Electrically-driven pumps are also at a disadvantage, compared with those driven by rods, in being unable to work under water. At the Yarlside mine, North Lancashire, two ram-pumps, 20 inches in diameter and 10 feet stroke, continued working at the rate of 8 strokes per minute for a month while submerged in water to a depth of 90 feet.† They were actuated by an overground engine with quadrants, and raised the water from a depth of 435 feet to the surface.

For pumping small quantities of water at points a long distance from the source of power, electricity is sometimes the only satisfactory way of transmitting the power; but, where great depths and large quantities of water have to be pumped, the greater efficiency of the hydraulic system, using water at a high pressure, will probably cause it to be preferred despite the somewhat heavy capital outlay.

As already mentioned, underground steam-engines have little to recommend them, except cheapness in first cost; their foundations are liable to be disturbed by movements of the floor, while the cost of running and of repairs is higher than is the case with aboveground engines. When saving of coal becomes important, no doubt rotative engines will supplant the use of direct-acting engines placed underground. The use of a fly-wheel is there a distinct advantage. The momentum of the rods, which enables an aboveground engine to cut off early
in the stroke, is replaced in an underground engine by the fly-wheel, which stores up sufficient energy to allow of an equally high grade of expansion, with a resultant economy of fuel.


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The direct-acting underground engine is, however, frequently adopted as a stand-by to other and more economical pumping engines. Running as it then does, during a limited period, the extra cost of fuel is not an important item, and may be counterbalanced by the saving in interest on the capital outlay. A rotative engine, of the same power, would cost more, and owing to the greater space occupied, would be more expensive to instal; consequently, in order to decide upon the preferable type, it becomes necessary to consider the number of hours that each will be required to run.

It is to be regretted that some system of measuring fuel analogous to the old Cornish duty in millions of foot-pounds, is not more largely adopted; but that system had its disadvantages, because it involved the efficiency of the boiler in addition to that of the steam-engine. A preferable plan would be to compare the weight of steam used by the steam-engine with the actual footpounds of work done in water raised by the pumps, commonly expressed as pump-horsepower. The ratio, thus obtained, affords a means of comparing different systems and it is in this sense that the term "efficiency" might be advantageously employed.

In conclusion, it may be said that each system has its disadvantages, and that every proposed installation must be studied on its merits. In order to facilitate a decision as to the best type of pumping-engine to be adopted, the writers have endeavoured to state the chief points relating to each system which have come under their notice: and in submitting them to the members they hope that the paper may be productive of an exchange of opinion on the comparative merits of different kinds of pumping machinery, more especially as regards cost of repairs and maintenance as well as the general convenience of the mine. These are matters which can only be thoroughly understood by those who are using the machinery, and consequently know "where the shoe pinches," an experience compared to which that of the maker of the machinery can at best be imperfect and second-hand.

The North of England has always been a pioneer of progress in mechanical invention, and its able practical sons are to be found directing mining operations in all parts of the world. Their experience gives to a discussion of this kind an importance which it is hard to overrate.

[Plate VI.]

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Plate VI. shews the duties of different systems of pumping water, expressed in millions of foot-pounds of work per 1 hundredweight of coal burnt. The light figures are taken from plants under ordinary working conditions, and the dark figures are the average duties of the different systems of pumping.
Mr. Henry Lawrence (Newcastle-upon-Tyne) asked what class of boilers were used at the Bradley and Moat engines, and whether there was anything to account for the large difference between the cost of repairs of the respective boiler-plants—the costs at Bradley being stated to be 4s. 10d. and at Moat to be only 1s. 9d. per continuous pump-horsepower per annum. In his opinion the most economical way of pumping water from great depths, was to have a series of small pumps delivering round the circle of the crank, or what would be the crank. He differed from the opinion expressed by the writers in the beginning of the paper as to the use of a flywheel, but they afterwards stated that under certain conditions a flywheel attached to a pumping-engine placed underground was a source of economy, enabling them to cut off and to work the engine expansively, and he accepted the latter as the correct view.

Prof. Henry Louis (Durham College of Science) said that he did not think that the authors had treated quite fairly the application of electric driving to pumping machinery; he did not believe that any great danger could arise from the dynamo or leads seeing that it was not customary to place a pumping-engine in the return-airway. In the usual position it might be considered fairly safe, and there would be little danger from sparking. He was convinced that much higher efficiencies had been repeatedly recorded for electrical machinery than those given in the paper, and the writers did not refer to the more modern type of pumps driven electrically. The Riedler express pump had been introduced lately, with mechanically-governed valves, which could be worked at a high speed, against fairly high lifts; and he believed that high efficiencies had been recorded for this pump. Several electrical plants claimed an efficiency of 60 per cent. or over. It was obvious that at a colliery having a lengthy range of coke-ovens, the waste-gases could be utilized for the generation of electricity, which could be economically applied in driving a pumping-plant, in which case a much lower efficiency could be admitted than would be the case if they had to use coal; and the convenience of carrying electricity to a considerable distance was a factor that should not be overlooked. If danger from sparking at the commutator did exist, they could always fall back upon the triphase system. So far as his (Prof Louis') limited experience went, he was not particularly in favour of this system, because if anything happened, and it was necessary to stop the pumps, one had to run off the water from the rising-main before restarting the pumps, although he understood that a means had been devised for overcoming this difficulty.

Mr. T. Y. Greener (Crook) said that, having regard to the fact that electricity at the present moment was being largely utilized for power-purposes, he did not think that any statement should be allowed to go forth uncontradicted that its application underground was unsafe. He asked the authors, whether the statement that among the dangers arising from the use of electricity an explosion might be caused by sparking, was merely an opinion or whether it was based upon actual knowledge, as he had heard the point frequently denied.

Mr. J. C. B. Hendy (Etherley) said that he had had some experience with hydraulic pumps, and for the particular conditions which prevailed at the Etherley collieries the hydraulic pump had certainly proved successful. He was not able to state the efficiency, as the boilers were
heated by the waste-gases from the coke-ovens. A Hathorn-Davey hydraulic pump had been working for about three years, placed about 1,400 feet from the shaft-bottom; it was pumping from various distances, from three different points in the dips; and, since it had been erected, he did not think that it had cost more than £1 or £2 per year for repairs. This was a case where the conditions were suitable for the use of hydraulic pumps; but if they had to place pumps at a considerable distance inbye, he thought that nothing could equal the efficiency of electricity. In the case of another hydraulic pump, there was a sudden inrush of water, which drowned out the workings; but the hydraulic pump worked for seven days under water and eventually it overcame the feeder and removed the water. This was one of the especial advantages attending the use of an hydraulic pump, which, if kept in order, would pump water, even when completely immersed.

Mr. F. R- Simpson (Ryton) said that he had employed an hydraulic pump when working to the dip in a heavily-watered colliery: it was situated 1,800 feet from the shaft-bottom, and had worked in a very satisfactory manner.

Mr. J. K. Guthrie (Preston Colliery) said that he had had an opportunity of seeing a Riedler pump at the Cramlington collieries, and it seemed to work in a highly satisfactory manner. It had only two valves of large area (one suction-valve and one delivery-valve). Indicator-cards had been taken, which showed great efficiency, and there was no "slip" or "hammer."

Mr. T. E. Forster (Newcastle-upon-Tyne) asked the authors to give further particulars of the installation of the electric pumping-plant in the North of England which gave the results quoted in their paper. Underground pumping could be divided into two heads, namely, shaft pumping and inbye pumping, and one method might be very good for one case, while another was the best for the other case. He thought that the use of electricity for underground pumping was very handy, and that it was probably as cheap as any other method. For pumping heavy feeders he was bound to agree that pumping-engines on the surface were generally the most economical, with possibly underground engines as a standby. In some pits, there was not much water, and where they could erect an underground electric pump, working in conjunction with dynamos and haulage and inbye pumping-plants, it might be, even supposing the efficiency to be little less, that it would prove the cheaper system. The idea that because a motor would spark it would therefore fire gas had not been proved, and the only experiments of which he had heard had pointed to the opposite conclusion. It was a point not yet satisfactorily settled, and it was very desirable that they should receive exact information upon the question.

Mr. C. W. Martin (Newbottle Collieries) wrote that the first note struck by the writers of the paper was a correct one. The day had gone by for the question of fuel-economy, even at collieries, to be regarded as of small importance. It was ever-increasing importance, and it was this fact which made even first cost a secondary consideration. The authors had shown
wisdom in the choice of a title for their paper. It was one thing to lay out pumping-plant for an entirely new colliery but it was quite another thing to instal suitable pumping-plant at an old colliery, and one must be content with what seemed best, all things being considered.

He (Mr. Martin) was inclined to disagree with the statement that underground direct-acting steam-engines had little to recommend them except low first cost. For depths of 1,200 or 1,400 feet, where the pumping must be done in the coal-drawing shaft, and steam was already conveyed down the mine for other purposes, perhaps the most satisfactory pump that could be installed was of the direct-acting compound type. It had few wearing surfaces and consequently cost little for stores, very little in the way of repairs, and required a minimum amount of attention. Where there was any movement of the floor, the direct-acting type had a distinct advantage over the rotative engine.

There were serious objections to placing heavy pumping sets in a working-shaft. In laying out a pumping-shaft at a new colliery or a central pumping-plant for a group of collieries, down to, say, 1,200 feet deep, undoubtedly the wisest plan was that of pumping by means of rods driven by a steam-engine placed close to the source of heat, and running on a high grade of expansion, and always taking the precaution of placing lifting-sets in the pit-bottom. A direct-acting condensing engine, with a long stroke and steam-jacketted cylinders, would probably give the best results.

The objection raised to the use of single clacks, with multiple beats, was not very obvious, as they worked well, and cost very little for up-keep. The danger arising from shocks could be readily averted by the use of relief-valves.

For dealing with large quantities of water from depths of 1,500 to 3,000 feet, the hydraulic system mentioned in the paper had much to recommend it. The engine on the surface could be made an economical engine, and the hydraulic motor in the mine was also highly efficient. But with this system of pumping, no fewer than four ranges of pipes were necessary, namely: Rising main, power-pipe, return-pipe and air-pressure pipe, but as these were small in diameter, they could be easily fixed in a working-shaft. The cost of this plant must of necessity be high when the enormous pressures were considered (up to 3,000 pounds per square inch) and they could only be satisfactorily controlled by a liberal use of cast steel in the manufacture of the plant.

The writers of the paper had done well in calling attention to the need of having some uniform method of expressing pump-efficiencies. German engineers, for instance, made statements of extraordinary efficiencies in setting forth the merits of their pumps, but on enquiry the basis of calculation was found not to be the same as that used in this country.

Mr. J. J. Prest (Castle Eden) wrote that the authors were no doubt correct in advocating the more general use of direct-acting triple-expansion condensing pumping-engines as a permanent installation for dealing with large volumes of water from shafts of a depth of, say, 1,000 feet. The only serious objection to the more general adoption of this class of pumping-machinery is the amount of room taken up in the shaft by the pump-work together with the first cost of the installation. The problem to be solved in all cases is, whether the economy capable of being effected by the adoption of this class of pumping-engine is sufficient
to return ample interest on the increased capital-expenditure required, as compared with an underground steam pumping-engine, all other things being equal. There can be no doubt that at least one-half of the fuel is wasted, by condensation, in steam-pipes conveying steam to many large underground pumping-engines. If the value of this fuel so wasted amounts to, say, £500 per annum in the case of a steam underground pump, and the increased cost of a high-class pumping-engine plant should amount to £3,000 only when compared with the underground pumping-engine, then there is sufficient margin to warrant the increased expenditure being incurred. In many cases, however, the economy resulting from the increased capital-expenditure necessary to replace existing plants would not warrant the conversion. For unwatering sinking shafts, the class of pumping-engines advocated by the authors was not suitable.

Mr. A. H. Meysey-Thompson (Leeds), replying to the discussion, said that none of the results given in the paper were their own figures. Lancashire boilers were used at both the

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Bradley and Moat pumping-engines, and it was purely accidental that the cost of repairs at one place had been 4s. 10d. and at the other only 1s. 9d. per horsepower per annum. Possibly the feed-water had something to do with it, as the boilers were placed several miles apart. He believed that the Riedler pump with mechanically worked valves, was not largely in use in this country, although one had been working at the Powell Duffryn collieries for many years. The present electric pump was geared, and gearing was noisy and wasted a lot of power as friction. If a pump could be run at 100 revolutions per minute, with the motor directly connected, it would prove a most useful form of machine. He could not give any definite opinion with regard to the sparking of electric motors: he was told by mining-engineers that violent sparking was dangerous, and when a cable broke there was danger of sparking.

Mr. H. Lupton (Leeds) stated that the electric plant referred to in the paper from which the figures were quoted, was driven by a compound engine, with cylinders 18 and 30 inches respectively in diameter by 40 inches stroke, running at 80 revolutions per minute and supplied with steam at a pressure of 100 pounds per square inch. It worked two sets of three-throw pumps in the shaft; the actual horsepower in water lifted by the pumps was 121, and the duty of the whole plant was 29,000,000 foot-pounds. The average duty of the engines referred to in the paper was 51,000,000 foot-pounds for steam and 30,000,000 for electricity, where both plants were giving their ordinary duty.

Mr. J. G. Weeks (Bedlington) remarked that the use of compressed air had been totally ignored throughout the discussion, but there were circumstances under which its use was highly advantageous. He moved that a vote of thanks be accorded to the writers for their interesting paper.

Mr. J. H. Merivale seconded the resolution, which was cordially approved.

The further discussion was adjourned.
Mr. Mark Ford read the following paper on "Sinking by the Freezing Method at Washington, County Durham": —

[Sinking by the Freezing Method at Washington, County Durham.

By MARK FORD.

1. Introduction.—The great interest shown by the members in the operation at Washington, and the novelty of the method, probably adopted for the first time in Great Britain, has induced the writer to give the following detailed description of sinking through alluvial deposits to the stone-head at the Glebe Winning belonging to the Washington Coal Company, Limited.

The company, having acquired the royalties of the Oxclose and Glebe collieries, abandoned forty years ago, decided to sink two shafts, 14 feet and 12 feet in diameter respectively, in a position such as to secure the most economical arrangement of haulage, shaft-bottom and surface-plant in preference to reopening the old shafts.

2. Nature of Ground.—After trial-borings had been made over a certain area, it was found that the shafts would be sunk through drift, consisting of sand and boulder-clay. At the site adopted for the shafts, the following section was proved:

[Table of strata to 120 feet below surface, omitted.]

3. Method of Sinking.—The thickness of the sand-bed, the treacherous character of the quicksand, and the possibility of damaging the foundations of engines, boilers and other erections in the vicinity of the shafts, led, after careful consideration,

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to negotiations with Messrs. Gebhardt & Koenig, Nordhausen, Germany, who undertook to freeze two shafts to the stone-head. This method offered almost a certainty of success, a dry shaft to sink, and no water or sand to pump to the surface.

4. Preparatory Work.—The usual headgear and pulley were erected, and a permanent hauling-engine was so placed that both shafts would be served by it during the sinking (Fig. 5). This engine has two cylinders, each 18 inches in diameter by 80 inches stroke, and is geared as 2 to 1, to two drums, 6 feet in diameter. A locked-coil wire-rope is used for winding.

[Photograph: Fig. 5.—Washington Colliery: Glebe Shafts.]

The first and winding shaft will have a finished diameter of 14 feet. Its diameter to a depth of 24 feet was 24 feet, the sides being secured by ordinary wooden cribs, 6 inches square, placed 3 feet apart, and short backing deals were placed behind the cribs.
At 16 feet from the surface, a scaffold was erected, and on this scaffold, the holes in which the freezing-tubes, 22 in number, had to be placed, were marked off (Figs. 1 and 2, Plate VII.). This was done by drawing a circle on the scaffold having a radius of 10 ¼ feet, and the circumference of this circle was divided into 22 equal parts, giving the centre of each bore-hole.

Boring-tubes were forced down to form the holes through the sand. These tubes were 6 inches in diameter and 6 feet long, fitted with screwed flush-joints, the lower length having sharp end. The sand-pump was occasionally put in, and by turning the tubes with the grips, they gradually sank until the gravel was reached; and then screw-jacks were used to force the tubes into the clay.

When the boring-tubes reached the clay, boring was continued by means of a chisel working inside the tubes, making holes 5 ¼ inches in diameter (Fig. 6). Ordinary bore-rods were employed, a wooden rocking-lever being used to counterbalance the weight of the rods in the hole. On account of the hardness of the boulders, most of which were whin or dark blue Mountain Limestone, of large size, with ice-worn smooth sides, exceptional difficulty was experienced in boring through this clay, progress was extremely slow, and the holes were constantly liable to deflection from the vertical by reason of the impact of the boring-rods upon the edge of these boulders, which no doubt often moved in their bed of soft clay. It was imperative that the tubes should be vertical, in order to secure an ice-wall of sufficient thickness and of uniform frozen condition. The vertical direction of the holes was tested by suspending a plummet from the surface at a point immediately above the centre of the top of the boring-tube. If during its descent the plummet came in contact with the side of the hole a deviation of the cord was seen at the top of the tube. But in no case was the deviation of any of the tubes found to be more than a few inches.

As soon as a hole had attained the intended depth, the freezing-tubes were inserted. These tubes are 4 inches in outside diameter and 16 feet long, the lowest length having a closed end. The joints consist of a sleeve, 6 inches long, screwed inside to receive the screwed ends of the tubes. As the tubes were being placed in the holes they were tested by hydraulic pressure:—15 atmospheres for the first pipe, 14 atmospheres after a pipe had been added, and so on, reducing the pressure by one atmosphere for every pipe that was added. As soon as the freezing-tubes were inserted, the boring-tubes were removed and used for other holes, so that six sets of boring-tubes were used in putting down 22 holes.
5. Refrigerating-plant.—The entire plant (Fig. 7) was provided by Messrs. Gebhardt & Koenig and brought from Germany. The motive power was steam, and was provided by the colliery-owners from two Lancashire boilers working at a pressure of 75 pounds per square inch. The steam-engine, A (Fig. 4, Plate VII.) had an horizontal cylinder, 18 inches in diameter by 20 inches stroke, fitted with ordinary slide and adjustable expansion-valves, and was run at a speed of 90 revolutions per minute. A flywheel, B, 16 feet in diameter, on the crank-shaft was fitted with a belt to drive shafting, C. On this shafting, two pulleys, D and E, were placed, and by means of belts they drove two flywheels, F and G, which gave motion to the cranks of two horizontal compressors, H and I (Fig. 4, Plate VII.). The compressors are double-acting and fitted with conical valves kept in place by springs. The refrigerating agent, ammonia, is raised by the compressors to a pressure of 150 pounds per square inch. And for this purpose it is absolutely necessary that the gland in which the piston-rod works shall be efficiently packed, or ammonia will escape: the packing consisted of alternate rings of whitemetal, gutta-percha and chalked hemp, with a total length of 15 inches. Provision has also to be made for the continuous injection of oil into the gland, and this was effected by a small pump driven by belting from the main shaft. The oil passes into the cylinder, and, in addition to lubricating, tends to fill up the clearance-space of the cylinders. The ammonia, under pressure, is delivered into a small receiver, where the oil is separated and periodically drained into a lower receiver, whence it is used again. When the oil is mixed with the ammonia under pressure, it loses part of its heat and on being drained into the lower receiver at a pressure of 15 pounds per square inch it has a tendency to freeze, and this is prevented by passing a steam-pipe, ½ inch in diameter, through the oil.

The ammonia leaves the receiver for the condensers, through a pipe, 3 inches in diameter, and thence passes into four tubes, each 1 inch in diameter. The condensers, J and K (Fig. 4, Plate VII.), are vertical iron cylinders, 10 feet high and 5½ feet in diameter. These condensers contain, in tiers of four rings, 1,600 feet of tubing, inch in diameter, through which the ammonia is circulated. About 4,000 gallons of water per hour circulate through the condensers, and the water is kept in constant motion by means of paddles, ab and cd, driven by belting from the engine flywheel. This water cools the ammonia, reducing it from a gas to a liquid,
When the four pipes emerge from each condenser, they are immediately connected to a pipe, 1 inch in diameter, leading to the refrigerators. The refrigerators, three in number, L, M and N, are vertical iron cylinders 10 feet high and 7 feet in diameter (Fig. 4 Plate VII.) They are jacketed with 3 inches of peat-moss and encased with wooden cleading. They are filled with brine and contain 2,000 feet of tubing, 1 inch in diameter, through which the ammonia circulates after passing through reducing valves, which has the effect of lowering the pressure from 150 pounds to about 15 pounds per square inch. The ammonia immediately changes its state from a liquid to a gas; and this can only be done by absorption of heat corresponding to the latent heat of vaporization. This heat is taken from the surrounding bath of brine, which is thereby greatly reduced in temperature. Efficient and uniform reduction of the temperature of the brine is obtained by rotating a paddle in each refrigerator, similar to that in the condensers.

The ammonia leaves the refrigerators, passing direct to the suction-side of the compressors, and it keeps constantly passing through the actions already described.

A duplex pump, O, with rams 6 inches in diameter and steam-cylinders 8 inches in diameter by 6 inches stroke, is used to circulate the brine through the tubes in the bore-holes, and back to the refrigerators. This pump makes 60 strokes per minute, and produces a flow of 144 gallons per minute.

On a scaffold, 8 feet above the bottom of the pit, there were placed two rings of pipes (Fig. 9). One ring was connected to the delivery-end of the duplex pump while the return-pipe was connected to the refrigerators. The return-ring also, had separate connections to all the freezing-tubes; and the inlet-ring, conveying the brine, was fitted with tubes, 1 inch in diameter, branching off to every bore-hole. These small tubes entered, through a gland, into the freezing-tubes in the boreholes, and reached to the bottom. The brine flows down the smaller tube and is discharged through perforations near the bottom of the tube, returning up the outer tube to the return-

ring, and thence to the refrigerators. The connections from the rings to each hole, were fitted with cocks so that the supply and return side could be closed at will. The pipes, after the freezing commenced, were soon coated with ice; and, to ascertain that each pipe was receiving its proper supply of brine, a few square inches of ice was cleared every morning, and the rapid formation of ice on the exposed part was proof of satisfactory working. Fig. 8 records, for each day, the average temperatures of the brine as it left the refrigerators and as it returned from the shaft. As a rule, the temperature was increased about 2° Cent.

[Photograph: Fig. 9. Rings and Connexions to Freezing-pipes.]

The brine, which is used to freeze the quicksand, circulates in tubes sunk at intervals in the sand, and has its temperature lowered below that of the freezing-point of water, being robbed of its heat in the refrigerators, previous to circulation by the pump, owing to the vaporization of the ammonia on its way to the suction-side of the compressors.

6. Agents.—The refrigerating agent used was anhydrous ammonia (NH₃) and while other agents (carbonic acid, sulphurous
acid, etc.), can be used, ammonia is considered to be the most efficient, and certainly the most harmless in case of accidental escape. This substance has a molecular weight of 17, and as a gas had a density in relation to hydrogen of 8.5 and in relation to air of 0.59, and boils at -40° Cent. at atmospheric pressure. It has a latent heat of vaporization of 287 calories, and a vapour-tension of 108 pounds per square inch at a temperature of 16° Cent. Gaseous ammonia can be liquefied at a pressure of 128 pounds per square inch at a temperature of 21° Cent.; and at a pressure of 150 pounds at a temperature of 25° Cent., the pressure required to produce liquefaction rising very rapidly with the temperature. The latent heat of ammonia is very great, consequently its value as a refrigerating agent is proportionately large. It possesses greater heat-absorbing properties than other agents, and it liquefies at a comparatively low pressure. It acts injuriously on copper and brass. It is combustible, and when mixed with twice its volume of air is capable of exploding with great violence. The ammonia was brought from Germany in steel cylinders, 4 feet long by 8 inches in diameter, at a pressure of 300 pounds per square inch.

The brine used consisted of a solution of chloride of magnesium. The salt was dissolved in hot water, the resultant brine consisting at first of 21 per cent. and being gradually raised to 26 per cent. of the salt. The latter solution freezes at a temperature of —34° Cent. It will therefore be seen that it is capable of circulating in tubes at a temperature that would solidify any water in contact with the tubes. A float was used to indicate the height of the brine in the refrigerators, so that any abnormal leakage would be detected. The quantity of brine was kept constant.

Before commencing the freezing process, the top of the shaft was enclosed, and the exposed pipes were covered with straw-ropes. A hole was bored, and a pipe 18 feet long inserted, in the middle of the shaft, and the height and temperature of the water in the hole was noted as the gradual increase of ice-wall slowly caused the water to rise.

7. Difficulties.—No special difficulties or accidents were experienced. There were a few cases of the packing being blown out of the compressor-glands. A slight shrinkage, owing to the temporary character of the foundations, caused the crank-shaft to heat on several occasions. One of the freezing-tubes split probably owing to the effect of a shot, the leakage of the brine was seen in the side of the shaft, and the connections to the supply and discharge-rings were immediately closed. The brine was withdrawn, and the pipe thrown out of use.

Owing to a missed-shot, one of the sinkers working in the shaft-bottom struck a gelignite-cartridge with his pick, causing it to explode, and he received injuries that resulted in his death 4 days later. Eight other workmen were in the shaft-bottom at the time, and all received slight injuries. Two similar accidents, happily, without fatal results, occurred while using the same explosive, at a sinking in Northumberland, three and four days later respectively, so that the accident could not be alleged to be due to special circumstances connected with the freezing system. Probably, the quality or condition of the explosive may have been such that missed-shots were likely to occur.
The large quantity of water used for cooling the ammonia, in the absence of a reservoir, rendered cooling arrangements necessary, and this was accomplished by allowing the water to trickle through perforated boxes.

8. Excavation.—On May 5th, 1902, forty-three days after freezing commenced, the excavation of the frozen ground was commenced. The shaft was sunk 17 feet 10 inches in diameter, and the freezing-tubes extended 16 inches beyond the sides. The comparatively dry sand was found in a hard state near the sides of the shaft, but it readily yielded to the pick. The 6 feet core in the centre of the shaft was always soft, and in the quicksand the latter was in its natural wet condition. Ordinary cribs and backing-deals were used to secure the sides of the shaft to a depth of 18 feet. In passing through the quicksand, pointed chisels struck by hammers were a valuable aid to the pick, and the working-time occupied in sinking the length of 55 feet through the sand was only 11 days. The wet sand contained 19.6 per cent. of water by weight or 37 per cent. by volume.

On entering the clay, the aspect of affairs altered. Probably owing to the higher conductivity of the clay, the ice-wall was much thicker, and the soft central core was partly frozen, and never more than 2 feet in diameter. The clay was full of stones or boulders, varying in size from a pea to 3 feet in diameter: coal in small pieces, shale, sandstone, Mountain Limestone, red and grey granite, and whin all being represented. Some of the larger limestone-boulders were striated, showing the effect of glacial action. In the clay, recourse was had to blasting, but on account of the brittle condition of the tubes carrying the cold brine, the depth of the shot-holes was restricted to 42 inches in the sump and 30 inches in the canch. A shot was not allowed to be placed within 15 inches of the side of the shaft, and it was sloped at an angle of not less than 20 degrees to the centre of the shaft. The quantity of gelignite was restricted to \( \frac{1}{4} \) pound in each hole. Under these conditions, the comparative inefficiency of the pick, on account of the clay being of a tough leathery nature, and the boulders large and numerous, caused progress to be extremely slow, and the freestone was not reached until June 10th, 1902. In drilling the holes in the clay, brine was used, as water quickly froze and held the drills in the holes. Ordinary wooden cribs, 6 inches square, with backing-deals, were used in securing the dry sand, and for a length of 6 feet in the wet sand iron rings were used to keep the backing-deals in position; but, in neither case, was it necessary to secure the sides, and the remainder of the sinking was finished without supports.

9. Permanent Lining.—As soon as the freestone was reached, water was seen in the bottom of the shaft, and a bed was prepared for a cast-iron ring made in eight segments, 20 inches on the bed, and 2 inches thick. The edge was turned up at the front so as to form a water-ring. Oaken sheathing, 1 inch thick, was placed between the segments, and bolts were passed through the flanges and sheathings.

A solid wall of bricks and cement-mortar was built on the cast-iron crib: the bricks being shaped at the ends so that, although set back 4 inches from the front at the first course, they came gradually into the required size of the pit at a height of 5 feet above the crib. At 18 feet above the crib, the walling as altered to two concentric rings of brickwork, each 9 inches thick, and
the intervening cavity, 2 inches wide, was filled with cement. Three stretcher-courses alternated with one header-

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course. To prevent the cement-mortar from freezing, the mixing water contained 7 per cent. of caustic soda. The soda was dissolved in hot water. The cement-mortar consisted of 1 part of cement to $2 \frac{1}{2}$ parts of dry yellow sand taken out of the pit. The sand was not very sharp. The bricks (9 inches by 4 $\frac{1}{2}$ inches by 3 inches) were obtained from a colliery in the vicinity, made from a seggar or coarse fire-clay, and locally termed "plate-bricks." One side of the brick was curved to suit the circle of the shaft.

10. Extraction of the Tubes.—The removal of the freezing-tubes was commenced, as soon as the walling was completed, above the water-bearing strata. By means of the inner tube, steam was used to thaw the surrounding strata. A pair of hydraulic jacks were used to move the tubes, and they were then drawn out by the sinking-engine. The outside socket-joints increased the labour of removing the tubes, and two weeks expired before the work was finished; and in two cases the bottom length of the tubes was left in the holes, as the screw-thread at the joint had stripped by the force applied. As the tubes were withdrawn, the holes were filled with cement-mortar consisting of 1 part of cement to 3 parts of sand, so as to prevent the sand-feeder from passing through the clay into the freestone.

11. Conclusion.—There can be no doubt as to the reliability and efficiency of sinking by the freezing system through water-bearing strata; and with ordinary care, the possibility of a mishap is very remote. In the present case, the slow progress of the sinking was due to the boulder-clay, and a large amount of time was spent in boring and sinking through it. Opinion varied as to the desirability of freezing the boulder-clay, in the circumstances of the case under discussion; but the contracting firm held that it was absolutely necessary that the boulder-clay should be frozen.

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Mr. T. E. Forster (Newcastle-upon-Tyne) asked whether any difficulty had been experienced with the walling, since the ground had been thawed; and whether there had been any difficulty in the setting of the cement, while the ground was frozen.

[Plate VII.: Diagrams illustrating sinking by the freezing method at Washington.]

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Prof. H. Louis (Durham College of Science) asked whether the contractors had changed their opinion with reference to boring the holes through the boulder-clay and into the solid freestone. Many engineers who saw the process at Washington, could not imagine any valid reason for freezing this clay; but the contractors stated they had experienced considerable trouble in freezing strata containing boulder-clay in Germany. He (Prof. Louis) imagined that these were only lenticles of clay lying in the quicksands, and did not compare with the immense beds of boulder-clay found in this country.
Mr. J. K. Guthrie (Preston) said that he had sunk a shaft (14 feet in diameter) through boulder-clay in the ordinary way, putting in cribs, etc., and no trouble whatever had been experienced.

Mr. A. Gobert (Brussels) wrote that he noted with pleasure that the Centigrade thermometer had been adopted for observations of the temperature of the brine and cooling-water, and he would suggest that British mining engineers should also adopt the Continental calorie as the unit of heat, as by so doing it would be much easier to compare results obtained on both sides of the Channel. The description of the permanent lining used at Washington was interesting, but he would like to have some indication as regards prices. The question of cost might also be usefully discussed for all parts of the process of walling. He might point out that very important sinkings by the freezing process were contemplated in Belgium, and it was expected that the soil of Brussels would be frozen for the line of railway to be made between the Nord and Midi railway-stations. The government had consulted the writer, and he had given them a complete report upon the subject.

Mr. F. R. Simpson (Ryton) said that he had read Mr. Ford's paper with interest, not only because he had seen the process in operation at Washington, but he had recently made himself acquainted with what was being done by this method on the Continent. There, it was recognized as one of the regular methods of sinking through sands, either at the surface or at great depths. At one colliery, a shaft had been sunk by this method to a depth of nearly 800 feet. Difficulties had been experienced in boring vertical holes, and from the breaking of the pipes, but in every case these difficulties had been overcome and he had not heard of any case in which there had been failure to complete the shaft in the contracted time. The members were indebted to the Washington Coal Company Limited, for showing what could be accomplished by this method of sinking, and there could be no doubt that the sands met with in the east of Durham, could be successfully sunk through with the assistance of the freezing method. He moved that a vote of thanks be accorded to Mr. Ford for his valuable paper.

Mr. J. G. Weeks (Bedlington), in seconding the vote of thanks, said that the recent excursion of the members to Washington colliery had been most successful.

The vote of thanks was cordially approved.

Mr. Mark Ford, in acknowledging the vote of thanks, said that a slight feeder of water was coming through the walling. The addition of caustic soda to the mixing water prevented the cement from freezing, and allowed time for its setting. Before sinking the second pit, he wrote to the contractors as to whether they still considered it necessary to freeze the boulder-clay; they maintained their previous opinion, and stated that they absolutely refused to take any responsibility as to the sinking of the shaft unless the boulder-clay was frozen.
Mr. James Stewart's paper on "The Valuation of Gas-coals" was read as follows: —

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THE VALUATION OF GAS-COALS.

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By JAMES STEWART, Editor of the Gas World.

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The valuation of coal for gas-making purposes is peculiar in that no ordinary laboratory-method of analysis, such as serves to value most technical materials, will suffice. It is not like lime, for instance, the value of which, either for gas-purification or as a cement, can be inferred from its chemical analysis; nor like a lubricant, the utility of which can be estimated from its behaviour when exposed to certain physical and chemical tests. An ultimate analysis, revealing the elementary constituents of the coal, may perhaps show its fitness or otherwise for gas-making, but it is no trustworthy guide as to its value for that purpose. And a proximate analysis, showing the respective amounts of volatile and fixed products when the coal is subjected to destructive distillation, is of little, if any, greater utility. The actual value of a gas-coal can only be ascertained by imitating the treatment which the coal will receive in the gas-works, and thus producing from it the gas and bye-products for which it is valued.

The scale on which the process is carried out may vary considerably, according to the resources at command and the preferences of the operator. The minimum, however, is fixed, in that at least sufficient gas must be produced to enable its illuminating power to be determined by the Bunsen photometer; which means that not less than 1 pound of coal, yielding, say, 5 cubic feet of gas, must be carbonized. Ordinarily the laboratory apparatus is of little more than twice this minimum, and carbonizes at one operation 2 ¼ pounds of coal, which is practically 0.001 ton. The experimental plant of a modern gas-works is generally on a much larger scale, being arranged to carbonize 1, 2, 3 or 4 cwts. of coal at once; and in a few cases it is on a scale of still greater magnitude, constituting, in fact, a small gas-works in itself.

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In skilled hands, the small laboratory-apparatus above-mentioned is able to furnish very trustworthy results: but it has the drawback of almost invariably attributing to the coal a higher value than is borne out on the working scale. And, paradoxical as it may seem, this failing is likely to be the more accentuated in the hands of the less experienced operator. The reason for this will be seen on a brief review of some of the particulars wherein the laboratory-apparatus necessarily differs from the actual plant employed in the gas-works: —

(1) The retort is of iron, which is a better conductor of heat than clay, and can always be ascertained to be perfectly sound before making a test; whereas the clay-retort in the gas-works is of a porous nature, and has to be made tight by rendering with cement or by filling up its pores with deposited carbon, and is therefore more liable to spring accidental leaks. Then, (2) the temperature is under complete control and, if not high enough, a test can be delayed until the proper heat is attained; or experiments may be made to find the most suitable temperature for obtaining the best results from the coal. Again, the coal will usually be perfectly dry before it is introduced into the retort, and that introduction will be effected with such celerity
that no gas is lost in the operation; whereas, in practical working, there is necessarily a considerable loss of gas ere the lid of the retort can be closed and sealed. And there is some slight further advantage in the fact that the gas is measured at a pressure little if at all above the pressure of the atmosphere; whereas, in the gas-works, there is an additional pressure, generally of 6 or 7 inches of water, due to the weight of the gasholder.

But there is another particular in which the laboratory-method differs from the working-scale operation that, perhaps more than all those above enumerated, allows of unduly favourable results being obtained; and that is the different treatment in the matter of condensing, washing and scrubbing, which the gas receives. With the very best intention to obtain trustworthy results, it is impossible to subject the gas to the same rigorous treatment in the laboratory as it receives in the gas-works. Owing to the smallness of the scale on which the operation is conducted, the gas cannot be washed and scrubbed with ammoniacal liquor and clean water, as is done in the gas-works, without using a proportionately much greater quantity of the fluids and so overdoing the cleansing—to the great detriment of the gas. Therefore it is usual to dispense with the washing process, and the experimenter is content with cooling the gas to a sufficient degree, before purifying. Unfortunately mere cooling, except when carried to an extreme, does not suffice to rid the gas of the minute vesicles of tarry hydrocarbons (which are carried along with the stream in an exceedingly minute state of division, and require prolonged contact with wetted surfaces, combined with some stagnation of flow, to enable them to coalesce into drops of liquid, and so allow of their removal from the gas). If every trace of these condensable hydrocarbons be not removed before the gas is tested for its illuminating power, its quality will appear unduly exalted. For the illuminating power of coal-gas is due to its containing from 4 to 6 or 7 per cent. of heavy hydrocarbons, which, in their composition and nature, greatly resemble much of the liquid constituents of the tar: but differ from the latter in the important property of being, under ordinary conditions, uncondensable from the gas. A very slight increase in the percentage of hydrocarbons, which may be caused by inefficient condensation, is therefore calculated to make a considerable difference in the result on the photometer. And if such a result may obtain with every desire to be fair, what may not be done when the gas is purposely coddled with a view to high results?

Sufficient has been said to show how a much higher value can be attributed to the coal than it may really have for the practical gas-maker. By how much the estimate should exceed the reality has never been determined, though many opinions have been hazarded. It is, in fact, incapable of solution. However carefully and conscientiously the test may have been carried out, it is hopeless to attempt to predicate from the result the corresponding result that will be obtained in the gas-works. It must obviously depend upon the skill and intelligence brought to bear upon the working, as well as on the degree of perfection of the plant employed. While, therefore, it will be the aim of the analyst to arrive at the ultimate value of the coal, he must ever keep in view the actual conditions of gas-making, and not take advantage of his favouring circumstances to obtain results which cannot, even with the exercise of great care and skill, be realized in practice.

There is one other matter that requires to be taken into
consideration in interpreting the results of a coal-test; and that is the question of the burner with which the illuminating power of the gas is determined, including the manner in which it is used. Obviously the burner used should be the standard one for the particular quality of gas, that is to say, the London argand for qualities up to 18 candlepower, and the batswing for qualities of 19 candlepower and upwards. But it is neither necessary nor desirable that it should always be used under standard conditions. Under the absurd regulations which, everywhere but in London govern the testing of coal-gas, the illuminating power has to be determined with a fixed consumption of exactly 5 cubic feet per hour. When burning different qualities of gas in the argand burner, a uniform consumption must be prejudicial to the lower qualities; because more air is drawn upon the flame than is required, thus cooling and over-oxidizing it, with the result of depreciating the illuminating power. The analyst should therefore vary the consumption to suit the quality of the gas, and calculate the result to the 5 cubic-feet rate. But, if this be done, it is very important that the fact should be stated in the report, so that the gas-manager may know that he has to expect a less satisfactory result when the gas is consumed at the standard rate.

Mr. W. Doig Gibb (Newcastle-upon-Tyne) wrote that the teaching of Mr. James Stewart's paper on "The Valuation of Gas-coals" was that what was known as a "laboratory test" would not give results comparable to those which could be obtained in actual working. This had been known for a long time. The paper was, however, of value in that it marshals the arguments for and against the "laboratory test" in a terse and lucid manner. In larger gas-works, where the capital expenditure required could be afforded, there was no doubt that an experimental plant on a working scale was of much greater advantage to gas engineers generally than a laboratory plant could be, but even then it was still a benefit to have a laboratory-plant in addition, since, with the latter, tests could be taken quickly and without great cost, and though the results might not be comparable to the actual working-results they were trustworthy (if proper care were taken in testing) in comparing the different results got from the various coals tested. Mr. Stewart did not seem to believe in the future possibility of the tests on a laboratory-plant being made in such manner as would approximate the results got on a working scale. It might not be possible, but at all events it would be a step in the right direction if standard laboratory apparatus and standard methods of using the same were adopted. This would at all events result in the different published analyses of coal being comparable with each other. At present, owing to the different methods employed in sampling and testing, and also owing to the absence of any information on the printed analyses sheets as to the methods, etc., employed, an interested reader had great difficulty in comparing, in any accurate way, the value of one with another.

The President (Sir Lindsay Wood, Bart.) moved a vote of thanks to Mr. Stewart for his interesting paper.

Mr. G. May seconded the vote of thanks, which was cordially approved.
DISCUSSION OF Mr. G. P. LISHMAN'S PAPER ON "THE ANALYTICAL VALUATION OF GAS-COALS."*

Mr. G. P. Lishman wrote that the main intention of his paper had been to emphasize the advantage derived from the regular introduction of a coal of known value into the testing of an unknown coal. This certainly introduced other difficulties, as Dr. Pattinson had pointed out, but in his (Mr. Lishman's) opinion they were considerably less than those which were overcome. A colliery-manager knew fairly well that certain of his seams varied in quality, and that others were very constant; and this, combined with his (Mr. Lishman's) own knowledge, derived from testing, led him to adopt the coal of the Maudlin seam at one of the Lambton collieries as his standard, whereby others were checked. The method had been in use, with great advantage, at the Lambton collieries for over two years; still it was not claimed that perfection had been reached, as the introduction of further refinements was desirable and might reasonably be hoped for. He (Mr. Lishman) did not entirely understand Mr. W. D. Gibb's alternative suggestion from the outline given, but possibly there might be some manner of combining it with the standard-coal method.


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The difficulty was that in winter the iron of the purifiers and pipes (apart from the condensers, which might if necessary he kept warm) was very cold, and owing to this the illuminating power of the gas made in winter-tests was usually of 14 to 16 candlepower as against 10 to 18 candlepower obtained in summer. The purifiers and all the other pipes, except the condensers, were not water-jacketted—it would hardly be practicable to have them so—this perhaps best supplied the answer to Dr. Pattinson's query on the subject. No doubt, the effect of condensation was increased by the slower passage of the gas; and, if, as mentioned by Mr. Gibb, the entire room in which the gas was treated were kept at a constant temperature in summer and winter, there would be no necessity either for water-jacketted condensers or even a standard coal. Probably, a room could be arranged so that this might be effected, but in his (Mr. Lishman's) particular case the controlling of the room-temperature was found to be so troublesome that the idea was given up.

The time required for distillation was a question of retort-temperature, and when he (Mr. Lishman) stated 60 to 90 minutes, the latter was an outside limit seldom reached: one hour was regarded as the regular time for a test, but if any further gas was coming away at the end of that time the distillation was allowed to proceed until it ceased, or nearly so. The usual time actually taken varied from 60 to 70 minutes. It was frequently stated that the results from a laboratory coal-testing plant were higher than those likely to be obtained in a gasworks, but this by no means followed, and it depended entirely on the amount of condensation or scrubbing applied. The effect of the lower retort-temperature was to increase the illuminating-power, the yield being reduced.

Mr. Stewart took the writer to task on the two statements that "there is an almost total absence in scientific journals of papers on the testing of gas-coal" and that "although coal-testing plants are attached to most gas-works now, they are usually of but limited use to the engineer, who still has to rely mainly on his working-scale results." He (Mr. Lishman) did not wish to appear contentious on minor points such as these, more especially as Mr. Stewart agreed with him
on the main issues of the paper, but considering the enormous number of papers published on all gas-matters in these days, the three or

four papers on laboratory-testing of gas-coal which had been published in the last ten years could hardly be regarded as numerous. Perhaps the best of them was that of Mr. Thomas Glover, read before the Midland Association of Gas Managers in 1896, but the scale was much larger than that referred to in the present paper. If there was any German or other literature of which he (Mr. Lishman) was ignorant, he would be very glad if Mr. Stewart would point it out. Regarding the second statement, he (Mr. Lishman) had evidently credited more gas-works with coal-testing plants than actually possessed them, but this was not Mr. Stewart's point. The idea that coal-testing plants were of limited use to gas-engineers was a general impression from his (Mr. Lishman's) knowledge of the industry. Since Mr. W. Doig Gibb was evidently in agreement with him on this point, he saw no immediate reason to alter his opinion on the subject. The underlying assumption in the early part of Mr. Stewart's remarks (scarcely carried through to the end) that gas-coal testing was, and had been, for many years, a sufficiently simple matter to those concerned, would hardly meet with wide recognition.

With reference to the use of a standard coal, Mr. Stewart said that "the idea is not, of course, entirely original," but as it was stated in his paper that "at any rate the idea is by no means novel" Mr. Stewart's remark was apparently unnecessary.

An interesting point had been raised, that the sperm-value of a coal was not always the measure of its value to the gaskmaker; for with two coals of equal sperm-value one might take longer to carbonize than the other and therefore be more costly. This was so, and the difference between two such coals would not be indicated by any figure in the analysis. Eight or nine years ago, the writer made observations of the volume of gas given off every five minutes during a test, and diagrams (similar to Fig. 1) were prepared, which indicated the progress of the carbonization As the diagrams obtained from the coals then tested, were mostly very similar, the practice was discontinued. Coals from different parts of the country, however, were known to vary greatly in this respect, and he (Mr. Lishman) thought that such a diagram might with advantage be appended to the analysis of a gas-coal. In comparing diagrams made at different times, it should be borne in mind that differences of retort-temperature might have somewhat altered the general direction of the line, but this need not confuse the experienced diagram-reader.

It would be an advantage to many chemists, besides those actually engaged in making tests on gas-coals, if Dr. Anderson's suggestion, as to the adoption of a single standard gas-coal for the whole country, could be carried out. Perhaps this was too much to hope for at present, but the interests involved were considerable, and many might be found to support such a scheme.
TREATMENT OF LOW-GRADE COPPER-ORES.

By Dr. EDWARD DYER PETERS.

Introduction.—In the introduction to Mr. Muir’s paper* reference was made to the fact that extremely low-grade ores are treated in the Lake Superior district of the United States of America, one of the mines actually finding it profitable to work an ore that contains only 0.65 per cent. of copper, or 13 pounds of the metal to a ton (2,000 pounds) of the ore.

It seemed to the writer that when making use of Lake Superior results, as a standard of comparison, in a paper on the treatment of sulphide-ores of copper, reference should be made to the fact that the conditions at Lake Superior are extraordinary, and unparalleled anywhere else in the world. It is, of course, well known to all who are interested in copper that this metal, in the Lake Superior veins, occurs in minute (and sometimes large) particles of pure metal, that only require a cheap washing process to be recovered in a nearly pure state; and that a single refining operation yields ingot-copper of the very highest grade and value. To the public at large, therefore, should be afforded the opportunity of realizing that the metallurgical operations at Lake Superior do not furnish a standard that can properly be compared with any other mining district in the world.

Mr. Muir is grappling in Australia with almost exactly the same problem as that which confronts many of us in the United States. For, although we have the unusually rich and extensive copper-areas of Montana, Arizona and Utah, we have also far greater areas of low-grade, disseminated and highly siliceous sulphide ores, situated far from a market and from fuel, and too often scantily supplied with water. Mr. Muir, in his paper, and Mr. Eissler, in his discussion of the same, had so covered the ground that there did not seem to be much new to say on the subject. Still, the writer would venture to offer a few suggestions based upon his own experience, as well as upon information


In order to narrow the field of enquiry, it may be well to enumerate all the methods that seem to have any claims at all to consideration, in connection with the treatment of the ores in question. We may then eliminate all those processes that, on examination, appear economically inapplicable, and consider the few that then remain. (1) Direct smelting; (2) mechanical concentration, followed by the smelting of the concentrates and the lixiviation of the tailings; (3) lixiviation of the ore direct, with a solution of ferrous chloride and salt; (4)
lixivation of the ore direct, with hydrochloric and sulphuric acids, which are regenerated in the solution by the precipitation of the copper from a chloride solution by means of sulphurous acid; (5) lixiviation of the ore direct, with sulphuric acid; and (6) the Rio Tinto method of gradual lixiviation in heaps.

1. Direct Smelting.—Wherever it is in any way practicable, the American metallurgist prefers smelting to any form of wet process. The perfect continuity of the operation, the ease and simplicity with which the unpulverized ore pursues its steady course from the mine to the blast-furnace, from the blast-furnace to the converter, and from the converter to the refinery, lend themselves to operations on a very large scale, and permit the substitution of mechanical appliances for hand-labour to an extent unapproachable in any other method. Another great advantage of smelting (absent in the present case) is the almost complete recovery of the precious metals present, with but little extra cost.

Nor need we be deterred from the employment of direct smelting, by even a very considerable excess of silica, and a corresponding deficiency of iron in the ore. Perhaps this was most clearly pointed out by Mr. F. R. Carpenter in the Deadwood and Delaware smelter, South Dakota, U.S.A. He demonstrated conclusively that highly siliceous ores, containing a little pyrites, and with extremely expensive coke, could be smelted direct in the blast-furnace, with the production of slags containing 50 per cent. of silica, 30 per cent. of lime and magnesia, and only 16 per cent. of ferrous oxide. The lime and magnesia were added to the ore in the form of barren dolomite; 20 to 30 tons of ore produced 1 ton of matte; the slags were exceedingly clean; and the precious metals and copper (very little) that were contained in the ore, were almost entirely recovered in the matte.

The most interesting features of this unusual type of smelting are the fusibility of the very acid silicate of lime and magnesia with but little iron, and the high rate of matte-concentration. The latter result is due to the very acid slag which decomposes the pyrites present, carrying their iron-contents into the slag as ferrous oxide. It is not always understood by blast-furnace smelters that, other things being equal, an acid slag means a high-grade matte, while a basic slag is accompanied with a low-grade matte.

The writer has only gone into this detail in regard to the direct smelting of very siliceous ores in the blast-furnace in a raw state, in order to call the attention of metallurgists to possibilities that may solve certain difficult metallurgical problems.

In the case cited by Mr. Muir, however, it may be feared that the absence of silver or gold in the ores, and the non-existence of limestone-ores for fluxing purposes, with the high cost of fuel, would compel us, most reluctantly, to give up the idea of direct smelting.

2. Mechanical Concentration, followed by the Smelting of the Concentrates and the Lixiviation of the Tailings.—The writer has met with, or been cognizant of, so many difficulties and failures in attempting to concentrate low-grade, disseminated sulphide ores of copper, that he has always advised exhaustive mill-tests on a large scale before venturing to employ this method. It is only suitable for very exceptional ores and conditions.

Mr. Muir's results seem to be stronger arguments against the employment of this process than any that the writer could adduce. * Without attempting to analyse his experiments in detail, the
writer would simply point out that the results of Mr. Muir’s concentrating tests show a saving in the concentrates amounting to about 20 per cent. of the original copper contained in the ore, and a loss of nearly 80 per cent. in the tailings. This, of course, means no concentration whatever, and there must be some reason, not apparent to the writer, why Mr. Muir attempted to concentrate at all.


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If a portion of the copper in the ore were present in the shape of some mineral that would exercise an injurious effect upon the subsequent lixiviation, and if this mineral had a higher specific gravity than the remainder of the sulphides present, there might be some question of attempting to remove it by concentration. But, as the 20 per cent. of the copper that was removed by concentration had, as the writer understands, exactly the same chemical composition as the 80 per cent. left in the tailings, he fails to see the use of employing concentration; nor does he believe that these ores should be subjected to concentration. (It will be understood that the writer is referring solely to the ordinary methods of wet-concentration in making this statement and that he is not expressing any opinion as to the results that might be obtained by one or two novel patented methods of which he has no personal experience.)

It seems to the writer most advantageous, therefore, to subject the entire mass of ore to lixiviation, rather than to complicate matters and increase expenditure by any preliminary concentration.

3. Lixiviation of the Ore direct, with a Solution of Ferrous Chloride and Salt (old Hunt-and-Douglas Method).—Considerable quantities of ore have been successfully worked by this process in the United States. The method depends upon the fact that oxide of copper is decomposed by ferrous-chloride solutions, forming insoluble ferric oxide, while the copper goes into solution as cuprous and cupric chlorides. It is precipitated in a very pure metallic form by iron, the ferrous-chloride solution being thus also regenerated, and requiring only the addition of a little salt to fit it for further use. The consumption of metallic iron in this method is very small, as much of the copper is in solution as cuprous chloride.

As the copper must be in an oxidized form, in order to go into solution quickly and thoroughly, the ore will require a preliminary roasting of sufficient thoroughness to convert most of the copper present into oxide or sulphate. This means that the ore must be crushed dry, though not to nearly so fine a state as would be required for its concentration. Therefore, instead of wet crushing followed by concentration, the writer would suggest dry crushing followed by roasting.

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It is impossible to make a comparison of the costs of these two different plans of operation without being accurately acquainted with the physical and chemical character of the ore under consideration. By the use of modern high-speed rolls of great diameter and weight, and of the automatic reverberatory roasting-furnaces so generally in use in the United States of
America and elsewhere, the cost of dry-crushing and roasting should not exceed the cost of wet-crushing and concentration, while the condition of the pulp for lixiviation is incomparably better when produced by the former treatment. Apart from the advantage gained by the coarser condition of the pulp, and the much lesser proportion of very fine powder, the ore undergoes a physical change in roasting, which makes it much like sand and gravel, and enables the solutions to permeate it with a completeness and rapidity that are quite surprising. The advantages thus gained will only be fully appreciated by those members who have had experience in leaching the same ore both before and after roasting. They are so great that, in several instances in this country, tailings are roasted previous to lixiviation, solely for the purpose of improving their physical condition, and of increasing the thoroughness and rapidity of the latter operation.

The writer desires to emphasize this dry crushing and roasting as being, in his opinion, the most important step towards a successful leaching of these ores by the methods that he has called Nos. 3, 4 and 5.

4. Lixiviation of the Ore direct, with Hydrochloric and Sulphuric Acids, which are regenerated in the Solution by the Precipitation of the Copper from a Chloride Solution by means of Sulphurous Acid (new Hunt-and-Douglas Method).—By this method, the copper is precipitated from its chloride solution, by means of sulphurous-acid gas, which throws down the copper as a very heavy white cuprous chloride, that settles almost instantaneously. Sulphuric and hydrochloric acids are generated in the solution, which only requires the addition of salt to make it ready for further use.

One great advantage of this method is the rapid dissolving of the oxidized copper present by the strongly acid solution, which even attacks sulphides with considerable energy. Any lead and silver present remain undissolved. The ores require to be roasted, as in the previous process. A supply of pyrites is essential to the economical working of this method, and, of course, it is very advantageous if these pyritic ores contain some metal of value.

5. Lixiviation of the Ore direct, with Sulphuric Acid.—Mr. Muir has already considered this method in his paper, though he confined it to the treatment of the tailings after concentration. The writer can only add that, if lixiviation is at all suited to the fine tailings and slimes from the concentration-process, it is still more feasible, and much more economical, when employed upon the coarsely-crushed and roasted ore; and, that instead of taking 11 weeks for the extraction of the copper, it is probable that, with roasted ore, an equally perfect extraction would he accomplished within 2 or 3 days.

6. The Rio Tinto Method of Gradual Lixiviation in Heaps.— The writer agrees with Mr. Eissler in having a strong leaning towards this process of slow, but inexpensive, lixiviation, in cases where the climate is suitable, and where the chemical and physical condition of the ore favours the gradual and persistent formation of sulphates. From the description of the ore given by Mr. Muir, the writer fears that, in the present instance, the percentage of sulphides might not be
large enough to maintain the energetic and persistent chemical action necessary for the gradual decomposition of the chalcopyrite, and the formation of soluble salts of copper. There is another very serious objection to the Rio Tinto method that does not always weigh sufficiently with the metallurgist, who confines his attention too closely to the perfection of his technical results, namely: —The time and money required to demonstrate on a large and safe scale that any given ore will eventually yield up its copper to this slow and tedious process. There is also great difficulty in finding reliable deposits of sufficient size to yield the enormous quantities of ore of a nearly identical composition that are required for the profitable instalment of this method, as well as in raising capital willing to wait so long for returns.

This completes the list of methods that seem to the writer worthy of consideration in connection with Mr. Muir's Australian ores. There are one or two recent British patented methods that

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bear on this same subject. No doubt they have been investigated by British engineers who are interested in the mechanical concentration of difficult copper-ores, and the writer does not feel at liberty to discuss them in this place.

Recapitulation.—After enumerating the six methods of treatment that seem to the writer to be best suited to these Australian ores, he has eliminated the first two, namely :—(1) Direct smelting and (2) mechanical concentration and lixiviation of the tailings. The slow Rio Tinto method of leaching, which he has called No. 6, demands most careful consideration in the few cases where the magnitude of the ore-bodies and of the financial resources will permit of its application.

This leaves only the three methods of direct and rapid lixiviation of the ore without any previous mechanical concentration. An intimate knowledge of local conditions and costs, wide technical experience with modern lixiviation-methods, and long and careful experiments on an extensive scale, on the ore to be treated, can alone decide the method to be chosen.

The writer is pretty well convinced, however, that if the choice should fall upon any one of these three methods, it will be found advantageous to crush the ore dry and roast it, before lixiviation.

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Mr. James Douglas (New York, U.S.A.) wrote that he concurred with Dr. Peters' preference for smelting over leaching, whenever conditions made the former possible. The greater simplicity of plant and process was overwhelmingly in favour of smelting, and the large size of the cupolas now used, 22 feet by 42 inches or 48 inches, enabled a small plant to do a large amount of work. The Rio Tinto method could be employed, even on suitable pyritic ore, only in a hot climate; and many ores (even though their chemical composition would point to this process as applicable) would not heat up and decompose.

The President (Sir Lindsay Wood, Bart.) moved a vote of thanks to Dr. Peters for his valuable paper.

Mr. J. G. Weeks seconded the resolution, which was cordially approved.
THE UTILIZATION OF EXHAUST-STEAM BY THE COMBINED APPLICATION OF STEAM-ACCUMULATORS AND CONDENSING TURBINES.*

By Prof. A. RATEAU.

1. Introduction.—The ceaseless march of competition and the continuous rise of costs in these days impel the leaders of industry to seek more actively than ever the means of improving methods of working and processes of manufacture. Within the last few years, extraordinary efforts have been made:—(1) In the direction of concentrating the means of production and the diver industries connected therewith; and (2) in the direction of a more rational and thorough application of scientific method to the purely technical conditions of industry.

In this last order of ideas, the utilization of the heat of fuel, which is still far from having attained its absolute maximum, presents to the inventor's mind an inexhaustible source of possible improvements. Investigation has been especially active along that line, and has indeed been productive of quite remarkable results. In this connection, we may recall the direct use in piston-motors of fuel previously converted to the gaseous condition, and more particularly the utilization in such motors of blast-furnace gases, the calorific power of which had up till that time mostly gone to waste.

Alongside this, the writer may perhaps be allowed to place the economy which he proposes to effect in a whole group of the innumerable appliances of motive power now in existence, by utilizing the enormous quantities of steam daily wasted by intermittently-running engines and exhausting into the atmosphere, such as winding-engines at mines, the reversing-engines of rolling-mills, steam-hammers, etc. One result of the particular conditions, under which these engines must perforce be worked,

* Translated by Mr. L. L. Belinfante, M.Sc.

that condensation or compounding by the usual methods is more difficult and less efficacious in their case than with ordinary continuously-running engines. Thus it is that the former class of engines has on the whole profited but little by modern improvements in the direction of economy, and thus it is that they continue to lose daily much unapplied energy.

2. Principle and General Arrangement.—The system proposed by the writer consists essentially in accumulating in an appropriate apparatus the non-continuous exhaust-steam of intermittently-running engines, so as to obtain from that apparatus a regular flow of steam, which may be subsequently utilized in a secondary engine (preferably a turbine) provided with a condenser.
This arrangement thus enables intermittent engines to take full advantage of condensing arrangements, and to store up mechanically the considerable stock of energy which these engines have hitherto freely exhausted into the surrounding atmosphere.

It is easy enough to demonstrate the theoretical advantage that is to be gained in a general way, by condensing exhaust-steam, that is by pushing to its extreme limits the liberation of steam within any motor. If, in fact, we recall a formula, given elsewhere by the present writer,* for the theoretical consumption of steam in kilogrammes per horsepower-hour, namely: —

\[
K = 0.85 + (6.95 - 0.92 \log P)/(\log P - \log p)
\]

(P being the entrance-pressure of steam and p the exit-pressure in kilogrammes per square centimetre), a formula which may also be expressed as follows: —

\[
K = (6.95 - 0.07 \log P - 0.85 \log p)/(\log P/p)
\]

We recognize that the last two terms of the numerator being always insignificant in comparison with the first, the theoretical consumption of steam per horsepower is inversely proportional to the logarithm of the ratio \( P/p \) of the entrance- and exit-pressures, and that consequently the power produced per kilogramme of steam is sensibly proportional to that logarithm.

* Rapport au Congres International de Mecanique appliquee de 1900, sur les Turbines a Vapeur (report on steam-turbines).

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It results from the formula, for example, that the theoretical consumption of an engine, between the pressure \( P \) of 6 kilogrammes per square centimetre (85 pounds per square inch), and \( p \) of 1 kilogramme per square centimetre (14 pounds per square inch), is equal to 8.8 kilogrammes (19.4 pounds) of steam per horsepower-hour; while the consumption per horsepower would only be 9.3 kilogrammes (20.5 pounds) between the higher atmospheric pressure \( P \) of 1 kilogramme per square centimetre or 14 pounds per square inch and the lower pressure of 0.15 kilogramme per square centimetre or 2.13 pounds per square inch, which may be produced by an ordinary condenser. We see then that, by applying condensation to steam-engines, the total work theoretically done per kilogramme of steam may be almost doubled.

This considerable advantage may now be utilized in intermittently-running engines also, by means of the steam-accumulator and the condensing-turbine.

To utilize the supplementary energy made available by the application of condensation, it was, of course, necessary to transform this energy into mechanical work by means of a suitable engine. And that is the purpose of the steam-turbine, which is introduced between the accumulator and the condenser. The powder developed by the turbine is henceforward obtainable without any additional expenditure of fuel, and may be practically reckoned as all gain for working purposes. At all events, its relative value is so great, when compared with the total efficiency of most winding-engines, that the application of the writer's system appears likely to prove a source of considerable profit at those mines or works where it is adopted. We shall see, for instance, that a pit winding 150 tons of coal per hour from a depth of 300 metres
(984 feet), may, under these new conditions, utilize an additional force of 500 horsepower hitherto wasted.

3. Use of the Turbine for utilizing Exhaust-steam.—It would not be impossible to expand in a piston-motor the regularized jet of steam, but turbines in the case of low-pressure steam offer manifold advantages. It will be easily understood that a piston-engine working at a pressure scarcely equal to that of the atmosphere would involve, in order to utilize properly the entire fall of pressure created by the condenser, dimensions so enormous that the mere cumbrousness of it, not to speak of its weight and cost of installation and maintenance, would prove impractical. Moreover, the efficiency of such an engine would be much inferior to that of a turbine, because of the exaggerated importance of the part played by condensation in cylinders of such huge dimensions: and also because of the inevitable strangulation in the inlets and exhaust-outlets of a steam-jet, the flow of which would be always too abundant (in comparison with the cross-section of the steam-pipes).

On the other hand, the tremendous speed with which steam is ejected in turbines and the resultant great capacity of outflow favour the erection of a turbine capable of utilizing at low pressure a flow of steam of several thousand kilogrammes per hour, while at the same time restricting the size of the apparatus to moderate dimensions. It is noticeable even, and in this practice agrees with theory, that turbines in contradistinction to piston-engines yield on working at low pressures an output slightly greater than that attained with high pressures. Thus, according to the power of the turbine, the output amounts to 60 or 70 per cent. in relation to the theoretical consumption of steam per horsepower-hour,* while the output of a piston-engine working under similar conditions, would hardly exceed 40 per cent. It is well known that the individual output of the low-pressure cylinder of a triple-expansion engine ranges between 35 and 40 per cent., although the cylinder works generally at a pressure exceeding that of the atmosphere.

In other words, if the theoretical consumption of any given engine, working between atmospheric pressure and a pressure at the condenser of 0.15 kilogramme per square centimetre or 2.13 pounds per square inch), amounts, as we have seen, to 9.3 kilogrammes (20.5 pounds) per horsepower-hour, the real consumption will figure out at only (9.3 ÷ 0.65 equals) 14.3 kilogrammes (31.5 pounds) or so per effective horsepower for the turbine, as compared with at least (9.3 ÷ 0.40 equals) 23 kilogrammes (50.7 pounds) for the piston-engine.

There could then be no question of hesitation in making use of the turbine, the more so as it offers in practice a whole series of

* All the figures relating to output in this paper represent the ratio between the work that is actually done and the energy that is theoretically available under such conditions of pressure, so far as the latter can be calculated from the formula set forth on an earlier page. This point should be borne in mind, in case the reader should have occasion to compare the efficiencies stated farther on with the efficiencies usually recorded from piston-engines, which (as a general rule) only express the ratio between the effective work done on the shaft and the work indicated on the pistons.
advantages attaching generally to that type of appliance, namely maximum compactness, low cost of installation, absence of all complication in erection, working and maintenance, and finally its ideal adaptability to the direct driving of dynamos.

It is only just to say that the Hon. C. A. Parsons, who had contributed more than anyone to the present development of steam-turbines, had also noted, in the course of his experiments the capability of these appliances for utilizing the lowest pressures of steam and the consequent advantages which might be derived therefrom in practice. The present writer believes however, that Mr. Parsons' observations in regard to this matter were not followed up by any industrial application. Moreover Mr. Parsons had in this regard confined himself to the consideration of the direct combination of turbines with piston-engines, with the view of securing more perfect expansion of the motor-fluid. He did not enter into the particularly interesting question, dealt with in this paper, of the utilization of intermittently ejected steam. Moreover, the possible application of turbines to this use could hardly form the subject of serious consideration until engineers had at their disposal appliances capable of regulating the flow of steam (an aim which is attained in the heat-accumulator that the writer is about to describe) and capable of ensuring the complete independence of the second motor in relation to the first. This object also is attained by means of certain complementary arrangements devised by the present writer.

4. Description of the Apparatus which serves to regulate the Flow of Exhaust-steam. -- The aim which this apparatus was devised to attain will be easily perceived. Let us consider, for instance, the case of winding-engines at mines. These engines only yield steam at the beginning of the wind, finishing it without the aid of steam; then they pause for about ½ minute during the moment when the tubs are being changed. The quantity of steam thus ejected, at each working interval, that is, at the beginning of each wind, often exceeds 150 kilogrammes (330 pounds), or in volume, more than 250 cubic metres (8,800 cubic feet). Now, it is easy to see that an ordinary reservoir, capable of accumulating without too much variation in pressure, so vast a quantity of steam must needs be of huge dimensions; whereas, in the case of

the apparatus to be presently described, both the size and the cost of erection are comparatively moderate.

This apparatus plays the part of an accumulator-regenerator of steam. The solid and liquid substances which it contains form a sort of heat-accumulator, thanks to which, steam, when it flows in abundantly, accumulates, condenses, and is regenerated in the interval during which the flow of exhaust-steam from the winding-engine slackens or ceases. The variations of temperature requisite for the condensation and regeneration of the steam correspond to small fluctuations of pressure in the accumulator. The pressure rises while the apparatus fills, and falls while the latter empties, in response to the turbine.

The amplitude of these oscillations of temperature and pressure is inconsiderable, being 3° to 0° Cent. (6° to 11° Fahr.) for the temperature, and 0.15 to 0.25 kilogramme per square centimetre (2 to 3.5 pounds per square inch) for the pressure. Moreover, this amplitude may
be restricted as much as one pleases, provided that in designing the apparatus an ample margin be allowed, according to the periods of activity and repose of the winding-engine. If we call \( t \) the variation of temperature, \( P \), the weight of the substances that form the heat-accumulator; and \( C \), the mean specific heat of these substances; the quantity of heat, stored up by the accumulator and given out again at each interval is \( PCt \) calories. To these \( PCt \) calories corresponds a weight of steam, first condensed, then vaporized, equal to about \( PCt/L \), \( L \) being the latent heat of vaporization of water.

The apparatus consists (as will be seen from Figs. 2 and 3, (Plate VIII.), which are respectively a vertical and a transverse section) of a cylindrical sheet-iron cistern, \( CC \), which may be either vertical or horizontal, wherein are piled up, one on top of the other, a series of cast-iron basins, \( A_1B_1, A_2B_2, A_nB_n \), of annular shape, made of several pieces so as to facilitate handling. These basins, always nearly full of water, rest one on the top of the other by means of studs, and there are interspaces of a few centimetres (½ inch), so as to allow of the passage of the steam. The result of this arrangement is:—(1) To offer a very considerable surface to the steam both for condensation and revaporization; and (2) to allow of the inclusion, within a small space, of the largest possible mass of metal and liquid.

This mass, which forms a heat-accumulator, should naturally be of greater volume, the greater the quantity of steam that has to be stored and the less the irregularity that appears desirable in the pressure of the exhaust-steam. It may be increased by casting ribs on the bottoms of the basins (aa, Fig. 3), and placing therein fragments of iron-scrap and such like material.

The steam, entering the apparatus by a pipe, \( D \), passes to the basins by means of the central distributor, \( F \). That portion which remains uncondensed, as well as that which is subsequently revaporized, flows downward along the lateral walls of the cylinder, \( CC \), to the outlet-pipe, \( E \), which conveys it to the low-pressure engine.

The water, which the particles of steam have carried along with them, separates out in the upper chamber, falling from basin to basin, first of all through holes, pierced in the sheet-iron diaphragm, \( TT \), then through the overflow-pipes, \( b \), to the bottom of the cylinder, whence it is drawn off by the pipe, \( de \), and an automatic steam-trap. As a steam-trap, when the apparatus works at a pressure approximating to that of the atmosphere (which is usually the case), a \( U \) tube is employed, forming a reversed siphon. It will be observed that by the arrangement adopted here, the steam passes through all parts of the apparatus in such a manner that there is no chance of air accumulating anywhere. The necessity is obvious, of preventing any air that is dragged along with the steam, from being localized in some place where it would interfere with the exchange of heat between steam and metal or steam and water.

It might be feared also that the oil, carried along in the steam coming from an engine, the cylinders of which must needs be lubricated, would cling to the metallic surfaces and form an insulating film that would constitute an obstacle to the free interchange of heat. As, however, the duration of the passage of heat is far from being a negligible quantity, and amounts usually to at least \( ½ \) minute, the drawback just referred to need not cause much concern. The present writer has, moreover, planned an arrangement whereby the steam enters through the bottom of the accumulator, and is easily rid of the particles of oil and water immediately upon its entrance, so that the basins are kept clear from oil.
5. Installation of the Apparatus.—Fig. 4 and 5 (Plate VIII) illustrate the general arrangement, and represent an apparatus

which has been working at the Bruay collieries (Pas de Calais) since August, 1902.
A is the steam-accumulator, divided in this case into three compartments, into which the steam flows from the winding-engine through a pipe, V.
T is the steam-turbine, which receives by means of a pipe, BC, the steam coming from the accumulator. This turbine may also be supplied directly with live steam from the boilers by means of a pipe, H, whenever the supply from the steam-accumulator proves insufficient. G is an automatic valve which admits of the entry of live steam direct from the boilers when needed, without the engineman having to trouble himself about it. It opens when the pressure in the steam-accumulator falls below a given point, which may be fixed at pleasure.

[Photograph: Fig. 1.—Rateau Turbine-dynamo.]

FF are the dynamos coupled directly up to the turbine. They are of continuous-current type, and supply a triplex or three-wire installation. Turbine and dynamos are set up on one and the same cast-iron bed. The exhaust-steam from the turbine is led by a pipe, E, to a condenser, whether it be an injection-condenser, or a surface-condenser, or a central condenser (as at Bruay), or even an ejector-condenser.
S is an automatic valve intended to allow of the direct escape into the atmosphere of the steam from the winding-engine when it is not all utilized by the turbine. The pressure of ejection may be regulated at will by means of a spring that acts on the valve.

A very sensitive regulator, R, whereof the component parts may be seen to the left of the turbine, controls the speed in such a way that it does not vary by more than 2 per cent., despite the changes of load and the fluctuations of pressure in the accumulator.
It will be observed that these arrangements ensure the complete mutual independence of the winding-engine and of the turbine. Thus, if the latter does not take all the steam from the former, the winding-engine exhausts directly into the atmosphere by means of the automatic valve, S. On the other hand, if, during pauses of more or less duration, the winding-engine does not supply enough steam to the turbine, the latter is supplied direct from the boilers by its own automatic valve, G.
One might also arrange for a stop-valve, which would permit of the turbine being cut off from the accumulator when necessary, in such wise that steam could be fed to the turbine from the boilers at as high a pressure as might be needed to perform all the work. The writer is thinking of those cases where condensation being at a standstill, the turbine would have to eject steam at atmospheric pressure and not in vacuo.
The entire plant takes but little room. Turbine and dynamo together, of a capacity which may go up to 500 horsepower, can be lodged in a space of 4 metres (13 feet) in length, 1.5 metres
(5 feet) in breadth, and 1·7 metres (5 ½ feet) in height. The steam-accumulator, if the receiver be arranged vertically, occupies a very small area. As a rule, it may be erected out of doors, as there is no need to protect it from the weather. The only precaution in this regard that need be taken is to cover the accumulator with a layer of some insulating material, so as to obviate too rapid radiation of heat from it.

6. Working of the Apparatus.-In order that the working of the apparatus herein described may be more clearly understood, the writer has reproduced in Figs. 8, 9, 10, 11 and 12 (Plate IX.), the actual diagrams obtained from the plant working at Bruay collieries by means of a recording pressure-gauge. This indicates in functions of time the pressure of steam within the accumulator.

The abscissa, AB (Fig. 8), corresponds to the duration of a complete wind, which at Bruay colliery lasts rather more than 1 minute. During about 18 seconds, that is, from A to C, the winding-engine expends progressively the whole effort of which it is capable for raising the cages. The exhaust-steam meanwhile flows to the accumulator, and the pressure consequently rises therein up to 1.3 or 1.4 kilogrammes per square centimetre or 18.5 or 20 pounds per square inch (absolute pressure). This limit is fixed by the tension, which may, however, be varied by hand, of the spring that controls the valve, S (Fig. 4, Plate VIII.). * If, therefore, more steam comes in than the accumulator can absorb, the excess immediately escapes by means of the valve, S. At C, the engineman shuts off the steam from the winding-engine, which by its impetus continues to raise the cages up to the pit-mouth, when it stops to allow of the changing of the tubs. This working with steam shut off lasts for about 15 seconds, and at B, the engine starts a fresh wind, after a stoppage of about 35 seconds.

As the turbine inhales continuously the steam, which it needs, supplied to it by the accumulator, the pressure in the latter falls so soon as the inflow of exhaust-steam ceases, that is from the point, C, onwards. So long as this decreasing pressure remains below the working pressure of the turbine, the accumulator alone supplies the steam. But if the pressure in the latter threatens to fall below the limiting pressure, the automatic feed-valve, G, which has been regulated accordingly, opens, and supplies the steam that the accumulator (deprived for one reason or another of the main intermittent supply) is momentarily incapable of furnishing. That is what happens every time that the winding-engine is prevented from restarting with sufficient rapidity its periodic wind, and is precisely illustrated in Fig. 9. At E, the feed-valve has begun to come into play, supplying just the pressure needed for the working of the turbine. As, however, it feeds both the turbine and the accumulator, the pressure in the latter rises almost immediately (from E to F) a little above the working-pressure of the turbine. Nay more, at G (Fig. 8) this continuously rising pressure enables the accumulator, the feed-valve closing sharply, to yield up again (from G to H) a little of the live steam which it had just stored up.

* In the experiments, this maximum pressure amounted to 1.4 kilogrammes per square centimetre or 20 pounds per square inch, yielding a total pressure-variation of 0.40 kilogramme, or 5.7 pounds, that is, higher than the variation of 0.25 kilogramme or 3.5 pounds,
which has been previously mentioned as the most suitable. But this initial excess-pressure was then needed in order to make up for the comparative inefficiency of the accumulator, as will be explained on a later page.

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Then at H, the feed-valve opens again, and finally at I, the winding-engine restarts running. The writer need hardly point out that it is the right-hand portion of Fig. 8 which illustrates the normal working of the plant, prolonged stoppages of the winding-engine being rather the exception than the rule when a pit is in the full tide of activity.

It will be observed that the appended diagram (Fig. 10) indicates at K and L, two secondary periods of momentary rise in pressure. The first represents the sudden closure of the throttle-valve of the turbine by the governor following on the excessive opening which had at first resulted from the sudden stoppage at C of the flow of steam from the winding-engine. The second period probably has to do with the complicated handling which four-decked cages necessitate; they have to be unloaded in two operations, and involve repeated inflows of steam to the winding-engine.

As to the pressure of the steam at its very entrance to the turbine, this is continuously controlled by the governor, and will therefore depend solely on the amount of work absorbed by the dynamos. Therefore, it will be absolutely independent of the variations of pressure in the accumulator, provided the centrifugal governor be sufficiently sensitive.

Attention may be further directed to the fact that, at those times when the turbine must be necessarily fed with live steam, its consumption per horsepower-hour will evidently exceed that of an ordinary continuously-running engine, under the same conditions, working at the full pressure of the boilers (that is, about 16 kilogrammes or 35 pounds per horsepower-hour instead of 10 to 12 kilogrammes or 22 to 26 pounds).

If the irregularities in the working of the winding-engine are reduced to a minimum, the total duration of the inflows of live steam will be inconsiderable in practice, and the consumption (slightly heightened during those intervals) will not materially affect the final economic result, yet such will not be always the case, and then the greatest possible economy in the working of the turbine may be ensured under any circumstances, by one or other of the following arrangements.

7. Expansion-turbine.—The first consists in adding to the low-pressure apparatus, with which we have been hitherto dealing, a

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high-pressure apparatus, the function of which will be to take from the boilers live steam during the stoppages of winding. Meanwhile, the low-pressure turbine will take indifferently either the steam from the accumulator or the exhaust from the other engines, each of these sources of supply predominating in turn.

The two turbines taken together may be considered as an ordinary high-pressure plant capable of receiving at any moment and utilizing in the best way possible the steam ejected from a primary engine. With an ordinary vacuum, the combined apparatus would only
consume from 6 to 9 kilogrammes (13 to 20 pounds) of steam per electrical horsepower-hour at full load, if supplied solely with live steam at say 8 kilogrammes per square centimetre (114 pounds per square inch); and, as aforesaid, it would consume from 14 to 18 kilogrammes or 81 to 40 pounds (as the case might be) if supplied solely with exhaust-steam at atmospheric pressure. Of course the inflow of live steam would be arranged automatically according to the power required of the turbine and so as to complete the quantity of low-pressure steam already flowing in.

8. Raising of the Exhaust-pressure of the Primary Motor.— The second arrangement admits of a simple solution. It consists in deliberately raising the exhaust-pressure of the winding-engine (by fixing the normal pressure for the accumulator at, say, 3 kilogrammes or 43 pounds per square inch), and in utilizing the regular flow from the last-named in a medium-pressure turbine, working somewhere between 3 kilogrammes or 43 pounds and the lower pressure (0.15 or 0.10 kilogramme or 2 or 1½ pounds) of the condenser. As a rule, the working of the winding-engine will not be much affected by this increase of pressure, while some advantage will be reaped by making up with live steam, under favourable conditions, the full supply of the turbine. The necessity of resorting to a supplementary high-pressure turbine as in the previously described arrangement is also obviated. It is true that the live steam will have to undergo expansion up to 3 kilogrammes per square centimetre or 43 pounds, but this expansion being inconsiderable when compared with that necessitated in the previous case, its disadvantages will be greatly minimized. Thus from P (3 kilogrammes per square centimetre or 43 pounds per square inch) to p (0.15 kilogramme per square centimetre or 2 pounds per square inch) the consumption will only be 10 kilogrammes or 22 pounds of steam per horsepower-hour, the turbine being fed either with exhaust-steam or with live steam. This result is numerically comparable with those yielded by good compound high-pressure condensing engines.

In the writer's opinion, it would be advisable to resort to the simple arrangement just described when erecting a new winding-engine, for it involves the considerable advantage of utilizing in the fullest possible manner the steam produced by the boilers. It will not have escaped notice, to begin with, than the consumption by the turbine of 10 kilogrammes or 22 pounds of steam per horsepower-hour ensures very fair efficiency. Then, too, the efficiency of the primary engine, in which the steam is used before reaching the turbine, is itself improved by the heightening of the exhaust-pressure, one of the results of this heightening being the limitation of the temperature-interval to the cylinder of the primary engine, and consequently the limitation of condensation in that cylinder.

But, if the output, compared with the ideal engine, be thus improved, the consumption of steam per horsepower-hour of the primary motor is, however, slightly increased. It will, then, be necessary, to obtain the full benefit of this device, that the full stream of steam, which the primary motor is able to supply, or at least the greater part of it, be utilized in the turbine. Yet that supposition will only be fulfilled if the turbine is so designed as to produce at its normal working-speed a sufficient quantity of electric energy.

The arrangement just described might be still further improved by combining it with the preceding one; in other words, by causing live steam to expand, between the boiler-pressure
and the pressure at the inflow into the secondary turbine, in a small turbine adjusted to the same shaft.

9. Condenser.—The condenser may be of any type. Most often it will be a mixing-condenser provided with an air-pump. It may also be a surface-condenser or else an ejector-condenser, which latter possesses the merit of simplicity. The writer thinks it necessary to observe, however, that in these low-pressure engines there is every advantage in aiming at the best possible vacuum, in view of which the use of surface-condensers, although more costly, appears preferable.

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If there be already a central condenser, as was the case at colliery, it will suffice to interpose the accumulator and the turbine between that condenser and the primary engine. It is, of course, assumed that the use of condensers implies the supply of sufficient cold water to absorb all the exhaust-steam. But, it is quite possible to dispense with renewed supplies of water by using over and over again the same water cooled either in pulverizing sprays in the open air or in cooling-towers. We know that in the case of mixing-condensers, the quantity of steam given up to the air is sensibly equivalent to, or even less than the quantity of water re-introduced into the boilers, in such wise that with these condensers the condensation-water, far from being wasted, is regained. In plant of this kind, however, the water never undergoes complete cooling, and so we can only reckon on a comparatively perfect vacuum.

10. Results which it is possible to obtain by Means of the Rateau System.—(a) Mines.—Let us consider first of all the case of the winding-engines at a colliery, taking as an example the actual conditions that obtain at one of the twin shafts at No. 5 pit at Bruay colliery, where the writer's system has been applied. This shaft winds coal from a depth of 230 metres (755 feet), and although it is not yet in full activity, no less than 64 winds per hour have been accomplished, during which time 256 tons of coal and refuse have been brought to the surface. Now, 50 winds per hour constitute the usual average in collieries; with eight-tub cages this is equivalent, when the pit is in full work, to an output of 200 tons or thereabouts. But 200 tons raised through 230 metres (755 feet) necessitate an expenditure of energy represented by 175 horsepower-hours. A similar figure would be arrived at if we were to consider the case of a shaft 310 metres (1,017 feet) deep (which is the average depth obtaining in the Nord and Pas-de-Calais coal-fields) winding 150 tons per hour. On the other hand, we may reckon at 45 kilogrammes or 100 pounds per utilized horsepower-hour the consumption of steam in non-compound winding-engines with free exhaust. Therefore, the consumption of steam of such an engine will amount to about (175 horsepower by 45 kilogrammes or 100 pounds) 8,000 kilogrammes or 17,500 pounds per hour, under normal conditions of working. This is a considerable expenditure, easily explicable,

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however, if we reflect that the engine works intermittently and consequently cools down at each stoppage in a way that affects very unfavourably its efficiency or output.
Out of these 8,000 kilogrammes or 17,500 pounds we may reckon that about 20 per cent. (or say, 1,600 kilogrammes or 3,500 pounds) is lost by various condensations taking place in the pipes and internal parts of the engine. There would then remain available about 6,400 kilogrammes or 14,000 pounds of steam per hour, the complete utilization of which is now ensured by the writer’s system.

Since the consumption of a turbine, working between the atmospheric pressure and a pressure in the condenser of (for instance) 0.15 kilogramme or 2 pounds amounts to about 14.5 kilogrammes or 32 pounds per effective horsepower-hour, that is, 16 kilogrammes or 35 pounds per electric horsepower-hour, it follows that the application of the writer’s system to a colliery-shaft will entail the production of additional power to the extent of \((6,400 \div 16)\) or \((14,000 \div 35)\) equals 400 net electric horsepower-hours.

Such estimates, moreover, are extremely moderate, since the lowering (perfectly feasible in practice) of the lower pressure to 0.10 kilogramme or \(\frac{1}{2}\) pounds (instead of 0.15 kilogramme or 2 pounds) would of itself have the effect of reducing to 13 kilogrammes or 284 pounds per electric horsepower-hour the steam-consumption of the turbine. Thereby, the additional power obtainable in the aforesaid colliery-shaft would be increased to 490 electric horsepower-hours.*

Nay, more, if we decided to utilize also in the turbines the exhaust-steam of the accessory engines, driving ventilators, air-compressors, etc., before sending it to the condenser, the additional power which could be safely reckoned as available in such a case would no longer be a matter of merely 400 or 500, but often more than 1,000 electric horsepower.

(b) Steelworks.—If we turn now to the great steelworks, we shall find that it is by no means unusual to see there reversible plate-rolling engines consuming some 20,000 kilogrammes or

* It will be noted that, at the rate of 13 kilogrammes or 28 \(\frac{1}{2}\) pounds of steam per electric horsepower-hour (a result which can be most certainly attained in practice) the low-pressure electric generator would perform about three times as much useful work as the winding-engine; and at the rate of 18 kilogrammes or 40 pounds, it would still perform about twice as much.

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44,000 pounds of steam per hour. From what has been said above, it may be inferred that such an engine could be made to feed a turbine yielding 1,000 effective electric horsepower. And if we supplemented the exhaust-steam of the main engine by that from all the other motors, especially from the steam-hammers, we would obtain from a works of ordinary size consuming about 60,000 kilogrammes or 132,000 pounds of steam per hour, an additional supply of about 3,000 horsepower.

It may be observed, moreover, that this recovery of power would be more simple, more immediate, more certain in its working, and above all less costly than an equivalent recovery by means of the direct utilization of blast-furnace gases.

11. Adaptation of the Rateau System to Intermittently-running Engines already provided with Condensing Apparatus.—In cases where the intermittently-running engine is already provided
with a condenser, it would still be found advantageous to interpose between the engine and its condenser the proposed group of accumulator-cum-turbine. In other words, the advantage derived from the application of the writer's system would far more than compensate the loss entailed by raising the exhaust-pressure of the principal engine so as slightly to increase the consumption of steam. Indeed, the writer has shown, at the very beginning of the present paper, that the application of his system to an intermittent engine allows of the completest possible utilization of the fall of temperature that becomes available on the adjunction of a condenser, and ensures thereby a practical advantage represented in figures by much more than 50 per cent. (in relation to the consumption of steam in intermittently-working engines with free exhaust). Now, experience proves that condensation alone, in that type of engine, fails to reduce their consumption by more than 15 or 20 per cent. Therefore, the writer's system would still ensure, even in those engines already provided with condensers, an additional saving of at least 30 to 35 per cent.

This can be shown also in the following way. Suppose that we are dealing with a primary engine consuming 6,000 kilogrammes or 13,200 pounds of steam per hour, when not working with the condenser. If we apply condensation, the actual saving in practice will be from 15 to 20 per cent., that is, for the same amount of work performed by the engine, condensation will economize from 900 to 1,200 kilogrammes or 2,000 to 2,050 pound of steam at boiler-pressure that can be used in another motor. Now, with these 900 to 1,200 kilogrammes or 2,000 to 2,650 pounds of steam a good ordinary condensing piston-motor will develop some 90 to 120 effective horsepower.

With the writer's system of accumulator and steam-turbine the primary engine will still consume the aforesaid 6,000 kilo-grammes or 13,200 pounds of steam per hour; but about 80 per cent. of that amount, say 4,800 kilogrammes or 10,560 pounds of dry steam, will be utilizable in the turbine. This, at the rate of 16 kilogrammes or 35 pounds per horsepower, will give us 300 effective horsepower instead of the 90 to 120 obtained previously. The great advantage to be derived from the new arrangement may be thus accurately gauged.

12. Saving to be effected by the Proposed System.—The economy which may be expected to result from this arrangement belongs to two categories:—(1) Saving on the cost of installation of a group of electric-energy generators; and (2) saving on the cost-price of the energy thus furnished in the course of working.

(a) Economy in the Cost of Installation.—This will arise chiefly from the suppression of the boilers, which it would have been necessary to put down if the writer's system were not adopted, in order to produce the electric energy required for certain auxiliary purposes in the mine. It will arise also from the lower price of the turbine and dynamos and the reduced cost of installation, in comparison with what would be involved by a group of piston-engines of the same power. On the other hand, the saving will be to some extent diminished by the cost of the accumulator and the corresponding pipe-connections, although it is evident that the accumulator will in any case cost less than a range of boilers producing equivalent power.
These different factors will vary considerably in relative importance according to the additional power required, the mass of the accumulator, the system of working of the main engine, and the working conditions generally. It is consequently rather difficult to name definite figures. We may, however, reckon that in order to obtain in a colliery 500 electric horsepower, absorbing about 5,000 kilogrammes or 11,000 pounds of steam per hour, it would be necessary to expend at least 80,000 francs (£3,200) on boilers, whereas the price of the writer’s accumulator, including 75 tons of cast-iron, the needful pipe-connections, and the cost of erection, would hardly exceed 30,000 or 40,000 francs (£1,200 to £1,600). This alone, then, would imply a saving of 40,000 or 50,000 francs (£1,600 to £2,000). On the other hand, to erect a generating-plant actuated by piston-engines (dynamos and cost of installation being included) would involve, at the rate of 225 francs (£9) per horsepower, an expenditure of about 112,500 francs (£4,500). The adoption of the turbine would constitute another probable saving on this of about 30 per cent. (say, 35,000 francs or £1,400). It would seem then that, taken altogether, the saving on the cost of installation of an additional 500 horsepower may (by using the writer’s system) amount to as much as 75,000 or 85,000 francs (£3,000 to £3,400), namely, about 30 per cent. compared with an ordinary plant. These, of course, are only rough calculations, but they suffice to demonstrate the absolute certainty of an initial saving on the cost of erecting plant in those cases where the writer’s system is adopted.

(b) Economy in the Current-cost of Production of the Additional Power recovered.—There is no need to compare the total expenditure involved in the production of the additional power by a piston-engine with that by the proposed system, in order to obtain an idea of the enormous saving in the current cost of working. This saving will in greatest measure arise from the suppression of any additional expenditure on fuel, so long as the primary engine is at work. It will also arise from the possibility of dispensing with the firemen who would have had to be engaged if new boilers had been put down, and also from the annual amortization of the 30 per cent. saved on the first cost of installation.

For the same reasons as those assigned on a foregoing page, it is hardly feasible in a general way to express these savings numerically. We may, nevertheless, attempt to form some idea of what they imply in the case (already considered) of a colliery-plant that is to be provided with an additional 500 electric horsepower. The annual economy would then be approximately, on the assumption that the machinery works 10 hours a day:

1. Saving in coal at 2 kilogrammes or 4.4 pounds per horsepower, or 10 tons per diem or 3,000 tons per annum, at 10 francs or 8s the ton.

   Francs  £

   30,000  1,200

2. Saving in labour: 2 firemen

   4,000  160
3. Saving on the amortization in 12 years of the installation, about

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<th>7,000</th>
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<tr>
<td>Totals</td>
<td>41,000</td>
<td>1,640</td>
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It will be noted that the saving here is most considerable on the coal-bill. Consequently the economy thus effected would bulk still greater in the case of steelworks, which generally pay from 15 to 20 francs (12s. to 16s.) per ton for their fuel, while the engines are more numerous, more concentrated, more diverse than those used in collieries, and for the most part are kept working day and night. The annual saving effected on the hypothetical 500 additional horsepower, even if the working day were restricted to 10 hours, would then (in the case of steelworks) amount to 70,000 francs (£2,800) or so.

Finally, we may observe that the annual economy, that of amortization, being deducted, represents, in comparison with the total cost of installation of the system: in the case of a mine, 25 per cent. of the estimate, and in the case of steelworks, more than 40 per cent. In other words, the cost of installation would be gradually extinguished by the sinking-fund which the actual saving on the mere cost of working represents, in the one case in 2 1/2 years, and in the other in 4 years.

13. First Results obtained at the Bruay Collieries, Pas de Calais.—No. 5 pit of the Bruay collieries, at which the apparatus devised by the writer has been erected, has only lately been sunk, and is not yet in full activity. At present, the daily output from this pit ranges from 700 to 800 tons, but it is expected ere long to average 1,200 tons. The consequence is that the winding-engine, with which the writer’s accumulator is connected, only works 2 hours per diem up to its normal, not to say maximum, capacity. It is, of course, only these periods of regular working that will be considered in the synopsis of results obtained. On the other hand, the electro-turbine plant is just now burdened with a very exacting task, supplying among other things large weight-lifting motors, which involve continual and considerable variations of current. But a few months hence, the conditions will have

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Altered, for the plant in question will have to supply current to the electric motors actuating the ventilators of No. 5 ter pit (now being sunk). These motors will take up about 100 horsepower, and it was indeed mainly with the view of utilizing the current for working the new ventilators that the management decided on erecting the steam-accumulator and turbine.

Despite these rather unfavourable conditions, the accumulator fulfils the expectations formed in regard to it, and the turbine works with satisfactory regularity. In the note appended to this paper will be found a succinct description of the electric plant (turbine and dynamo) erected at Bruay colliery. The turbine, fed by the accumulator, exhausts its steam into a central condenser, which also receives the exhaust-steam from the air-compressing engines and the ventilating engine. It will be shown further that the vacuum yielded by this condenser was at first far from satisfactory, and, consequently, the power produced by the turbine was much less than it would otherwise have been.

With regard to the accumulator, it consists, as was shown on a previous page, of three chambers, and comprises in all 30 tons of cast-iron distributed over a series of annular and segmented basins, 10 centimetres (4 inches) in height. With this weight of metal, this
accumulator is at present a little too weak, as will be seen from the diagrams shewn in Figs. 8, 9, 10, 11 and 12 (Plate IX.) to which we may now direct our attention.

14. Diagrams of the Pressures in the Accumulator.—The diagrams of pressures recorded in the Bruay accumulator have already been used in a preceding chapter to show in a general way how the writer's system works. It remains now to study them from the point of view of the particular results yielded in practice by this first installation.

The reader will bear in mind that the graphic curves now referred to were traced out by a Richard recording pressure-gauge; that the pressures are measured along the ordinates, and time-intervals along the abscissae. The horizontal line, 0, corresponds to the pressure of the atmosphere, and the intervals between the principal vertical arcs represent each one minute of time.

Fig. 8 was taken at a moment when the winding-engine was working at normal speed, while the turbine was working at an average inflow-pressure of 0.89 kilogramme or 12.7 pound per square inch absolute, which corresponds to a calculated* flow of 4,950 kilogrammes or 10,900 pounds of steam per hour; as the vacuum at the condenser did not exceed 56.4 centimetres (22.2 inches) of mercury, the power produced amounted to 198 electric horsepower.

It will be observed in the diagram, that the pressure, in the accumulator oscillates between 0 (atmospheric pressure) and 0.40 kilogramme per square centimetre or 5.7 pounds per square inch at which point the exhaust-valve opened into the atmosphere. Therefore, the accumulator would suffice to supply the turbine if this maximum variation of 0.40 kilogramme or 5.7 pounds in the pressure were deemed admissible. Yet this cannot be, for so marked a fluctuation is much too excessive, in comparison with that which had been laid down as best satisfying all the conditions of the problem.

Fig. 9 was taken under analogous conditions, though the winding-engine was working somewhat differently towards the end of the record. The period of a wind, instead of being only 1 ¼ minutes (as at the normal speed recorded in Fig. 8) now amounted to more than 1½ minutes. The accumulator was then no longer equal to the task of regularizing the flow of steam (5,000 kilogrammes or 11,000 pounds per hour) needed by the turbine; and the automatic feed-valve opened at E so as to draw upon the boilers, so soon as the accumulator had been emptied of steam. At each opening of the automatic feed-valve rises in pressure took place, indicated at EF in Fig. 9.

Fig. 10 indicates a load on the turbine equivalent to 115 horsepower, the inflow-pressure amounting only to 0.63 kilogramme per square centimetre or 9 pounds per square inch and the flow of steam to about 3,500 kilogrammes or 7,000 pounds per hour. The curve shows that the accumulator in this case works with tar greater ease, and that under such conditions it is quite adequate to supply the turbine even, if the wind-intervals last as long as 2 minutes. The vacuum in the condenser was then 57.2 centimetres (22.5 inches) of mercury.

Fig. 11 was taken at a moment when the turbine was only

* This flow was calculated by applying the results previously obtained from experiments in the factory to the conditions of pressure above cited.
producing 85 horsepower, with the same vacuum of 57.2 centimetres (22.5 inches) and with a higher pressure of 0.54 kilogramme or 7.7 pounds corresponding to an hourly flow of steam of 3,000 kilogrammes or 6,550 pounds. The accumulator this time is far more than adequate, and the lower pressure rises to 0.10 kilogramme or 1½ pounds above atmospheric pressure, the upper pressure being determined (as before) by the valve exhausting into the atmosphere, as it did at each wind.

Fig. 12 indicates an analogous consumption of the turbine, the higher pressure being equivalent to 0.60 kilogramme per square centimetre or 8.5 pounds per square inch, vacuum 52 centimetres or 20.5 inches of mercury, and power produced, 65 electric horsepower. It will be noticed that here again the live-steam feed-valve was not called upon to enter into play, although the valve exhausting into the free air had been so adjusted as to open at a pressure only 0.25 kilogramme or 3½ pounds higher than that of the atmosphere.* On the other hand, the valve admitting the live steam had been adjusted so as to let it in only at a pressure slightly less than that of the atmosphere, and this explains the lowering of the minima of the curve below zero.

In all these diagrams a peculiarly rapid rise of the pressure is noticeable at the time when the winding-engine begins to work. In concert with the colliery-engineers the writer, in planning the accumulator, had calculated that the winding-engine would eject steam during about ½ minute (duration of movement of the cages); while in reality, as the graphic record proves, this exhaust only lasts over 15 to 18 seconds. Consequently, the speed at which the steam reached the accumulator was far greater than could have been foreseen, and the apparatus proving rather inadequate, it was found necessary to load the valve which exhausts into the free air, so as to ensure a rise or back-pressure of 0.40 kilogramme or 5.7 pounds per square inch above the atmospheric pressure, instead of the 0.25 or 0.30 kilogramme (3.6 to 4.3 pounds) which had been provided for. It would suffice, however, to add

* The exhaust-valve still allowed a great quantity of steam to escape into the atmosphere, even when the turbine was taking up nearly 5,000 kilogrammes or 11,000 pounds of steam per hour supplied solely by the accumulator, while the automatic steam-trap of the last named was ejecting 1,000 kilogrammes or 2,200 pounds per hour. Hence it may be inferred that the total consumption of an engine like that at Bruay is at normal speed much more than 6,000 kilogrammes or 13,200 pounds per hour.

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to the apparatus a fourth unit, which should comprize about 10 tons of cast-iron, in order to reduce the back-pressure to the desired amount.

These same diagrams show also that, after each interruption of the inflow of steam into the accumulator, there is at first very rapid and then a slower, diminution of pressure. Such variations in the rate of vaporization are evidently due to the fact that the whole mass of cast-iron and water contained in the apparatus does not immediately assume an equilibrium of temperature with the steam. The heat, of course, takes a certain time to penetrate fully into the body of the metal, and the delay thus involved produces a rise and then a fall in pressure,
both far more rapid than if a temperature-equilibrium could be set up immediately. It is, however, easy to ascertain by calculation that the greater part of the metal and of the water contained in the basins plays in fact the part of a heat-accumulator.

Figs. 8 and 9 represent, on the whole, the normal working of the turbine, since this had been designed for a higher pressure of 0.90 kilogramme or 12.8 pounds absolute. If the whole system then produced only 200 instead of the 300 horsepower which it is capable of producing, this was entirely due to the unsatisfactory vacuum yielded by the condenser, which only reached 56.4 centimetres (22.2 inches) of mercury, instead of the 65 centimetres (25.6 inches) which had been reckoned with. For with 65 centimetres (25.6 inches) the expected 300 horsepower could certainly be obtained, as the factory experiments prove—whereof an account is appended at the end of this paper.

It may be mentioned also that the variations of the speed of the engine are of greater amplitude than will be admissible in another installation, as here they amount to about 3 per cent. This variation in speed results partly, it is true, from the irregularity of the work which the turbine is called upon to perform. It is evidently due also to the variations of pressure in the accumulator above the turbine. As the pressure oscillates at each interval, that is, about every minute, between 1 and 1.40 kilogrammes or 14 and 20 pounds absolute, we are confronted with much the same result as if the work exacted from the turbine varied from minute to minute by about 30 per cent. As, however, this variation is not excessively rapid, since the rise and fall in pressure each take more than ¼ minute to come about, a fairly sensitive governor has certainly all the time been needed to prevent the speed from varying by more than 2 or even 1 per cent. When the accumulator shall have been supplemented by a third section, and when the difference in pressure becomes only 0.30 instead of 0.40 kilogramme (or 4.3 and 5.7 pounds) the fluctuations in speed of the turbine will be considerably diminished.

It should be added that at No. 5 pit at Bruay, which (as previously stated) has been working for a comparatively short time, the winding-engine on the shaft where the writer’s apparatus has been erected is not yet worked up to its normal capacity, since it winds only 700 or 800 tons instead of the 1,200 tons for which it was designed. It follows that, for the moment, the emission of steam is not altogether regular, and the automatic live-steam valve on the turbine calls more frequently and during comparatively longer periods upon the boilers for a supply than would be the case in an older-established colliery. But this state of things will quickly change for the better, pari passu with the development of the workings.

To sum up: despite the not very favourable conditions under which, the writer’s first steam-accumulator must needs work, it has already proved, and proves daily, that the practical and economical utilization of intermittently ejected steam is a problem that has now been solved. At Bruay colliery, the improvement in the vacuum yielded by the condenser and an increase in the bulk of the heat-accumulator will in the very near future ensure the full advantage that may be expected from this first application. A fortiori will this hold good of new installations, for most collieries, from the standpoint which we are occupying, work under far more favourable conditions than No. 5 pit of the Bruay collieries. In steelworks, the circumstances should prove still more favourable.
The writer has thought that it might be of interest to summarize in the appended note a description of the low-pressure turbine and the experimental results obtained at the factory. These results were recorded partly by himself, and partly by Mr. Sauvage and Mr. Picou, in the presence of the engineers of Bruay colliery.

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In conclusion, he wishes to express his thanks, first of all to the board of directors of the Bruay colliery and more especially to Mr. Soubeiran (who was confident as to the practical value of the writer's ideas): secondly, to the engineers of Bruay colliery who took every care in erecting the various portions of this new installation.

APPENDIX.— Results or the Experiments carried out in April, 1902 on the Low-pressure Turbine for Bruay Colliery, in the Workshops of Messrs. Sautter-Harle & Cie.

The Bruay turbine, designed and constructed in the workshops of Messrs Sautter-Harle & Cie, is a multicellular turbine comprising a series of wheels 88 centimetres (34.65 inches) in diameter, adjusted upon one and the same horizontal shaft. These rotate, according to the arrangements that characterize the writer's system, between diaphragms, which are fixed within the cylinder of the engine, and on the periphery of which the distributors are set. The whole thus constitute a consecutive series of turbines with partial injection, which the steam traverses parallel and concentrically to the axis, passing alternately from a crown or ring of fixed blades to a wheel or ring of moving blades, and from this last to the next following distributor.

The working being effected by impulsion, the expansion of the steam takes place only in the successive distributors, while the fluid acts on the moving blades by its vis viva. Therefore, each moving wheel rotates within a medium of uniform pressure which allows of considerable play between the blades and the adjacent fixed parts (3 to 5 millimetres, or 0.12 to 0.20 inch). The radial section of the blades and in particular the section of the various distributors increase the farther outward flow of steam and afford continuously wider passage to the fluid in proportion as its pressure and density diminish. The maintenance of a constant speed for variable loads is ensured by means of a ball-governor, which adjusts the higher pressure of the steam supplied to the engine to the power required. This governor is provided with a Denis compensator, which is designed to maintain the speed permanently at a fixed rate. Moreover, the speed may be modified at will between 1,500 and 2,000 revolutions a minute, thanks to a spring the tension of which can be varied by hand. Moreover, an automatic valve is adjusted, so as to admit into the turbine live steam coming direct from the boiler in case the supply of exhaust-steam proves inadequate.

Two continuous-current dynamos, supplying a triplex-wire 500 volts system, are mounted on the same shaft, directly coupled to that of the turbine. They are two-pole dynamos, but are also provided with two supplementary poles so that there may be commutation at the brushes without throwing these out of gear. The induction-coils, series-wound, can each furnish a current of 400 to 400 amperes at a tension of 250 volts.

Fig. 1 is a general view of the machinery, reproduced from a photograph. [Page 169.]

The experiments conducted with this turbine lasted in each case about 20 minutes, and allowed of 8 series of observations every 3 minutes. The average mean results are embodied in Table 1.
In all the experiments, steam was superheated from 40° to 50° Cent. (104° to 122° Fahr.), in view of the expansion, which it would at first have to undergo in order to be brought down from the pressure at the boilers to a pressure barely equivalent to that of the atmosphere. But the results contained in Table I. have been so calculated as to take this superheating into account, and they must be sensibly equivalent to those obtained when working with saturated steam which is the ordinary course in practice at Bruay collieries.

It will be seen that the consumption of steam per electric horsepower-hour at full load amounts to about 18 kilogrammes (40 pounds) at 1,600 revolutions per minute, but only to 17 kilogrammes (37 ½ pounds) at 1,800 revolutions and that with a bad vacuum of only 63 centimetres (24.8 inches) of mercury. If the vacuum had attained 70 centimetres (27.6 inches), which is quite practicable with a good condenser, the above-stated rates of consumption would have been reduced by about 26 per cent., falling consequently to 13 and 12 kilogrammes (28 ½ and 26 ½ pounds) respectively.

The efficiency at 1,600 revolutions, at full load, of turbine and dynamo taken together, amount to 55 per cent., and at 1,800 revolutions it rose to 58 per cent. The structural conditions involved in the fact that the dynamos had been designed to run at a speed never exceeding 1,800 revolutions per minute, alone prevented the writer from increasing the experimental speed. Nevertheless the diagram which it is possible to plot out from the foregoing results in functions of the speed, allows us to estimate that at 2,500 revolutions per minute an efficiency of 64 per cent. would be obtainable.* In fact, this has been obtained since then, from a similar group of machinery, but of twice the power, and supplied with high-pressure steam. Fig. 13 (Plate IX.) shows the curve of efficiencies in functions of the speed.

Fig. 14 (Plate IX.) shows the curves of efficiencies at two different speeds in functions of the load, that is, of the electric power produced at the dynamos. It will be observed that the efficiency becomes considerable at one-third load, and on the other hand remains practically unchanged from half-load upwards.

Finally, Fig. 15 (Plate IX.) illustrates the total consumption of steam in functions of the load. It shows clearly that the total consumption at zero load, the electric apparatus being excited, does not exceed 12 per cent. of what it is at full load. With other groups of turbines and dynamos, the writer has known it to fall to 10 per cent. This peculiarity of turbines is worthy of note, for it is known that electrogenerative groups, comprizing piston-engines, consume generally when running at zero load about 20 per cent. of their total consumption at full load.

The Hon. C. A. Parsons (Newcastle-upon-Tyne) wrote that the members were much indebted to Prof. Rateau for bringing this matter prominently before them, as there were, undoubtedly,
many cases where such a system would probably lead to a great saving in the consumption of coal, and a reduction in the number of boilers required.

* It is possible then to design when needed, low-pressure plant which shall have an efficiency of 64 per cent. This, between a steam-pressure equivalent to that of the atmosphere and a vacuum-pressure of 0.08 kilogramme or 1 pound, corresponding to a good vacuum of 70 centimetres (27.6 inches of mercury), would show a consumption of only 11 kilogrammes (24 pounds) of saturated steam per electric horsepower-hour, excitation included.

[Plate VII.—Figs. 1-5, showing plans of the turbine and accumulator.]

[Plate IX.—Figs. 1-15, showing graphs of pressures, etc. during the experiments.]

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It might be interesting to add a short, and perhaps incomplete, history of the initiation and application of the fundamental principle. The first suggestion of the storage of energy by condensing and re-evaporating the water in a chamber, well lagged with non-conducting material, was probably to be found in connection with the hot-water locomotive. Such a system was prosed for the motive power on the Metropolitan Railway in London many years ago. Then there are (previously or subsequently) Mr. Smith Halpin's patents, No. 20,203 of 1891, and No. 363 of 1892, describing and claiming the same principle of the storage of energy in water in conjunction with steam-boilers generally, for dealing economically with a varying load and in particular with reference to electric-lighting generating-stations. Prof. Rateau, in his interesting paper, proposes to utilise this principle by the storage of energy at or about atmospheric pressure. The formation of his storage-vessel differs somewhat from previous designs, in placing the heating element—the hot water—in shallow trays. The advantage of such an arrangement over that previously adopted, of blowing the steam below the surface of the water, would seem doubtful: in both cases, the result desired was easy condensation, and the tray system appeared to be the more complex of the two. In both cases, the re-evaporation takes place with facility.

The first suggestion, as far as he (Mr. Parsons) was aware, of utilizing the reciprocating engine for the expansion of steam from boiler-pressure, down to a moderate pressure—such as the atmospheric pressure—and completing the expansion in a steam-turbine, occurred in his (Mr. Parsons') patent, No. 367 of 1894:—“The method of obtaining work from expanding steam by combining together a reciprocating-engine and a steam-turbine, the turbine being operated wholly or partially by the exhaust-steam from the reciprocating-engine;” and that patent described many uses for the low-pressure turbine, one of which was for electric lighting.

Prof. Rateau wrote, thanking the Hon. C. A. Parsons for the support which he had kindly accorded to his communication, and expressed his delight at availing himself of the opportunity thus offered to express his due sense of the remarkable ingenuity and high value of Mr. Parsons's various inventions, as also his

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appreciation of the originality of the process suggested by Mr. Smith Halpin in 1893, for accumulating heat in central electric generating-stations. But he (Mr. Rateau) was desirous of removing any misunderstanding that might possibly arise in regard to his own invention, which was absolutely independent of the ideas put forward by Mr. Parsons and Mr. Halpin. He (Mr. Rateau) had in his paper referred to the arrangement described by Mr. Parsons, which consisted in using a low-pressure turbine in place of the last cylinder of a continuously-running piston-engine, so as more fully to utilize the expansion of the steam.* In this arrangement, the turbine and the piston-engine are placed in the most intimate association. They form a whole, the parts of which are completely interdependent, and could not therefore work if the primary piston-engine were to run as irregularly as, say, the winding-engine placed on a pit. By his (Prof. Rateau's) system, however, thanks to the steam-accumulator on the one hand, and to the automatic valve on the other, the primary-engine and the turbine are mutually independent. Each can work separately, without influencing in the slightest degree the working of the other.

The Halpin process consists in accumulating, in hot-water reservoirs, the heat of the excess-steam coming from the boilers at an electric lighting-station during periods of light load, and then in regenerating this excess in the evening when the machinery is running at full load. It constitutes neither more nor less than an indirect means of increasing the total volume of water contained in a set of boilers, and forming a calorific accumulator. These reservoirs, being interposed between the boilers and the high-pressure engines, are evidently not adapted to fulfil his (Prof. Rateau's) object, that of utilizing the exhaust-steam of intermittently-running engines. Mr. Parsons, however, appears to consider that this same apparatus, if interposed between an intermittent high-pressure engine and a low-pressure one, would fulfil all the purposes of his (Prof. Rateau's) accumulator, and that perhaps still more simply. An adaptation of this kind is indeed not impracticable, but it implies essential modifications, as demonstrated in a later arrangement with which he had devised. Steam cannot be regenerated so easily within a compact mass of water as within relatively thin films of liquid spread


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over a great surface; and this applies not so much to the moment at which the steam is reconstituted as to that at which it is condensed. At the period of condensation, the mass forming a heat-accumulator must be made to absorb within a very short space of time (usually 15 to 30 seconds) a vast quantity of calories. This operation cannot be performed efficiently, unless the aforesaid mass is divided into comparatively thin layers; or unless very active circulation of the liquid is ensured, in such wise that the steam shall enter into direct contact with every part of it. The Halpin apparatus, designed for very slow progressive condensation, would certainly not permit of the almost instantaneous condensation of an abundant flow of steam, such as that necessitated by intermittent engines. It does not, therefore, seem to be applicable in practice to the special case which he (Prof. Rateau) has in view.
The PRESIDENT (Sir Lindsay Wood, Bart.) moved a vote of thanks to Prof. Rateau for his valuable contribution to the Transactions.

Mr. C. C. LEACH seconded the resolution, which was cordially approved.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

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GENERAL MEETING.
Held in the Wood Memorial Hall, Newcastle-upon-Tyne,
February 14th, 1903.
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Sir LINDSAY WOOD, Bart., President, in the Chair.
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The Secretary read the minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on January 31st and that day.

The following gentlemen were elected, having been previously nominated: —

Members—
Mr. Herbert Ainsworth, Mining Engineer, P.O. Box 1553, Johannesburg, Transvaal.
Mr. James Thom Beard, Civil and Mining Engineer, 640, Clay Avenue, Scranton, Pennsylvania, United States of America.
Mr. Walter Richard Highton Chappel, Mining Engineer, Batu Gajah, Perak, Straits Settlements.
Mr. Ralph Clough, Mining Engineer, Kilton Mines, Brotton, R.S.O., Yorkshire.
Mr. James Mill Crawford, Colliery Manager, Shildon House, Shildon, County Durham.
Mr. William Stephen Davies, Colliery Manager, The Poplars, Mountain Ash.
Mr. Richard Percival Forster, Mechanical Engineer, Mount Pleasant, Spennymoor, R.S.O., County Durham.
Dr. Clement Le Neve Foster, Professor of Mining, Royal College of Science, South Kensington, London, S.W.

Mr. George Charles Fox, Consulting Mechanical Engineer, P.O. Box 1961, Johannesburg, Transvaal.
Mr. Charles George Henzell, Engineer, Catcleugh, Otterburn, R. S. O., Northumberland.

Mr. Frederic Octavius Kirkup, Colliery Manager, Langley Park, Durham.
Mr. Graham Campbell Lathbury, Assistant Colliery Manager, East Indian Railway Collieries, Giridih, E.I.R., Bengal, India.

Mr. Francis Douglas Osborne, Mine-manager, Gopeng, Perak, Federated Malay States.

Mr. John Ridley Ritson, Mining Engineer, Burnhope Colliery, near Lanchester, County Durham.

Mr. Thomas Trowell, Mechanical Engineer, 17, Acutt's Arcade, Durban, Natal, South Africa.

Mr. Thomas Welsh, Colliery Manager, Woodhouse, Whitehaven.

Mr. Thomas Outterson Wood, Mining Engineer, Harraton Colliery, Washington, R. S. O., County Durham.

Associate Member—
Mr. Percy Copeland Morris, 79, Elm Park Gardens, London, S. W.; and 1, Garden Court, Temple, London, E.C.

Associates —
Mr. Edward Stokoe Clough, Assistant Surveyor, Bomarsund House, Bomarsund, Bedlington, R.S.O., Northumberland.

Mr. Joseph Hodgson, Under-manager, West Thornley Colliery, Tow-Law, R.S.O., County Durham.

Mr. Henry Marshall Imrie, Overman, Western Hill, Durham.

Mr. John Charlton Pearson, Back-overman, Montagu Colliery, East Denton, Scotswood, R.S.O., Newcastle-upon-Tyne.

Mr. Thomas Urwin, Deputy-overman, Dipton Colliery, Lintz Green, R.S.O., County Durham.

Students—
Mr. Ernest Humble, Mining Student, Shotton Colliery, Castle Eden, R.S.O., County Durham.

Mr. George Heron Dinsdale Thompson, Mining Student, Dinsdale Vale, Windsor Avenue, Waterloo, Blyth.

Subscriber—
The Most Honourable the Marquess of Bute, Bute Estate Office, Aberdare., South Wales.

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DISCUSSION OF MR. W. C. BLACKETT'S PAPER ON AN "IMPROVED OFFTAKE-SOCKET FOR COUPLING AND UNCOUPLING HAULING-ROPES."

Mr. F. Coulson asked whether there was any chance of the space within the sockets of the coupling being filled with dirt. The principal advantage of the coupling seemed to be quickness-of detaching and attaching; but it occurred to him that there


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might be a possibility of the connecting-piece or link coming out in the case of a slack rope, and more especially when the rope was twisted.

Mr. W. C. Blackett said that in trials of the socket no trouble had been experienced in the direction indicated. It did not pick more dirt than any other socketting arrangement; and, in fact it would pick up less, as it was much smaller. The link could not slip out unless the two sockets were placed at right angles one to the other, and this was a position which was never assumed in an ordinary way. The first samples were made too weak, and it had been necessary to increase the dimensions and to harden the bulb of the link. The sockets were made of manganese-steel, and it might be of interest to mention that although this metal was extremely hard, it should not be heated to redness. Some men, for instance, were in the habit of removing wheels from their axles by means of heating, but if wheels of manganese-steel were heated to redness, they became short, and brittle, and the steel was spoiled.

DISCUSSION OF MR. ROBERT MARTIN'S PAPER ON "SINKING ON THE SEASHORE AT MUSSELBURGH."*

Mr. F. Coulson said that the system adopted by Mr. Martin appeared to be an ordinary "sinking-wall," protected by a casing of steel-plates on the outside, and the cost would probably be much greater than to use a "sinking-wall" in the ordinary way--bolting it together and using cast-iron rings. The use of the outer steel frame would prevent the wall from separating while going down. He thought that it was somewhat risky to sink the full size from the surface, and starting with an external diameter of 18 feet and a wall, 2 feet thick, the diameter of the Pit was only 14 feet. If the wall stuck, as it did at 48 feet (though it moved again by putting on an increased weight) and stopped there, the pit could not have regained its diameter except by cutting off a certain depth of brickwork, and that under certain circumstances might not have been possible.

He thought that it would have probably been desirable to have used a walling of a less thickness than 2 feet in that


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particular kind of ground, when the sinking was dry for a depth of 30 feet. An important matter had been mentioned in the previous discussion, as to the relative value of cast-iron or steel for resisting the action of salt-water. He thought it would be generally admitted that cast-iron was better than steel, and he imagined that if cast-iron was always under water, as it would be at Musselburgh, there would not be much risk of corrosion. Experiments had recently been made as to the use of cast-iron in docks, and it was found that cast-iron, left in the bottom of the dock and always covered with salt-water, was apparently uninjured; but cast-iron that was exposed to the air at every tide was very much corroded, and its strength was almost wholly destroyed. He noticed that the cylinder varied 18 inches from the vertical, so that the pit would be 12 ½ feet in diameter, unless some of the brickwork was cut out of the inside walling. The method of walling below the pumps was very interesting: short lengths of walling (9 to 12 feet) were put in. A system was largely adopted on the Continent, of hanging cribs and using concrete, instead of putting in timber to secure the sides, as it was difficult to wall
past the pumps, and it was not always possible to build short lengths of walling owing to the nature of the ground. The barrels of the Evans pumps were brass-lined, but Mr. Martin did not state definitely what had been found to be the best kind of bucket for the pumps.

Mr. J. B. Atkinson (H.M. Inspector of Mines) said that the sinking, at Olive Bank, had been a successful operation, and the only difficulties experienced had been with regard to the brickwork and the enclosing cylinder getting slightly out of the vertical. Also, when the cylinder was nearly on to the rock, they ceased adding the steel-rings and depended only on the brickwork, which was caught and held by woodwork at the surface: the steel-cylinders and enclosed brickwork continued travelling downward, leaving the unenclosed brickwork hanging at the surface. In another sinking, near Larbert, where there were many feet of alluvium, the pit was started by forcing steel-sheaths down the sides, but was not successful; cast-iron cylinders were next tried, and that also was not successful. Then steel-cylinders were adopted, following the plan adopted at Olive Bank, but after they sank down to a certain depth, they became fixed owing to the occurrence of boulders; and eventually the shaft was enclosed, and sunk with compressed air. He thought in both cases, and certainly in the case near Larbert, that the freezing process would have been more successful. The risk was certainly less, but without details of costs, it would be difficult to decide which would be the best system to adopt.

Mr. A. L. Steavenson said that he would like to make a protest against the use of steam-engines and pumps in sinking pits: there was little enough room for the rods and pumps, without introducing steam-pipes. He was not surprised to learn that, owing to the limited area of the shaft, and the number of pipes, it was found impracticable to sink and wall the shaft simultaneously. There had been some very extensive sinkings in South Yorkshire with steam-engines and steam-pipes in the shafts: of course, the pit was sunk in time, but the period would have been reduced if the engines had been placed on the surface and the ordinary pumping-rods had been placed in the pit. Steam-pumps in a shaft were a source of considerable danger, and also of inconvenience. He agreed that cast-iron was more suitable as a lining than steel. The system of forcing down a weighted cylinder was by no means new; it was tried 25 years ago in Cleveland, but it was found that it would deviate on one side, and it had to be pulled out.

Mr. T. E. Forster said that he agreed with what Mr. Atkinson had said about the freezing process, but when it came to a question of cost they could not tell in starting the sinking with cylinders what the cost was likely to be, and there were very few sinkings by this method that had not gone to one side and had to be pulled out. On the other hand, it was easy to form an idea of the cost of the freezing process, and there were contractors who would tender a price for carrying out the whole work.

Mr. F. Coulson said that he agreed with Mr. Steavenson, with reference to the use of steam-pumps in shafts; and the best pump for sinking was the old lift-pump, or pumps of that class. There was always much trouble with a hanging steam-pump: if water rose over it from any
cause it was necessary to lift it, and if water rose to a considerable height it was a very slow process to lower it down again.

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Mr. W. C. Blackett said it appeared to him that there was a proper place for both systems, depending on the depth of the sinking and the quantity of water to be expected. A shallow sinking would usually be put through with a steam-pump, while a deeper and more important shaft it might be better to use rod worked by an engine on the surface.

The President (Sir Lindsay Wood, Bart.) thought that at the depth referred to, only 100 feet, it would have been much cheaper to have sunk through the strata by the freezing method. With the method adopted there was always a great risk of not being able to press down the cylinder on account of boulders, and when once it stuck, they could not tell what the cost of the sinking would be.

Mr. Robert Martin, replying to the discussion, wrote that Mr. F. Coulson refers to the use of the steel-cylinder. At Olive Bank, it was used principally to reduce the skin-friction, and no doubt it held the brickwork together until it had time to set. He quite agreed with Mr. Coulson that it would be less risky, when sinking a cylinder through a soft deposit, 108 feet thick, to sink it in two or three divisions in telescopic fashion. This would almost certainly ensure a truly vertical pit. This method was considered and abandoned, because the result of a previous trial afforded a very good idea of the nature of the ground to be penetrated, and it was thought advisable to risk the running of the cylinder in one length, a course which was justified by the result. The cylinders deviated only 18 inches from the vertical, and this can be corrected by cutting and carving the brickwork upwards from the foot.

Sinking and walling, at the same time, may be possible in some circumstances, but risks must always be incurred in removing the cribbing and exposing a portion of soft ground; and it will continue to be dangerous, until the brickwalling becomes set and is strong enough to sustain the pressure against it.

For sinking pumps, indiarubber buckets were found to be the best; in clean water gunmetal cups or angular rings were preferred; and in every case the working-barrel should be lined with brass.

The trouble described by Mr. J. B. Atkinson would have been avoided, if the steel-cylinders had been made the whole depth of

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The deposit, 108 feet instead of 80 feet. The wooden shaft, in the boulder-clay, was intended to form a sort of guiding frame for the steel-cylinder, but owing to irregular subsidence, the frame became twisted and the upper portion of the cylinder was not built, until the cylinder, 81 feet long, rested on the bed-rock. A cylinder, 110 feet long, would have been more economical than the one used.

He could not agree with Mr. A. L. Steavenson that an engine placed on the surface and working ordinary rods in the pit would be safer and more convenient; and until the cylinder
was sunk on to the rock-bed, it was impossible to erect any machinery on the surface. The temporary wooden frame, carrying the winding-pulley, sank and was raised daily, from 4 to 12 inches, until the surface-subsidence ceased. To pump, say, 1,000 gallons per minute from a shaft-bottom (and that is only a moderate quantity with ordinary pump-rods) would require a bucket, at least 30 inches in diameter, with a stroke of 8 feet going over 5 strokes per minute; a good deal of air must be pumped if the bottom is to be kept dry. In an ordinary shaft, there might be room for two such pumps. One pump alone is useless, as it is drowned in a few minutes, after a stoppage for repairs. He presumed that about 200 to 250 feet is the extreme limit that could be dealt with in one lift of such a bucket-pump; and when that point was reached what was to be adopted in a shaft that must reach a depth of 1,000 feet? To travel and secure for safe working two such columns of pumps would be a very difficult task; and it would be interesting to know whether it had ever been attempted. With three Evans steam-pumps (12 inches in diameter) in each shaft, a depth of 800 feet has been attained at Olive Bank; stationary pumps are placed in an offset to raise the feeders found at that depth; and sinking is again resumed, and in three stages a pit is sunk to a depth of 1,000 feet. The handling of a steam-pump means dealing with a load of only 4 or 5 tons, and, in the use of steam at a pressure of 100 pounds per square inch, so far as his experience had gone, it could not be said to be either dangerous or inconvenient.

He thought that Sir Lindsay Wood seemed to favour the freezing method. It would have been almost impossible to put bore-holes through the large boulders encountered in this sinking. The freezing tubes are passed, he understood, down through a large number of bore-holes to the necessary depth. The cost off boring alone, he feared, would be very great. The boulders had not been very troublesome, and they were removed, in every instance, before the cutting-edge of the steel-cylinder reached them. He considered that, where the workmen could stand on the bottom, even though boards are required for footing, and where the influx of water could be pumped, the freezing process was unnecessary and would prove more costly.

Mr. S. J. Pollitzer (Sydney, New South Wales) wrote that some 16 or 17 years ago, under his direction, a similar shaft was sunk at Maryville colliery, Newcastle, New South Wales. After these many years he (Mr. Pollitzer) could not exactly remember every detail about the sinking; its salient features, however, were quite fresh in his mind. In this shaft, no iron casing was used, not even an iron bottom-ring or shoe. This latter was replaced by a wooden one, made of the hardest timber that could be got, consisting of four circular rings, each 3 inches thick, well bolted and secured together: and the inside was bevelled, so as to be of conical shape, with a sharp, yet solid, cutting edge. The actual internal diameter had lapsed from the writer's memory, whether it was 14 feet, or more or less, he could not say. This ring had a width of 19 inches, allowing for a thickness of 18 inches of brick-wall laid in cement. Through the centre of this circular wooden ring or shoe, there went six vertical tie-bolts, 10 or 12 feet long, and these were embedded in the brickwalling for nearly their whole height, excepting 6 inches at the top, left projecting to receive an additional wooden ring of that thickness, and to be secured to the top of the brickwork by these tie-bolts. Before this second ring was tied down, another series of 6 tie-bolts was inserted into this new ring, for the purpose of repeating the operation, which was carried out for the whole depth of the shaft, about 135 feet, the thickness of the
drift-sand to be sunk through before reaching the Carboniferous sandstone (upon which the shaft rested) and the sandstone had a thickness here of about 45 feet before the coal-seam was reached. The external surface of this monolithic brick-cylinder was covered with a layer of cement, for the double purpose of making the cylinder water-tight and to obtain for it a perfectly smooth surface, which, perhaps, should not have a greater frictional resistance than iron. Excepting for

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A top layer of about 15 inches of vegetable soil, all the strata, as stated, above were sand, followed by watery drift-sand. After the removal of the few inches of soil, the bottom shoe was placed on the sand, and two sections of tie-bolts bricked up; then the removal of the sand began, first by hand, and subsequently as the depth became greater, by an endless bucket-pump driven by steam. As the excavation deepened, the brick-cylinder sank regularly day by day: the bricking and sinking were then a simultaneous process, and there was never any external weight applied to the top of the cylinder to force it down, as its own weight was sufficient for that purpose. The whole operation of sinking to the depth of 135 feet took about 4 months, and when the cylinder was once sitting on the bed-rock it was found to be practically perpendicular. This colliery was worked for 8 or 9 years when, as the writer was informed, a sudden inrush of water from some adjoining abandoned mine flooded it, and it also was abandoned. In his (Mr. Pollitzer's) opinion, if Mr. Martin had not made a square pit through the boulder-clay for a depth of 32 feet from the surface, he would have avoided many of the difficulties that he (Mr. Martin) had to contend with in sinking his shaft at Olive Bank, and he (Mr. Pollitzer) also believed that the shaft would have been perpendicular.

Mr. Thomas Adamson's paper on "Working a Thick Coal-seam in Bengal, India," was read as follows: —

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WORKING A THICK COAL-SEAM IN BENGAL, INDIA.

By THOMAS ADAMSON.

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System of Working.—The seam worked at the Komaljore mine of the East Indian Railway Company's Serampore colliery at Giridih, is 21 feet thick, the roof is of hard stone, and the thickness of cover over the seam ranges from 100 to 160 feet. A section of the strata, from the surface downward (Fig. 1, Plate I.), is as follows: —

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<td>2</td>
<td>Sandstone</td>
<td>70 0</td>
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<td>3</td>
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Fig. 2 (Plate I.) is a plan of the mine, and the area, AB, is that of a goaf-fall. The system of working the coal, which has been the most successful employed in getting this thick seam, is a modification of the pillar system. Roadways are driven from the shaft to the boundary, and sides of work are then opened out. Large blocks (square or rectangular) are formed next the boundary, these are again split up into pillars, 40 feet square, and these are taken out, working from the boundary towards the shaft (Fig. 3, Plate I.). The roads forming these pillars are driven in the lower part of the seam, and are 6 feet in height by 8 feet m width. The upper portion of the seam (15 feet thick) is worked as follows: ——The pillar (40 feet square) is split, by driving four roads, 6 feet wide by 6 feet high, across it, thus forming nine knobs (Fig. 3, Plate I.) to support the top coal. Small headings,

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one above the other (called chatnies by the natives) are driven (Figs. 4 and 5, Plate I.) so as to facilitate the falling of the top coal, when the knobs are blasted out. In the first dropping operation, these narrow headings (chatnies) are driven on the four sides of the block of coal which is to be dropped. But, afterwards, the headings are driven only on two or three sides, the goaf forming the other loose side or sides, as they are called by the Staffordshire overmen.

Fig. 3 (Plate I.) shews a side of work, the pillars (40 feet square) that are formed being taken out in steps. Eight pillars have been removed, and two pillars have been split and are standing on knobs. Fig. 4 is a vertical section shewing the top coal standing on knobs, and the nicking headings (chatnies) driven in the top part of the seam.

Two shot-holes, a and b, are drilled in each knob, the dimensions of the knobs are then reduced to 5 feet or 6 feet square, the size of the knobs depending on the indication of the weight of roof upon them. When the areas of the knobs have been sufficiently reduced, the shot-holes are charged with dynamite, and fuses placed to the charges. All timber is then drawn out, commencing next the goaf. The props are knocked out by means of a bunter, a bamboo rod, 2 inches in diameter, 12 to 20 feet long, and shod with iron (Fig. 7, Plate I.); and then pulled back by the pricker, a bamboo rod, 2 inches in diameter, 15 to 20 feet long, and fitted with a hook at one end (Fig. 8, Plate I.).

When the timber has all been withdrawn, the overman listens to the goaf and for weight on the knobs; and if all be quiet, he, with 2 or 3 trained shot-firers, enters the place, lights the shots, and retires. The knobs are thus blown out, and the top coal falls. The operation of reducing the knobs, until the coal is dropped, is done under the supervision of European overmen at the end of the shift. When the coal has fallen, the place is fenced for the night.

The overman examines the openings (gateways) next morning, and if he finds all safe, orders the workpeople to load the loose coal. As soon as sufficient coal has been cleared away to enable men to get on to the top of the fallen coal, the overman makes a careful examination of the newly-exposed sandstone-roof.
In the lower workings, props are set at distances not exceeding 3 feet apart. When the roof or top coal is being loaded, cogs,

5 feet square, are set at intervals of 15 feet; and props (long rollas) 7 to 8 inches in diameter, are set between the cogs, at distance apart not exceeding 5 feet.

When one fall of coal is being loaded, one or more falls are being got ready, so that the loading-gangs are kept constantly at work, and the output maintained.

All the coal is removed in the first lift (when starting a side of work), 40 feet wide by 200 to 600 feet long. In the next lift knobs from 8 to 10 feet square, the full height of the seam (chowkidars, or watchmen, as the natives call them) are left. These are used to indicate when the main-roof begins to weight.

No gas has been found in any of the mines, where explosives are used in working the upper portion of the seams.

By this system of working, about 90 per cent. of the seam is wrought. Six per cent. is left in the tell-tales, D, (chowkidars) and about 4 per cent. in the thin ribs, left next the goaf when a fall takes place, and separating the old goaf from the new side of work, which is opened out against it.

Heavy Fall.—The chowkidars are left 40 feet apart, one in each fall, after the first lift has been removed. The roof usually gives ample warning, and allows time to the overman to draw the timber and remove the workmen from the mine. As a rule, several days elapse from the first indication of roof-weight until the goaf falls. During this period that part of the mine or district is stopped, owing to the heavy blasts which are caused by falls of main roof. Sometimes, however, the roof quickly follows the first indication of coming weight—as on May 20th, 1902, when the writer was making an inspection of the mine.

The writer entered the mine at 8 a.m. and, accompanied by Mr. S. Hancox, overman, he inspected the travelling-roads, haulage-road and working-places; and he had been busy for about 10 minutes, while the roof was sounded, below which loose coal was being loaded, when pieces of coal commenced to roll from the sides of the chowkidars (tell-tales) in the goaf. The writer took immediate precautions, and all people who were engaged in loading loose coal close by were removed out of the goaf, some leaving their picks and baskets behind in their haste. Mr. S. Hancox and the writer were the last to retire, and, as we were doing so, pieces of roof began to fall and the main roof began to "bump" heavily to such an extent that we considered it unsafe to send the people out of the mine, as in case of a heavy fall of roof taking-place, they would be caught, by the blast, on the travelling-road. The people were ordered to go and sit down in galleries where the force of the blast would least affect them. Mr Hancox and the writer took up a position about 100 feet from the goaf in a gallery, C, running at right angles to the direction which the blast would
take (Fig. 2, Plate I.). While we were there, main-roof bumps occurred at intervals of from 5 to 10 minutes, and in 50 minutes from the time that we arrived at this part of the mine, a bump took place that shook coal off the sides of pillars, 100 feet back from the goaf. We immediately lay down, as a heavy fall of main roof took place, and for 5 or 6 seconds the air rushed past us, taking with it clouds of dust, and moved several loaded tubs that were standing on the rails near the goaf. The place was still “uneasy,” and 15 minutes afterwards another fall took place, which caused a blast a little less violent than the first. Then, as all was quiet, we came to the conclusion that all the roof had fallen. We made an inspection around the edge of the goaf, and found that all the openings were filled with fallen roof. We ascertained that all the people were safe, but in darkness, as their lights and ours had been extinguished by the air-blast. The interval between the first indication of weight, and the collapse of the goaf was the shortest that the writer had ever known. The dimensions of the fallen goaf, AB (Fig. 2, Plate I.), were 230 feet by 220 feet, and there were 15 tell-tales (chowkidars) in it. The thickness of cover over the seam was about 100 feet, and the fall was visible on the surface, causing it to subside in places to a depth of 12 feet.

Costs.—The coal-getters are paid 4d. (4 annas) per bucket of 10 cwts. for undergoing and driving main galleries; 8d. (8 annas) per bucket for driving chatnies (nicking); and 2d. (2 annas) per bucket for filling the dropped coal, the latter forming 75 per cent. of the whole of the coal worked.

Mr. A. L. Steavenson said that the method of working described seemed to him very dangerous, and one which would not be allowed by H.M. inspectors of mines in this district. If the coal could not be all taken away with the first passage of long-

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wall, he would advocate taking it out at twice, and not leaving the little knobs to come down at random. It would be interesting to know whether the seam described was in the Coal-measures or in the Mountain Limestone.

Mr. T. E. Forster said that no reference was made to the average area, which was wrought out without a very heavy fall. Usually, in working thick seams it is very difficult to get the roof to fall, but in the case described in the paper when a fall came on the trouble seemed to stop it, and the pillars would be all crushed Certainly, 10 per cent. seemed a very small loss, and it would be interesting to elicit further information on that question. He had, himself, worked a seam in Australia about 12 feet thick with a strong post roof; and in taking out the pillars a heavy fall took place, which ran over about 60 acres of the workings in a very short time.

Mr. J. B. Atkinson (H.M. Inspector of Mines) said that in working a seam in Fifeshire, about 18 or 20 feet thick, it was usual to leave 2 or 8 feet of coal at the top and about 3 feet at the bottom—this was not very good coal. The method of working was not that described in the paper, which, he agreed with Mr. Steavenson, seemed to be a somewhat dangerous plan, but it was worked by longwall in two "carries;" up to 6 feet thick in the first carry,, and then in the same longwall roads it was brought back in the top coal, 4 or 5 feet thick. The method of working was very successful.
Mr. T. E. Forster said that there were several bands in the Fifeshire seam, and it had a very strong roof. On the other hand, it must be remembered in the case described, that they had coolies to do the work, and working longwall there was a very different matter from what it was in this country.

Mr. Richard Kirkby (Leven) wrote that it would be interesting if Mr. Adamson would state the character of the coal, whether it has any partings, or is at all laminated, and whether there is any fire-clay underlying the seam. Is there not even 1 inch of under-clay, or does the coal rest directly upon sandstone? Are there any signs of plant-remains in the beds above and below the seam?

It appeared to be a rather risky mode of working the seam, and yet evidently no other method could be successfully adopted unless there were material for stowing the waste. If there had been stone-partings, to the thickness of only 18 inches, in the seam, or if stone could be taken down the pit and into the working-faces, then the coal might have been worked by longwall in, say, four lifts.

In Fifeshire, the Dysart Main seam is worked longwall in two lifts where it totals 14 feet of workable coal to 1 foot of stone-partings. Fires, however, are troublesome, and another method is now being tried, in which the seam is being worked in four lifts, with a total thickness of 19 feet of coal and 3 feet of stone.

Where the Dysart Main seam is thinner, it is worked successfully without any waste, in two lifts, the thickness of coal being 9 feet and of stone and fire-clay, 1 ½ feet. The amount of prop-wood used is only 3 to 4 feet per ton of coal raised.

Would Mr. Adamson kindly state whether his seam was troubled with fires?

Mr. J. P. Kirkup (Burnhope Colliery) wrote that Mr. Adamson's paper upon the method adopted to work the thick seam at Giridih, afforded the members an insight into the great advance made in the methods of mining coal in India, The old rabbit-warren system (Figs. 1 and 2, Plate II.) had, at the collieries of the East Indian Railway Company, given place to proper systematic methods under the able control of Dr. Saise, who introduced the system described by Mr. Adamson about sixteen years ago. Mr. Adamson's paper indicated some modifications of the original method adopted and described some years ago. All galleries were then driven from 10 to 12 feet wide; and the size of the pillars was proportioned to the depth of the seam from the surface: thus, the pillars were made 40 feet square, at a depth of 200 feet; 40 feet by 60 feet, at a depth of 350 feet; and 80 feet square, at a depth of 450 feet.

The method of dropping the coal had been modified, he supposed, from experience gained in its application. Formerly, as described by Mr. Ward,* each pillar was split in the lower

* The Indian Engineer, 1887, vol. iii., page 146 and plate. Prior to the introduction of the new system, all galleries were commenced at the top, and the bottom was dug up until the thill was bared (Fig. 1, Plate II.). This Indian system, necessitated the levering or chipping of every pound of coal by means of the pick or sabol (a crow-bar pointed at both ends). The downward
working of the seam also added to the danger of the process of removing the pillars (Fig. 2, Plate II.); and, as in the galleries, all the coal was dug out with picks. The coal at the top of the pillar was cut away, and the natural support of the roof was removed at an early stage.

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can by a jenkin, A, driven in the middle and towards the goaf or waste; cross-cuts, B, B, were then driven; and at the side of the pillar, next the goaf, a thin piece of coal, C, was sometimes left to keep back the fallen roof-stone and debris (Figs. 3 and 4, Plate II.). The cross-cut, B, was then widened, until about half of the pillar, D, had been undergone, temporary timber being set to support the upper coal. As soon as signs of weight were evident, they were assisted by drawing as much timber as possible and shots were put into the fast side. After the fall (Fig 5 Plate II.) the coal was got from the goaf-edge as far as the roof-stone would allow. To be able to drop and recover 90 per cent of a pillar of coal, 40 feet square and 14 feet thick would require an unusually good roof-stone, which might exist in opening out a side of work before the first collapse, but hardly after a larger area of goaf had been made. The work would require very careful and skilled attention, and Mr. Adamson was to be congratulated upon his success with Indian labour. The costs for coal-getting were very interesting, when compared with those current in this country: an average hewing price of 5d. per ton for hard coal could hardly be excelled by the much bepraised cheap working in America. Moreover, the percentage of coal actually won from so thick a seam far exceeded the results obtained by the wasteful methods customary in America in working similar seams. He had often observed that the advantage of machinery was not always apparent in competition with Indian labour, and he doubted whether any economy could be gained by machine-cutting against the cheap labour of India. It would have been of interest if Mr. Adamson had told the members how the system of working affected the sample of coal.

The President (Sir Lindsay Wood) moved a vote of thanks to Mr. Adamson for his interesting paper.

Mr. G. May seconded the resolution, which was cordially approved.

Mr. S. I. Pollitzer's paper on "A Measuring-tape and its Use in Mine-surveying," was read as follows: —

[Plate II., to illustrate “Working of a thick coal seam.”]

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A MEASURING-TAPE, AND ITS USE IN MINE-SURVEYING.

By S. J. POLLITZER.

The writer's opinion, backed up by experience, is that the connection of a surface and an underground survey can be effected by two plumb-lines, just as accurately as by the use of
any optical instrument. Further, to make a comprehensive survey of a mine an horizontal projection alone is not all that is wanted; vertical sections are equally as important, and to be able to prepare these one must have the means of measuring correctly the relative heights of the various points in the mine. These are the reasons that induced the writer to construct a measuring-tape, 3,000 feet long, which he presumes is long enough for use in any mine in Australia.

The wire used for the purpose is a soft pliable steel-wire of No. 24 Birmingham wire-gauge, weighing about 2 ounces per 100 feet, and Prof. Warren, of Sydney University, states that this wire will stand a strain of 84 pounds. In the writer's own experiments, the wire stood a strain of 56 pounds, without showing the least sign of weakness or over-strain. To one end of the wire is attached an excellently-made detachable plummet of brass, weighing exactly 9 pounds, and it is made in such a manner that additional weights can be added to it without greatly disturbing either the wire or the plummet. A weight of 9 pounds was chosen, because, in experiments, (1) it was found that a weight of even less than 9 pounds would keep this wire in a perfectly vertical condition, but there must be no kink in it; and (2) when the wire is played out in a shaft for nearly its whole length, the maximum strain on the upper end of the wire must not exceed one-fourth of that found in above-mentioned experiment.

Based on the 9 pounds' weight, the wire was divided at each length of 10 feet under a 9 pounds' strain and with a noted temperature: the correct strain was obtained by means of a spring-balance that had previously been tested with ordinary standard weights; and for each succeeding length of 100 feet, 2 ounces were added to the original 9 pounds of strain. At the exact 10 feet division-points, small pieces of the same wire were twisted across them, and soldered to them with a drop of lead-solder; at that end of the twisted bit of wire, where an eye was formed piece of white calico, measuring 2 ½ inches by 1 ½ inches, was fastened, and on the calico was stitched in black wool the number of feet at that spot, and at every 50 and 100 feet mark the calico was replaced by red Turkey cloth, of course, provided with its respective number stitched in black wool. The pieces of calico and Turkey cloth were also used for covering up and enveloping the twisted wires, to which they were attached, so as to prevent them from scratching or otherwise damaging the rest of the wire when being wound up. The length of wire is wound upon a cedar wheel, 18 inches in diameter and 1 7/8 inches thick, with a groove in its periphery, 4 inches deep. The wheel when in use is attached to a strongly-made wooden trestle, which is permanently fixed to a purposely-made staging placed over the mouth of the shaft. The wheel can be stopped at any single inch throughout the depth of the shaft.

Where a joint had to be made in the wire caused by its being accidentally broken, or adding a fresh coil, the two ends were overlapped for a length of about 2 inches and lightly twisted over each other, so as to keep them fairly close together. Afterwards this joint was closely wound with thin brass-wire, which was extended to about ½ inch on either side of the single wire; and the entire joint was covered with a thin coating of lead-solder.

When the tape was finished, it was taken to the Sydney Land Office, and tested on the standard length of 100 feet. It was found that to bring each 100 feet wire within the two standard-marks, the same strain had to be exerted almost in every instance as that under which the particular part was constructed; and in those few instances where the strains did not agree, the differences were never greater than 2 ounces more or less.
Before the wire is brought into use, the surveyor selects two points in the roof of each level that is to be connected, and these two points forming the ends of the base-line in that level are marked by two steel-pins, 5 to 6 inches long and ¾ or 1 inch thick; these pins are permanently fixed in the roof, and have a small hole drilled in their centres. They should as much as possible be placed in such a position, that neither of them shall form an ill-conditioned triangle with each cage-shaft, and the distances between the pins are carefully measured.

After one of the cages has been disengaged and secured overhead, a temporary staging is erected over that shaft-mouth, upon which the trestle for the wire-wheel is nailed down; the staging should be of such a height that there shall be between it and the surface of the shaft a clear height of about 44 feet. Then the 9 pounds brass plummet is hooked on to the wire, both are lowered 3 or 4 feet, and kept in that position until the plummet is quite still and there is no perceptible movement in it; this is done with the object of preventing any swinging or knocking of the plummet against the sides of the shaft while it is being lowered. The plummet is then slowly and gently lowered by turning the wheel, until it reaches the shaft-bottom or the required level; before the plummet reaches that point, the shaft below must be covered with planks, and a bucket of oil placed upon it to receive the plummet.

After the plummet and wire have been brought to absolute rest, and after having laid down on the surface a similar base-line to those in the various levels, and connected the surface-base to the general surface-survey, the surveyor connects the wire with the base-line by the triangulation-method, by sighting from each point of the base-line on to the wire, and carefully ascertains the angles included between the wire and the base-line at each end. This process he begins on the surface, repeats it in each level in succession, and finishes at the shaft-bottom. The bucket of oil is then removed, and the plummet is left free for the purpose of measuring the heights; if the plummet swings more or less, it does not affect the vertical measurements.

To measure the heights or depths, the surveyor begins, in the reverse order, that is, at the bottom. With the assistance of an ordinary spirit-level, he draws a line across one of the vertical beams of the timbering, level with the lowest point of the plummet; and this line he marks permanently, as the benchmark for the lowest level. In the second cage, he then goes to the surface and reads the number of feet on the calico-mark next below the surface, and thence to the surface or to a similar bench-mark, as the one at the bottom, he can measure with a small hand-tape or any other measuring staff, and in this way the depth to the bottom is ascertained. The plummet is then gently wound up to the next higher level, into a position similar to that in which it was placed in the one below it, and the identical operation is repeated. In fact, this operation is repeated until all the levels have been treated in the same way, and the survey of the shaft is finished.
Next, the wire and the second cage change places, and the operation is repeated through the second shaft, except that the measuring of the heights is entirely omitted, as the measurements in the one shaft will serve.

In this way, the writer brings down an azimuthal line of definite co-ordinates in every level, which is a correct way of connecting the surface- and underground-surveys in vertical shafts. It has been stated that the triangulation of the wire from each end of the base-line begins when the wire is at complete rest. When is the wire at complete rest, and how is that to be ascertained? One answer is given in Mr. G. R. Thompson's paper on the subject; but in addition to that, the writer uses another check. While he is observing the wire from each end of the base-line, two assistants stretch a thin strong piece of white cotton diagonally across the shaft at different levels, leaving a few inches in height between each cotton-strip; one end, the further one, is fastened to a nail while the assistant holds the other end in his hands, strains it, and brings it quite close up to the wire, without, however, touching it. He holds it in this position while the surveyor is making his observation: the least movement in the wire will in this way be surely detected, and the instrumental observation is stopped until the wire is again at rest. Of course, the surveyor detects the lateral motion of the wire through his telescope, yet it is desirable to have two assistants, each stretching a piece of cotton.

In mines, where there is either an artificial or natural air-current so strong that the wire will not come to rest, the only way of stopping the air-current is by placing doors temporarily across the levels whence the current comes. Of course, this means a cessation of all work below, for the time being, which is justified by the importance of the survey-connection. The use of a brass plummet prevents all local magnetic attraction, and this latter will hardly ever be strong enough to deflect the steel-wire from the perpendicular, when such a plummet is hanging from it.

Some 15 months ago, the writer's services were requested on one of the largest gold-fields in the western part of New South Wales. On this mine, there are a score of shafts and many miles of levels and drives. At the 800 feet level of one shaft, there was a large quantity of ore in sight ready for treatment at the battery. The battery was close to another shaft, and there was no connection between the 800 feet levels of the two shafts, and between the two shafts there is a fairly deep creek. They are about 1,000 feet apart in a straight line, and are vertical. The question was where and how to make the shortest possible connection between the respective levels, which were by no means at the same horizon. The survey, which was carried out very much in the manner here described, and the requisite calculations, were finished within less than three weeks; and then it was pointed out to the manager that over one of the pins driven in the floor of one level he must make a perpendicular rise in the rock overhead of about 45 feet, and, by driving in the direction indicated by two pins in the roof of the other level for a distance of about 270 feet, the connection would be effected. The country-rock through which this connection was made is very hard diorite, and it took more than seven months to complete the connection. One morning, the writer received a letter from the manager congratulating him on the successful connection, and stating that the survey was perfectly correct in every detail.
Mr. Arnold Lupton (Leeds) wrote that Mr. S. J. Pollitzer's paper was interesting, as describing the actual practice of a surveyor in Australia, and the exceedingly small wire used by him for measuring the depth of a shaft. The attachment of the marking tapes to the wire would, however, be apt to cause vibration in cases where there was a strong current of air in the shaft.

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Mr. Pollitzer appeared to use two shafts in connecting his surface and underground lines. It was not always easy to secure the use of two shafts, and where one shaft only was available the distance between two wires suspended in the same shaft was not always as large as would be desirable. But, if the distance between the two wires was only 60 inches, a line might be set out from them with great accuracy, provided that the wires were not unequally deflected from their true position by air-currents: and any effect produced by the rotation of the earth, being the same for each wire, would not, he thought, alter the direction of the line connecting the two wires. The accuracy to be obtained in connecting the surface and underground surveys by suspended wires was chiefly dependent on details. For instance, the points of suspension must be perfectly steady, and in order to ensure that, there must be no vibrating machinery at work near these points; there must be no high wind, nor movement of weights; there must be no eddying currents of air in the shaft; also the mean position of the wires at the pit-bottom must be noted with great care, and the observation repeated several times. Some years ago, he (Mr. Lupton) set out an underground line by three methods, namely: — By compass-needle, by marks fixed by a transit-instrument, and by two wires suspended in the same shaft; and the three lines agreed exactly one with the other.

Mr. Henry Jepson (Durham) wrote that the title of Mr. Pollitzer's paper seemed somewhat misleading, as the tape, in question, appeared to have been constructed for a specific operation in surveying, and its use was probably limited to that operation. Mr. Pollitzer commenced his paper by giving his opinion "that the connection of a surface and an underground survey can be effected by two plumb-lines, just as accurately as by the use of any optical instrument." As he did not state that his experience extended to the use of an optical instrument, one might be at liberty to doubt it. With 20 years' experience of the use of the transit-instrument for this purpose and some experience of wires, he ventured to assert that it was not possible to make the connection between surface and underground surveys as accurately by the use of suspended wires as by a powerful optical instrument. Throughout Mr. Pollitzer's paper careful and elaborate means were described to avoid movements in the wires suspended in the shaft. Therefore, he concluded that they were free to move, as they ought to be, and they did move; whereas in the use of the transit-instrument, the marks to be observed absolutely fixed, and could be observed as finely as any wire. Under the circumstances, the particular operation described in the paper might be most convenient. In using a transit-instrument it would be extremely unlikely that the conditions would permit of more than the surface and one level being connected at one time, as the marks at one level
would probably obstruct the view of the marks below. And, in addition, it was not likely that the exclusive use of a shaft could be obtained for so protracted an operation as that described. He suggested that, without materially increasing the strain on the wires, Mr. Pollitzer might devise some means by which the plummet would present an increased surface to the oil in the bucket, and thus still further reduce the tendency to movement.

The President (Sir Lindsay Wood, Bart.) moved that a vote of thanks be accorded to Mr. Pollitzer for his interesting paper.

Mr. T. E. Forster seconded the resolution, which was cordially approved.

Mr. S. J. Pollitzer's paper on "The Underlay-table" was read as follows: —

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THE UNDERLAY-TABLE

By S. J. POLLITZER.

There has of late been so much written on the methods of connecting the underground workings of a mine with the surface-boundaries, that it might almost appear that nothing new could be written on the subject, and less likely that anything new could be invented; and he would be considered very bold, who would venture to enunciate some new idea in the face of what European and American mining-engineers have accomplished in this branch of science. The writer wishes to state in all modesty that boldness is not exactly one of his virtues, but he believes that he has invented a useful mechanical appliance, and he desires the members to give an unbiased opinion on the same. If anything more should be added to this preamble, so as to produce a fair criticism, he wishes to state that he has absolutely no monetary interest whatsoever in his invention, which is not patented, and anybody who desires can have the appliance made without let or hindrance. The writer has had considerable experience in almost all classes of surveying on land and water, but during the last ten years his attention has principally been occupied with the underground workings of mines, and about five years ago he invented the abovenamed "mechanical appliance." The last two words are written, because, according to accepted notions an appliance that is not an "optical instrument" is simply a "mechanical appliance." It is quite needless to preface the paper with a disquisition on the necessity of correctly connecting the underground workings of a mine with some fixed data on the surface, as that has been done repeatedly, but particularly so of late by Mr. G. R. Thompson in his excellent paper communicated to the members.* Mr. Thompson and his numerous predecessors occupied themselves

with the question in all its various branches, finding the solution for all cases in the application of the optical instrument or the theodolite in one form or another.

With all due deference to these able workers, and in the light of his practical experience, the writer has come to the conclusion that in some instances the theodolite is not the most suitable instrument to use for the connection of the two surveys, below-ground and above-ground; and that is, in cases where the shafts are driven on the "underlay." If an underlay-shaft be driven in a perfectly straight line longitudinally and transversely from the top to the bottom, then no doubt, the transit-theodolite or one fitted with an eccentric telescope, according as the dip may allow of the use of one or the other, is the best instrument to use; because the process is not only the quickest, but there it risks the least possible chances of introducing an error into the survey.

However, let the reader imagine a properly-equipped working shaft, not a prospecting-shaft, that starts from the surface with a dip of say 75 degrees for, say, a depth of 90 feet; at this point, the inclination becomes 45 degrees and for a distance of say 50 feet takes a turn by a few degrees to the right; thence for 100 feet it may deviate several degrees to the left under an inclination of perhaps 85 degrees, and so it will go along at its own sweet will, to and fro, forwards and backwards, until the bottom is reached, at a depth of between 600 and 700 feet. This is, by no means, an hypothetical case, nor is it a solitary one; there are numerous such shafts in this State, and no doubt, there are similar cases not only in the other States of Australia, but also in other countries. Now, the use of any kind of theodolite in such a shaft may not only be highly objectionable to the accuracy of the survey, but it will be almost impossible. Take for instance, the simplest of all possible cases in such a zig-zag shifting shaft, which may hardly ever occur, that none of the various and continuous altering dips ever exceed an angle of inclination of 60 degrees with the horizon, when a 6 inches astronomical transit-theodolite could be used, because at about that angle the axis of the telescope just passes the tangent to the horizontal circle of the theodolite. Of course, at every point where an alteration of either grade or direction occurs, the instrument will have to be set up and this setting up, by no means an easy task, will consist in building a strong and rigid platform in such a way that the new point can be centred to the instrument with facility, and that there is no obstruction by it to the foresight after the telescope has been tied in to the backsight—and, say, if all goes satisfactorily, that there are two points which will vitiate a possible correct result and that is (1) to correctly ascertain the height of the axis of the telescope above the centred point, and (2) vibration in the platform, no matter how rigid it may be. However, to assume that a shaft will be nowhere steeper than 60 degrees, is highly problematic, and it is more than likely that there will be more inclinations of over 60 degrees than under; consequently, under such circumstances, the transit-theodolite becomes useless, and it must be replaced by an instrument fitted with an eccentric telescope. With such an instrument, the case is exactly reversed, it is an excellent appliance for steep grades, but it may be entirely useless for light ones.

When an eccentric theodolite is used, it must be placed on the rigidly-prepared platform in such a way that two legs of the tripod shall be placed on the same side as the telescope, and that their end-points shall be fairly placed in a line parallel to it; and, in this position, the top ends of those legs will afford the greatest opening for the telescope to sight through. This arrangement is convenient so long as only steep sights are to be observed; but so soon as
the dip flattens much, the line of sight will be obstructed by the forward one of the two legs, and if all these legs be shifted for this reason, into another position, it (more likely than not) may be found, that the top part of the leg obstructs the sight; in other words, under certain conditions, it may not be possible with this instrument to obtain an unobstructed line of vision. There is yet another way of overcoming this difficulty, by using a common transit for smooth grades and an eccentric transit for steep ones, or one of American make, as mentioned by Mr. H. D. Hoskold. Such an instrument, certainly would overcome all surveying obstacles, but the greatest care would have to be exercised, so as to prevent one's notes and calculations from becoming confused.

However, to overcome all these obstacles connected with surveying and confusing calculations, the writer has invented and practically tested successfully a new instrument called the

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"underlay-table," which on account of its simplicity of use in surveying, and still greater simplicity in computing the results, would appear to commend itself better for the purpose of under-lay-shaft surveys, than any of the wellknown optical instruments. Moreover, the appliance readily lends itself to surveying every kind of underlay-shaft, of steep or shallow inclination, or twisting in any direction. The only disadvantage which it possesses is, that it is the slowest imaginable process, as will be noticed later on. The principle, upon which the table is based, is to carry a short horizontal base-line from the surface down to the bottom of the shaft. To carry down this line correctly, a perfect rectangular table must be imagined, fixed level on its supports and level with the surface of the shaft; if the side of the table nearest to the underlay be the initial short base, then the opposite side of the table, that is the one nearest to the hanging-wall, will be the same line, except that it has been shifted parallel to the original line, by a distance equal to the width of the table, which of course is known. If now the second line or the forward side of the table be produced down the shaft by means of two plummets, wherever they may hit the shoot, and marked, and their depth measured, and noted from the surface of the level table; there is thus obtained a new position of the original first line. If now the table be shifted lower down, and be placed so that its back line shall coincide in azimuth and altitude with the two marked points, the front-end can again be produced lower down in the same manner as before, and in this way, the whole depth of the shaft can be passed through until the bottom is reached; by which process, the base-line is brought down, and it is parallel, by so many feet, to the original line and so many feet below it. As the co-ordinates of the original line were previously ascertained on the surface, those of the bottom-line become known also, and all underground surveys can now be safely tied into this bottom-line.

The appliance is not exactly a full table, for such an one would be too heavy and awkward to handle. It consists of a light cedar frame, made up of six pieces, 2 inches by 1 inch, properly screwed together, and shewn in Fig. 1, front-elevation; Fig. 2. side-elevation; and Fig.3, Plan (Plate III.). Before the table is brought into use, two points in the most favourable position,
and as close as possible to the hanging-wall of the shaft are dropped down from the surface, until they hit the shoot of the foot-wall; and, obviously, those two points have, previous to the plumbing, been tied into the surface-survey or their co-ordinates have been ascertained. Near the two points plumbed down and marked in the shaft, a temporary seat for the surveyor is provided; then the table with its three telescopic legs, which can be extended to a height of nearly 10 feet, is fixed in the shaft in such a position that its top shall be a few inches above the first two marks fixed in the shoot. By means of two levels and an union-screw attaching the table to its stand, the appliance is levelled in both directions, and permanently fixed. Along the whole length of the piece a (Figs. 1, 2 and 3, Plate III.), in front of which the surveyor is sitting, and of the piece b, there are two swallow-tailed grooves of brass fixed on the top of the frame; these grooves are for the purpose of receiving four similar sectioned slides of brass, c, which travel freely in the two grooves, and to each pair of these slides are permanently attached two hollow brass tubes, d; by these slides, the two tubes can be shifted over the frame or table in any direction to either side of the observer, parallel to themselves and at right angles to the longitudinal direction of the table, namely, the pieces a and b. These two tubes are of the same length as the width of the table, and with four mill-headed screws (not shown in the figures), attached to the slides, these tubes can be permanently fixed at right angles to the table at any desired point. Through each of these two tubes, another hollow brass tube, e, is passed, so that in telescopic manner, they can be made to travel forward or backward, and by means of another set of mill-headed screws on the outer tube the inner tubes can be fixed at any desired point in the transverse direction of the table. In the figures, the four tubes are shown of square section; however, one that was constructed is of circular section, and has the appearance of a long telescope (Fig. 4).

The mode of use is as follows:--The table is levelled, as stated above, the two pairs of tubes are shifted either to the right or to the left, and the two internal tubes are moved forward or backward, until the centre of the back-ends of the latter will touch two fine plumb-lines, being the raised points first determined on the shoot. In Fig. 3, it will be noticed that the two grooves and

four tubes are symmetrically divided into inches, by which correct parallelism and right angularity is obtained as abovementioned. When once the back-ends of the internal tubes have been made to touch the two plumb-lines, the surveyor reads the number of inches and fractions thereof that have been drawn out backwards from each, and if both have been drawn out to exactly the same length, then the instrument stands in perfect adjustment and in condition to the principle it represents; if not, the clamping-screw, f, must be loosened, and the table turned horizontally round its vertical axis by its levels, and the operation must be repeated so often as is required to produce an equal backward extension of the two internal tubes to meet the two plumb-lines, and after two or three trials the adjusted position will be found. When once adjusted, the height of the tubes over the marks in the foot-wall is ascertained and noted, as also is the backward extension of the tubes. Next, both of the movable internal tubes are moved forward, of course both to exactly the same extent, either until near the hanging-wall, or, if the latter will permit, to move them forward until they are nearly played out, and rest in the external tubes by a few inches only, sufficient to clamp down
on them the two front clamping-screws. The front central ends of the internal tubes are now plumbed down with heavy plummets of first-class construction, until they hit the foot-walls somewhere below, and a reliable assistant there steadies and marks the two new points. Next the field-notes are entered, consisting of the back travel of the rod, say, for instance, 10 ½ inches, plus the width of the table, which is constant, say 2 feet, plus the forward motion of the internal tubes, say 2 feet 6 inches, or a total of 5 feet 4 ½ inches, the initial base-line has travelled parallel forwards, and this new parallel line has been produced downward, equal to the depth from the tubes to the new points which is measured with a steel-tape, minus the height of the tubes above the first points. The instrument is now removed lower down to the two fresh points, and the operation repeated in this manner, until the whole depth of the shaft has been gone through.

When the above-described operation has been finished, and the information so obtained is plotted on paper, a true transverse action of the shaft will be the result. On the other hand, a longitudinal section of the shaft should appear as two vertical lines, being the perpendicular projection of the two internal tubes, which are always distant apart from each, other by the measured length of the original base-line.

The length of this base-line is between 24 and 26 inches, being then 1 or 2 inches less than the length of the table; and this latter must be at least 1 inch less than the clear opening between the skids of the shaft which is about 28 inches: hence, it follows that in metalliferous mines with shafts of this kind, no base-line can be longer than 26 inches at the most. However, if there are shafts in mines that are wider, a longer base-line can be obtained by using a longer table.

The verticality of such shafts, in longitudinal section, in metalliferous mines is very rarely to be found, and it happens that, even in the best constructed shafts, their longitudinal axis is never truly perpendicular, and invariably deviates more or less from the perpendicular. Suppose that this be the case: the appliance will detect it at once. Assuming that at any one stand, the table has been fixed and manipulated as described above, and when the front-ends are being plumbed down, it is found that either one or the other of the two plummets strikes the shaft-timbering before reaching the foot-wall: shewing that the shaft twists or takes a turn to the side opposite to where the plummet touches the timber: in such a case, the tube from which the obstructed plummet is hanging is shifted parallel to the other tube and towards it until the timber is cleared. If the case be reversed, of course, the reverse side has to be shifted; and in the book it is noted down by how many inches at each stand the shaft twists to the right or to the left, as the case may be.

There are a few more details that may be mentioned. The central longitudinal piece of the frame rests on the baseboard, g; the frame is fixed to it by two sets of clamps and screws, h: and on this base-board the union-screw works and keeps it and the table firm and immovable in any desired position. Round the base of the union-screw, there is a movable collar from which two arms branch off at right angles one to the other, each of which carries a vertical thumb-screw, i, intended to counterbalance that part of the table, which, at times, may, on account of twisting, happen to want shifting on the base-board more to one side than on the other. Experience has shewn that, though these two screws
Are an extra precaution, they are quite unnecessary, since the union-screw acts efficiently, and will even stand the strain when about half of the table only rests on the base-board and the other half is wholly unsupported, although such exaggerated cases do not occur.

The lower ends of the three legs are provided with three strong iron points, which will find a firm foothold in almost any crevice of the rock in the shaft; the three legs are placed in such position that two of them lie on either side of the observer and the third leg is placed in front of him, and all three sit in the country-rock in the foot-wall and hanging-wall respectively, where they are free from any vibration. Metalliferous-mine shafts generally consist of three compartments, two for the up-and down-cages, and one for the ladder, air-pipe, and other accessories. For surveying, the middle compartment is usually chosen, while the other cage is always at the disposal of the surveyor to move his instruments and his assistants wherever required; and when moving the appliance, the table is unscrewed and placed upright in the cage, the legs are shut, and the party move themselves in the cage to the next points lower down the shaft where the operation begins afresh. The appliance can withstand a reasonable amount of rough handling, without injuring its efficiency or being materially damaged; there is nothing in it that cannot be repaired or replaced within a few hours in the mine workshop, so as not to stop the progress of surveying. The legs are made of American ash, 1 inch by ½ inch, and braced with strap-iron; the table parts are made of cedar, 2 inches by 1 inch; the base-board is made of iron-bark, 3 inches by 1 inch; and the ball-and-socket of the union-screw is made of jarrah wood. Nearly the whole of the metal used is brass, but the bolt of the union-screw and the counterbalance-collar are made of iron. The weight of the instrument is as follows:—The table, 14 ½ pounds; two pair of tubes, 5 pounds; and the legs, 16 pounds; or a total of 35 ½ pounds. When not required for use, the table is completely dismounted, and packed in a strong suitable box; and made singly its cost will amount to about £35.

When surveying, three assistants are required, one on each side of the surveyor to plumb-up the back-points, after which they plumb-down the front-points; and a third, who marks the front-points; besides, there should be one, or preferably two, smart miners to assist in making-rough timber-seats, working the travelling cage, and all sorts of odds and ends that may be wanted; and lastly the engine-driver who has to work the winding-engine.

This instrument has been tried practically some three years ago in a large gold-mine in the southern part of this State, where there are three underlay-shafts of the above description.

[Photograph: Fig. 4. -The Pollitzer Underlay-table.]

The three shafts have a depth of from 300 to 700 feet, and in the aggregate they amount to not quite 1,400 feet; the three shafts are in a fairly straight line on the surface, and the
distance between each is between 500 and 600 feet. The underlay-table operation was carried out through the three shafts, and as two of the shafts at one of their respective levels were connected by a drive,

[Plate 3.—Diagrams of the Underlay Table.]

Though of a very tortuous character, there was an excellent opportunity for testing the efficiency of the table, by having a closed circuit. The result of the close, to be candid, was not satisfactory; the reader must bear in mind that the above-mentioned tortuous course consisted of a good number of traverses, the length of which was a good deal below the focal length of the telescope of the theodolite, and as the latter had frequently, to be placed in shifty and unsteady positions, the writer is forced to the conclusion that the mis-close of the survey was not caused by the table, but by the underground traverse. Moreover, the writer is convinced that, given fairly favourable conditions, the underlay-table will give satisfactory results, although the base-line be only 2 feet long.

Engineers and surveyors alike rightly avoid the use of very short base-lines, and so does the writer; but when circumstances arise that short lines must be used, then according to his experience they will assist in obtaining as correct surveying results as with long lines; the difference will only be in the time used, for in short lines much more numerous checks, hence more time, will be required to ensure that no mistakes are made. As an illustration of this, it may be mentioned that from a measured base-line of about 12 miles the earth's quadrant can be calculated, and the proportion between the measured and calculated line is roughly as 1 in 8,300 and such a small fraction might not often, if at all, occur in underground surveying. Certainly, with this underlay-table the difficulties are considerably increased by moving it so many times, but the writer is convinced that it can be used with accuracy.

Fig. 4 shews the underlay-table, and its construction in all its detail is very minutely visible.

Mr. Arnold Lupton (Leeds) wrote that Mr. S. J. Pollitzer's paper was interesting, as showing a method of surveying crooked and sloping shafts actually carried out by a practical surveyor. There could be no doubt that an accurate survey might be made by this method and a base-line accurately transferred from the surface to the deepest level. The accuracy depended entirely on the amount of care taken in hanging the plumb-bobs and in marking their exact position, reading the measurements, levelling

the table, etc., and as considerable time might be occupied doing the work it was necessary that the shaft should be at the service of the surveyors for considerable lengths of time, to ensure accuracy in the results. For similar work, he was inclined to think that the Hedley dial could often be used with great efficiency. If there was no attraction in the shaft, and the compass-needle could be used, it would be, by far, the quickest way of surveying the shaft. Even if the compass-needle could not be used, still the Hedley dial was so handy an instrument that the survey could probably be made much more expeditiously with it than by the use of the underlay-table. The Hedley dial, as commonly made, could be used for angles up to 65
degrees from the horizontal, and a slight modification would enable it to be used for any angle. The accuracy of the work would depend on the care with which the instrument was levelled, etc., and where two or more shafts were connected underground, the accuracy of the survey could be readily tested. He (Mr. Lupton) supposed that the Hedley dial would come under Mr. Pollitzer's definition of a "mechanical appliance," except when the magnetic needle was used; but he left it for philosophers to decide as to whether or not it would then become an "optical instrument."

Mr. Bennett H. Brough (London) thought that, with care, accurate results could be obtained with the ingenious underlay-table invented by Mr. Pollitzer. The appliance was, however, costly; and the process of using it would be extremely tedious. It was doubtful, moreover, whether better results would be obtained than those given by the T-square method,* in which the apparatus is made by the mine-carpenter and consists of a straight edge and two T-squares. The former is a planed pine-board, measuring 8 inches by ¾ inch, and 1 foot longer than the distance between the wires. It rests horizontally upon supports fixed across the shaft, and is brought to about 1/8 inch from each wire, and then nailed down to prevent slipping. The T-squares are most serviceable if made with a movable head, clamped by a thumbscrew. Except in cramped quarters, they are set at right angles. The T-squares are slid along the straight edge, until close to the wires, but not touching them, and there fixed. Another instrument of the same type is that devised by Mr. T. H.


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Wayne.* This consists of a collapsible triangular frame, fitted with levels and legs so that it can be supported horizontally. A telescope and a vernier are placed at the apex, and the two legs recessed at their ends so as to fit loosely round the two plumb-lines. If the telescope is clamped to a sight at one level, the frame may be transferred to another level where the telescope will give the same direction. Mechanical methods of connecting surface and underground surveys are the oldest, for they were used by Hero of Alexandria 2,000 years ago, and they are still most often employed, as the optical methods present serious difficulties. It is doubtful, however, whether, in shafts such as those described by the author, as satisfactory work could be done with his complicated mechanical table as would be possible with a transit-theodolite and an artificial horizon, or with the new form of theodolite invented by Mr. Dunbar D. Scott† in which the auxiliary telescope is interchangeable and may be used either as a side or as a top telescope.

The President (Sir Lindsay Wood, Bart.) moved a vote of thanks to Mr. Pollitzer for his paper.

Mr. J. G. Weeks seconded the resolution, which was cordially approved.

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Mr. E. Roubier read the following description of "The Max Electric Mining Lamp" : —

THE MAX ELECTRIC MINING LAMP.
By E. ROUBIER.

The Max electric mining lamp (Fig. 1) has been designed to fulfil the requirements expressed by French mining-engineers and has already met with considerable favour in the mines of the North of France. It is the outcome of a long series of experiments in which suggestions from practical men have been embodied as fully as possible. The accumulator is of the now well known Max type. In this cell, no plates are used, the electrodes are cylindrical, and constituted by rods of antimoniated lead, round which the active material is squirted, under pressure, and thereafter covered with asbestos braiding, the jackets thus formed effectually preventing disintegration, and all possible chances of the active material falling, and establishing short circuits between electrodes of opposite polarities.

Each cell comprizes 24 electrodes, arranged in three rows of 8 each, the middle row forming the positive, and the two outer rows the negative poles. The electrodes are arranged so as to give the best possible utilization of the space occupied, and their cylindrical form and relatively small diameter enable the whole of the active material to enter into play, thereby ensuring a very high output per unit of weight and space. The electrodes are made by machinery, by which an absolutely uniform application of the active material is obtained, and all the electrodes are alike. There are two cells in each lamp, and each cell has an electromotive force of about 2 volts. The accumulator is recharged from a continuous-current supply at the end of the day at the rate of 1 ampere, and as the lamp is not generally exhausted at the end of each day, it would be found that 10 hours charging at 1 ampere would be sufficient.

The maintenance expenses are reduced to a minimum, since no material can drop, and therefore no washings are ever required to keep the cell clean. Moreover, the subdivision of the material in small units allows of a rapid rate of charge, and this consideration is an all-important one at collieries, or in any industry where continuous working must be ensured. The peculiar construction of the accumulator allows of its being regenerated when its capacity has dropped for any reason whatever, by means of reversal of polarities. The spilling of the electrolyte is obviated by a special type of indiarubber plug, prepared in such a manner as to allow of the escape of the gases evolved at the end of charge, whilst preventing any drop of liquid from leaking. It has been found in practice that the immobilization of the electrolyte by admixture of silicates, which renders it gelatinous, very considerably reduces the actual capacity of any cell to which it is applied; moreover, the asbestos coating of the electrodes acts as a very effective absorbent and as a check against rapid movements of the liquid when the cell is accidentally tilted. The type of lamp, lamp-protector and reflector could be easily altered to suit particular requirements. The switch, which is placed under the incandescent lamp, is arranged in such a manner as to prevent the charging-current from going through the lamp instead of charging the cell, as the charging plug pushes back the lighting switch. The
Max lamp weighs about 5 ½ pounds, and it gives a light of 1 ½ candlepower for 10 to 12 hours, or a smaller light for a considerably longer period. It has not been thought advisable to add a gas-detector, as opinions on this subject appear to be extremely divided.

Mr. E. Roubier, replying to questions, said that if the charging current had a pressure of 200 volts a 32 candlepower lamp for 200 volts would be placed on the charging-board when charging one or two cells only; but the number of cells that can be charged on a given circuit is equal to the total supply-voltage divided by 20.

Mr. A. Andrews (Newcastle-upon-Tyne) said that the system of charging the lamp appeared to be a slow one. He supposed that with 100 lamps on a 200 volts circuit the lamps would be joined in series.

Mr. Roubier, replying to further questions, stated that there was only a small quantity of liquid in each cell, and the lamp could be turned upside down with safety; but if it were left in that position for 2 or 3 hours, a few drops of the liquid might escape. The lamp used a current of about 0.7 ampere; and the accumulator should be recharged when the pressure fell to 1.8 volts.

Mr. W. C. Blackett (Durham) said that he had used electric lamps in mines for many years for purposes of observation, and after provision had been made for the slight danger arising from the fact that electric lamps did not indicate the presence of dangerous gases, they were most useful in enabling one to see objects which could not be seen with the light of an ordinary safety-lamp. He had hitherto used a Bristol lamp, which seemed to be on the same principle as the Max lamp, but he could not remember whether the electrodes possessed asbestos-jackets.

The President (Sir Lindsay Wood, Bart.) asked whether the lamp, when not in use, would last a long time without the charge running down.

Mr. W. Walker (H.M. Inspector of Mines) said that at Murton colliery some 1,200 lamps of the Sussmann type were in use, and most, if not all, of the parts of these had been manufactured at the colliery; and similar lamps had also been used at South Moor colliery with satisfactory results for some time past.

Mr. W. C. Blackett said that it was a great advantage to have the absorbent firmly fastened round the plates, as it prevented the paste from falling out and short-circuiting the lamp.

Mr. J. B. Atkinson asked whether any case had occurred in France which led to the men working in a place where they ought not to have worked, on account of the presence of gas.

Mr. E. Roubier said that no such case had come to his knowledge.
Mr. A. Andrews thought that such a difficulty had been overcome by the addition of gas-detectors to electric lamps.

Mr. W. C. Blackett said that at Newbottle colliery the electric lamps were taken out, owing to this danger.

Mr. M. Walton Brown stated that the gas-tester attached to Swan lamp, when constantly applied, used up the charge of the lamp in about 30 mins.

Mr. J B. Atkinson said that if the gas-tester depended on the putting it into operation, he might be suffocated before he thought of using it.

Mr. A. Andrews said that there was an automatic gas-tester, in which a porous pot was employed, and the gas raised an india-rubber valve, and agitated a relay which put a switch into contact and lighted a red lamp, and that lamp remained lit until the switch was taken off. Some of the lamps were not fitted with the relay, and, therefore, when the gas agitated the valve the red lamp was only lighted during that time; and it was necessary to watch the red lamp to see if it was lighted. Lamps, fitted with relays, were usually used in the pit over the week-ends.

Mr. M. Walton Brown said that the gas-tester referred to by Mr. Andrews depended for its action on the diffusion of gases, and another test for gas could not be made until the appliance had been taken into a purer atmosphere. If this were not done, the pressure of the diffused gas diminished, and the red lamp would give no further indication of the presence of gas.

Prof. H. Stroud (Durham College of Science) wrote that it is important to obtain an electric mining lamp, whose weight is sufficiently small and which at the same time gives enough light for the purpose. From the description, the Max storage-cell seems well constructed and satisfactory.

Mr. G. E. Smith (Nottingham) wrote that, he trusted, the fact of the plates or electrodes in the Max lamp being circular would give them longer life, and render them better able to resist such rough usage as the miner's lamp frequently received in a mine. He thought that the number of electrodes (24) would also tend to extend the life of the lamp.

Mr. Henry Davis (Derby) wrote that the Max electric lamp, introduced by Mr. Roubier, appeared to be substantially conducted to stand rough usage in mining work and to give a good light; but he feared that the inventor was far from having produced a lamp which would suit the ideas of the miner or the
pocket of the mine-owner. The miner will object to the weight of 5 ½ pounds, over double that of the lamp it is intended to place. The mine-owner will hardly be anxious to adopt this or any electric lamp, unless the first cost and upkeep does not seriously exceed that of the oil-lamp. Inventors must bear in mind notwithstanding, that a portable electric lamp had received immense amount of thought for years, of encouragement from manufacturers, capitalists and the owners of mines; yet it could not be said to have obtained any foothold, except in cases of exploration after an explosion, when an oil-lamp requiring oxygen could not be supported, and then the electric lamp had rendered excellent and invaluable service.

The President (Sir Lindsay Wood, Bart.) moved a vote of thanks to Mr. Roubier for his description of the Max electric lamp.

Mr. W. C. Blackett seconded the resolution, which was approved.

DISCUSSION OF PROF. A. RATEAU’S PAPER ON “THE UTILIZATION OF EXHAUST-STEAM BY THE COMBINED APPLICATION OF STEAM-ACCUMULATORS AND CONDENSING TURBINES.”*

Prof. A. Rateau (Paris) wrote that since his paper was written, the air-pump of the condenser, into which the turbine at Bruay collieries exhausts its steam, has been perfected in such wise that the vacuum now reaches 65 centimetres (25.6 inches) of mercury-column at full load. The writer thereupon requested the mining-engineers at Bruay to be kind enough to repeat some of the experiments upon the turbine-dynamo, by increasing the load as much as possible.

These experiments were accordingly carried out on January 31st, in the presence of Prof. Hubert, and yielded the results summarized in Table II. The turbine, at that date, had been working for five months (with the exception of a six weeks lapse due to the general strike of miners).

In the course of these experiments the necessary variations of power developed were obtained by transferring progressively to the turbine the load of the reciprocating engines, which in


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[Table II., Experiments with the Low-pressure Turbine at the Bruay Collieries, omitted.]

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ordinary circumstances are conjoined with the turbine in providing the electricity needed for the working of the colliery. At the termination of the series of experiments, this provision was secured by means of the turbine alone, and, in order to increase the load, all the lamps in the pit had been lighted. It was not found possible, however, to increase this load beyond 241 horse-power for any appreciable length of time. For a moment only, on starting a large winch,
did the demand on the system attain 282 electric horsepower; but this was merely a matter of a few seconds.

Speaking generally, such experiments made in course of practical working are of only comparative accuracy, because of the continual variations of the load. The figures on the fourth and fifth lines of Table II. are undoubtedly the most exact, being each the mean of three concordant measurements, taken at times when the load was approximately stable. As to those of the sixth line which correspond as aforesaid to a merely transitory load, they must be considered as unreliable.

If the figures of Table II. be compared with those of Table I.,* it will be seen that the results of practical working agree very fairly with those obtained in the course of experiments at the factory. For instance, at loads varying between 213 and 241 electric horsepower, the counter-pressure at the outlet of the turbine being sensibly the same as that obtained experimentally at the works, the consumption of steam per electric-horsepower-hour approximates to 19 kilogrammes (42 pounds) and the efficiency of the turbine and dynamo taken together is 0.54 or 0.55, at a speed of 1,600 revolutions per minute. These results are concordant with those expressed by the curves drawn in Figs. 4 and 5 (Plate IX.).†

It may be added that the turbine and the dynamos work silently, without any appreciable vibration.

Mr. M. Walton Brown mentioned that after the erection of a high-pressure beam pumping-engine at the Farme collieries, with a cylinder 24 inches in diameter, the exhaust-steam was passed into a boiler, fitted with a safety-valve loaded at 5 pounds on the square inch. A pumping-engine and a winding-engine,

† Ibid., vol. xxiv., page 348.

with cylinders 60 inches and 42 inches respectively in diameter were thus supplied with steam, and any deficiency was supplied from a high-pressure boiler.

DISCUSSION OF DR. BROOCKMANN'S PAPER ON "THE GASES ENCLOSED IN COAL** AND DR. P. P. BEDSON'S PAPER ON "THE GASES ENCLOSED IN COAL AND COAL-DUST."†

Mr. J. W. Thomas (London) wrote that the accuracy of Dr. Bedson's and his own experiments on account of using india-rubber connections had been impugned by Dr. Broockmann, who said that "he (Dr. Bedson) used about the same method as that employed by Mr. Thomas . . . the glass vessel being closed by a perforated indiarubber-stopper," etc. Dr. Bedson had defended his own method. With regard to his (Mr. Thomas'), Dr. Broockmann had not even made himself acquainted with the facts. He (Mr. Thomas) had never used a stopper—his tubes were always drawn off and bent over in the blowpipe-flame, so as to make one joint with the Sprengel air-pump by an indiarubber tube, which was surrounded by a water-jacket in every experiment with all kinds of coal, a perfectly reliable method. Dr. Broockmann stated that "indiarubber is as permeable to gases as a sieve is to water." Such language was as
inaccurate as it was sweeping, and he (Mr. Thomas) did not think that any appreciable error could occur in Dr. Bedson’s analyses from the method adopted by him. Dr. Broockmann used the indiarubber chimera to throw discredit on the large volume of gases obtained from the coal of the North of England and of South Wales, but that large volume could be obtained from fresh coal without difficulty.

With regard to the action of oxygen upon coal sealed up in tubes with air, Dr. Broockmann’s remarks were incomprehensible.‡ If acetic acid was formed, why leave it questionable when it was so easy to detect? and further, as to its vapour not being "absorbed by caustic potash?" He (Mr. Thomas) did not wish to point out absurdities, but only to note that there was good reason for "doubting the accuracy" of Table II. Lignites and Tertiary coals did absorb oxygen at moderately low temperatures, but the

† Ibid., page 27.
‡ Ibid., page 24.

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best steam-coals of the North of England and South Wales were not appreciably affected. The reason why the latter stood for long periods practically unweathered and unchanged in the coal depots of warm countries was because they so strongly resisted oxidation.

Those acquainted with the analysis of compound and combustible gases would know that all errors of manipulation, where the real values were less than 100 (and they almost always were less than 100) appeared as nitrogen, because this was estimated by difference. A glance at Table I. in Dr. Broockmann’s paper* would reveal figures which any gas-analyst might challenge, and these, to say the least, were as much open to suspicion as Dr Bedson’s excess of oxygen in the analysis under dispute. He (Mr. Thomas) knew of no Carboniferous coal which did not contain nitrogen among its occluded gases before being subjected to exhaustion by the Sprengel air-pump; and it was always present in the blower-gases that he had examined, which were free from oxygen and contained no air.

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DISCUSSION OF MR. E. GOSSERIES’ PAPER ON “THE GUIBAL FAN COMPARED WITH A DYNAMO.”†

Mr. Sydney F. Walker (London) wrote that Mr. Gosseries appeared to have started with a good idea. His reasonings, though correct in the main, were exceedingly difficult to follow, but in the end he became greatly involved. He (Mr. Walker) thought, therefore, that he would render the best service that he could to the members if he gave simply the idea that he had formed on the subject of the similarity between the action of air in mines, and of electric currents in a supply-service, from his previous study of the question, and from the study which he had now been able to make of it, from Mr. E. Gosseries’ paper and from Mr. M. Walton Brown’s pamphlet.‡

The analogy between the two actions is very close indeed, especially if a dynamo be used as a generator. The electric generator corresponds to the fan; and the mine corresponds to the circuits, the distribution-service in connection with the electric generator.
I.—A. In electricity, there is the law: $C = \frac{E}{R}$, where $C$ is the strength of the electric current passing: $E$, the electromotive force or electric pressure; and $R$, the resistance of the conductors of the distribution-system, or any system of conductors supplied by the generator. It will be understood that the law as it stands, in the simple form given above, is really applicable to a single conductor, or system of conductors, all emanating from two points between which the difference of pressure exists. Thus, in any single conductor to which an electric pressure is applied, the current, passing through it, depends simply upon the law given above. This is well illustrated by the case of the incandescent electric lamp. The current passing through its filament varies directly as the pressure which arrives at its terminals, and inversely as the resistance of the lamp from terminal to terminal, while the current is passing. When a complete system is considered, including the generator, the law applies equally; but it is necessary to be sure that all the resistances, which the electric pressure will have to overcome, have been included in the equation. The most important, and the one likely to be omitted, unless warning is given, is the resistance of the generator itself. The law is usually stated, when the generator is taken into the equation, thus: $C = \frac{E}{R} + r$, where $R$ is the resistance of the circuits external to the generator; and $r$ that of the generator itself. In the electric service, the current, it will be remembered, passes through the conductors external to the generator, back to the generator, and through the generator-coils to the terminal whence it first started, the current passing continuously round and round, and the resistance of the generator-coils making a charge for the passage of the current through them, just as if they formed part of the external circuit, and were not engaged in generating the electric pressure. Again the electric pressure is created by the passage of the coils, usually of the armature, through the magnetic field of the dynamo, and the electric energy created is a direct conversion from the mechanical energy of the driving-engine. Also the electric pressure created depends directly upon the number of conductors assembled on the armature, and upon the speed at which it is driven through the magnetic field. Again, the charge for the passage of the current through the armature-coils depends directly upon the square of the strength of the current multiplied by the resistance of the coils, or it depends upon the current-strength simply multiplied by the pressure which is used to force the current through the coils. In any case, as the current which is being taken from the generator increases, so does the charge for its passage through the generator itself, and so does the pressure used in the generator.

B.—Passing on to the distribution-service, the current delivered to the service depends directly upon the pressure delivered to the terminals of the service, and inversely upon the total resistance offered by the distribution-system, the cables lamps, motors, etc.; and the total current passing through the service, and through the generator, depends upon the pressure created in the generator when the current is passing (the current at any particular instant) and
inversely upon the total resistance opposed to it, which is again made up of the resistance of the cables, lamps, etc., and that of the generator itself. The resistance offered by the cables and by any conductors through which the current passes, depends directly upon the length of the conductor, and inversely upon its sectional area. That is to say, the longer that the conductor is the greater is the pressure required to drive a certain current through it; or inversely, with a given pressure, the less will be the current that can pass. On the other hand, the larger the conductor, the greater its sectional area, the more easily will it allow the current to pass; the greater current will pass with a given pressure, and the smaller pressure that will be required for a given current. Further, unless special provision is made to counteract it, the passage of a larger current through the generator, that is to say the demand for a larger current by the external service, the lower will be the pressure delivered at the terminals of the service and the lower will be the pressure delivered at any point in the service. This is well illustrated by the case of a lighting-service at a colliery. The pressure at the pit-top will be, say, 100 volts, and so long as no current is passing it will be the same at the pit-bottom; but so soon as a current passes through the shaft-cables, the pressure is lowered in direct proportion to the strength of the current and the resistance of the cables. In most dynamos used for lighting and power at collieries, provision is made for keeping a constant pressure at the terminals of the generator, no matter what may be the current, and the alternator will, therefore, probably more nearly represent the action of the fan under similar conditions. With the alternator, as the current which is taken from the generator rises, the pressure at its terminals falls, unless provision is made for maintaining it, by increasing the speed, or increasing the strength of the magnetic field in which armature-coils move. The fall of pressure in the alternator is due to two factors, the increased charge made for the passage of the increased current through the coils, and the increased self-induction of the currents passing in the coils themselves. This is mentioned, as it has a counterpart in the fan.

II.---Now as to the fan and the air-distribution service.

A.---In the fan, the vanes represent the armature-conductors of the electric generator, and the total pressure delivered by the fan depends upon the number of vanes, and upon the speed at which the fan is driven. This, of course, may be taken as referring to any particular type of fan. The same thing applies to electric generators, as all the arguments, which have been enunciated, are to be taken as applying to a particular type of generator. Any type of generator will do, but the laws, for simplicity, must follow one type.

It appears to him (Mr. S. F. Walker) that pressure created by the fan corresponds to pressure created by the dynamo, and depends upon the quantities stated, irrespective of the quantity of air passing. The pressure gives the ability to drive air through air-conductors, mine-galleries, air-passages of various forms, including the passages of the fan itself. The useful pressure, which appears at the fan-outlet, is the total pressure which has been created by the vanes of the fan, less the charge made upon that pressure for the passage of the air-current through the fan, just as the pressure at the terminals of the electric generator is the total pressure created, less the charge for the passage of the current through its own coils. Further, it appears also that there will be additional charges upon the pressure delivered at the outlet of the fan, due to eddy-currents within the fan itself, which will increase in some ratio with the strength of the air-current itself, corresponding to the self-induction in the alternator. What Prof. T. Guibal had named the "temperament of the mine" corresponds to conductivity in an electrical
distribution-service, the reciprocal of resistance. In electrical work is has been found more convenient to use resistance in calculation, instead of conductivity, but the latter could be used, and

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there is a unit of conductivity, the mho, in contra-distinction to the unit of resistance, the ohm. The laws which govern the distribution of air in a mine appear to be the same as those governing the distribution of electricity to lamps, motors, etc., with certain important modifications. Thus, the resistance offered by any airway in a mine depends upon its length, inversely upon its area, but it also depends directly upon its perimeter, and this factor has to be included in the equation. With electricity the resistance offered by a conductor depends directly upon the length of the conductor, and inversely upon its sectional area, or equals \( l/a \), where \( l \) represents the length, and \( a \) the sectional area. With an airway in a mine, the resistance, it appears, is represented by \( lp/a \), where \( l \) again represents length, \( a \) the area, and \( p \) the perimeter; and the two quantities are brought closer into agreement by the fact that the actual resistance of an electric conductor is found, when its dimensions are known, by multiplying the above fraction by the specific resistance of the metal of which the conductor is made, that is to say by the proportion which any given section of the substance bears to the standard; and by the fact that, with air-currents, the actual resistance is found by multiplying the above fraction by the coefficient of friction. Given, however, the above modifications, the two seem to follow the same law. There is, however, another modification, to be introduced before the two sets of equations can be brought into line. With electricity, the current passing simply depends upon the pressure divided by the resistance; with air-currents, it depends upon the square of the pressure divided by the resistance. But, with this modification, it appears that the two, electrical distribution and air-distribution, follow exactly the same laws. Thus, what corresponds to current with air, the quantity of air passing, is found by dividing the square of the pressure by the resistance, as stated in the preceding equation. But the law must be applied fully, that is to say, the resistance offered by the fan itself must be taken into account. Thus, when additional roads are opened in the mine, offering additional paths for the air, the increased air-current passing through the fan lowers the pressure available on the outside, while the actual quantity of air passing in the mine depends upon the square of the available pressure at the fan-outlet, divided by the resistance offered by the mine itself. The case is similar to an electrical distribution, where with an

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incandescent-lamp service, additional lamps are turned on, and the the supply-cables are small. The light given by the individual lamps is less than before, but the total current passing through the cables is larger. The same thing may apply to an electric generator, if it is not properly compounded, or it is alternating, and provision is not made for raising the pressure as the current taken from it increases. The pressure at its terminals lowers, and with it the light given by the lamps supplied, though the total current being furnished by the generator may be considerably higher than when the lights are brighter. With air-currents, and with electric-currents, the same rule appears to hold good, with the modification mentioned.
The actual current passing depends upon the pressure available, or its square, and the resistance offered to it.

The question of splits with air, which Mr. Gosseries had attempted to discuss, appears to follow the same law as with electricity, so far as resistance is concerned, with the above reservations: the addition of the perimeter to one side of the equation, and the square of the pressure instead of the simple pressure. When two or more conductors are bridged between two points, between which a difference of pressure exists, the current which passes in each of them will be inversely as their resistances. That is to say, the total current which passes through the system of conductors connected to these two points will be divided between the conductors in the inverse ratio of their resistances: but the total current itself which passes will depend, again, upon the pressure available at the two points, and inversely upon the combined resistance offered by the system of conductors. In calculating the combined resistance offered by a system of conductors ending in two points, in electrical work, it is customary to make use of their reciprocals. Thus if \( r, r_1, \) and \( r_2 \) be three conductors connected in parallel, as it is termed in electrical work, to find their combined resistance, their conductivities, \( 1/r, 1/r_1 \) and \( 1/r_2 \) are added together, giving the fraction

\[
\frac{1}{r} + \frac{1}{r_1} + \frac{1}{r_2} = \frac{r_1r_2 + rr_1 + rr_2}{r_1r_2 + rr_1 + rr_2};
\]

and reversing this, the combined resistance is

\[
rr_1r_2 = \frac{(r_1r_2 + rr_1 + rr_2)}{r_1r_2 + rr_1 + rr_2},
\]

or the combined resistance of the several circuits is equal to the product of their resistances divided by the sum of the quantities shown. With a service, such as used for incandescent lamps, the matter simplifies itself very much: all the lamps may be taken to have the same resistance,

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and the combined resistance is equal to the resistance of one lamp divided by their number.

It appears that splits air in mines must follow much the same law. Each will take its share of the air available, in inverse proportion to its own resistance, or in Mr. Guibal's terms, in direct proportion to its temperament. But each will take air, irrespective of all the others directly in proportion to the square of the pressure available at its ends inversely in proportion to its own resistance. The combined resistance of the splits will determine what quantity of air will pass, because the pressure available at the ends of each individual split will be regulated by the quantity of air passing through the fan, and the roads leading up to the split, and away from it. One point, which Mr. M. Walton Brown makes in his pamphlet* appears to correspond directly with electrical conditions:---The return-airway, if not of sufficient area, will throttle the air, and so reduce the available pressure at the ends of any individual branch, just as much as the intake-airways or the branches themselves. The air has to be driven or sucked through the return-airways, before it can pass out of the mine and fresh air pass in, and any resistance offered by it will use up pressure exactly as does a return-cable.

Prof. H. Stroud (Durham College of Science) wrote that the reference to a dynamo occurs in two paragraphs of Mr. Gosseries' paper. In addition to the circuit where the electric energy is utilised, a second (shunt) circuit is arranged, and apparently the idea is to keep the current through the dynamo constant by varying the resistance of the shunt-circuit. It is certainly never desirable in the case of a dynamo (magneto-electric machine) to keep the current through the
dynamo constant, even when no electric energy is being utilized outside; and that it is desirable in the case of a fan to introduce air from the outside, by means of a tube communicating directly with the atmosphere, does not seem at all clear. There is also a statement that “the resistance to the movement of the air in each split shall be the same and equal to \( P_A - P_B \),” in which the author uses the word resistance in a sense different from its usual meaning.


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THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING

Held in the Wood Memorial Hall, Newcastle-upon-Tyne,
April 4th, 1903.

Sir LINDSAY WOOD, Bart., President, is the Chair.

The Secretary read the minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on March 21st and that day.

The following gentlemen were elected, having been previously nominated: —

Members—
Mr. Joseph MacLeod Carey, Mining Engineer, Coatham, Redcar, Yorkshire.
Mr. Charles Chandley, Mining Engineer, 120, Musters Road, West Bridgford, Nottingham.
Mr. Fred T. Greene, Mining Engineer, Butte, Montana, United States of America.
Mr. Ralph Lidster, Engineer, Langley Park Colliery, Durham.
Mr. Tom Pattinson Martin, Mining Engineer, Cumberland Coal-owners’ Association, Workington, Cumberland.
Mr. John Henry Miller, Colliery Manager, South Hetton, Sunderland.
Mr. William Oughton, Engineer, 33, Westgate Road, Newcastle-upon-Tyne.
Mr. Frank Holman Probert, Mining Engineer, 230 and 231, Bradbury Building, Los Angeles, California, United States of America.
Mr. Ithel Treharne Rees, Mining and Civil Engineer, Guildhall Chambers, Cardiff.
Mr. John Caverley Wasley, Mining Engineer, 184, Salt well Road, Bensham, Gateshead-upon-Tyne.
Mr. Stephen Waters, Mechanical Engineer, Apartado No. 96, Pachuca, Mexico.
Mr. James Wilson Williams, Mining Engineer, 15, Valley Drive, Harrogate.

Associate Members —
Miss Rosalind Watson, Victoria, British Columbia.
Mr. George Henry Wraith, Moor House, Spennymoor, R.S.O., County Durham.

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Associates - Mr. Albert Craggs, Assistant Colliery Manager, 10, Victoria Terrace, Pelton, Chester-le-Street, County Durham.
Mr. John Morris, Fireman, Gwalia House, Gorseinon Glamorganshire.
Mr. George Peel, Jun., Surveyor, 27, Langley Street, Langley Park, Durham.
Mr. Laurance Wylam Potts, Back-overman, The Leam, Felling, R.S.O., County Durham.
Mr. Alexander Seed, Back-overman, 1, College Terrace, Brandon Colliery, R.S.O., County Durham.

Students—
Mr. Cecil Graham, Mining Student, Sunniside, Tow Law, R.S.O., County Durham.
Mr. Rowland Frank Hutton Hedley, Mining Student, Langholme, Roker, Sunderland.
Mr. John Edward McGregor, Mining Student, 2, Murray Street, Stanley, R.S.O., County Durham.
Mr. George Michael Moncrieff Robinson, Mining Student, Springfield Terrace, Newbiggin-by-the-Sea.

DISCUSSION OF MR. E. ROUBIER'S PAPER ON "THE MAX ELECTRIC MIXING LAMP."
Mr. W. O. Wood (South Helton) wrote that the Max electric mining lamp did not appear to be any improvement on the Sussmann lamp, 1,200 of which had been in daily and successful operation at Murton colliery for some years. The Max lamp was 1 ½ pounds heavier than the Sussmann lamp, while the light was no better, nor was the period of burning longer, as the Sussmann lamp easily burnt for 10 hours, if required.

Mr. E. Roubier (London) wrote that he could only congratulate the makers of the Sussmann lamp, and perhaps Mr. Wood would be able to state the cost of maintenance and the life of this type of lamp, which is worth consideration, but as apparently Mr. Wood has neither seen the Max accumulator, nor the lamp in operation, he could not see that much weight reposed on his (Mr. Wood's) opinion. He (Mr. Roubier) thought that the Sussmann lamp weighed 4 ½ pounds, which is only one pound less than the weight of the Max lamp: anyhow, as the Max lamp gave a light of 1 ½ candlepower for 12 hours, while, he believed, the Sussmann gave 1 candlepower for 10 hours only, the extra 40 per cent. light was well worth 20 per cent. of enhanced weight.


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DISCUSSION OF MR. W. C. BLACKETT'S NOTE ON AN "IMPROVED OFFTAKE-SOCKET FOR COUPLING AND UNCOUPLING HAULING-ROPES."
Mr. J. H. Ronaldson (Johannesburg) wrote that he was interested in seeing that the coupling for haulage-ropes was to all intents and purposes the same as one that he designed and used in 1893 at Trabboch colliery, Ayrshire, for tail-ropes: it worked well and expeditiously. It was designed in the first instance to allow the couplings to pass through some particularly narrow sheaves, that gave trouble with the ordinary coupling.

Mr. W. C Blackett said it would have been more interesting had Mr. Ronaldson favoured the members with a sketch of his alleged similar offtake socket.

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DISCUSSION OF MESSRS. A. H. MEYSEY-THOMPSON AND H. LUPTON'S PAPER ON "SOME OF THE CONSIDERATIONS AFFECTING THE CHOICE OF PUMPING MACHINERY."†

Mr. A. H. Meysey-Thompson said that at the previous meeting questions were asked to which a complete answer could not be given at the time, and the authors wished to supplement their replies with the following remarks: — In the first place, some members spoke as if they thought that the writers were opposed to the electrical system of pumping. If they gave any such impression, the writers wished to correct it, as this was quite contrary to their belief. Indeed their view, as stated in the paper, was that for conveying power for pumping purposes to a distance from the shaft-bottom, electricity was, in the majority of cases, the most convenient medium, and they anticipated that, for such conditions, the electrical system of pumping would be largely adopted in the near future. On the other hand, the figures at their disposal (which were quoted in the paper) led inevitably to the conclusion that if pumping could be done direct by a steam-engine placed upon the surface, the conversion of mechanical into electrical energy and its subsequent re-conversion

† Ibid., 1903, vol. xxiv., page 276.

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for use in driving a pump was a mistake when economy of fuel was of importance. And this contention was emphatically supported by the very great economy obtained over a long period of years by Cornish pumping-engines and by the Bradley and Moat engines of the South Staffordshire Mines Drainage Commissioners.

Messrs. T. Y. Greener, H. Louis and others, questioned the liability of an electric spark to fire gas, and the former enquired whether any case could be given where such had occurred. The authors referred him to the inquest on the victims of the fatal explosion at Edge Green colliery last year, where the verdict of the jury was that "the explosion was caused by the ignition of gas, which ignition was brought about by some damage to the electric cable." Mr. A. M. Henshaw stated that the spark of an ordinary signal-bell would ignite fire-damp, and he further stated that it would be most unfortunate if any indiscretion in its use should result in disaster, thereby tending to check the employment of electricity.* With these words the authors thoroughly agreed, and they were of opinion that the system adopted in South Wales and Derbyshire of burying the cable in the ground and adopting three-phase current was a wise precaution, well worthy of more general application. Regarding the use of three-phase
induction-motors, the authors agreed with Prof. Louis that they presented some disadvantages when used for driving pumps, on account of the difficulty in starting and the impossibility of greatly varying the speed. The first difficulty could, in practice, be surmounted by fitting the pump with a large bye-pass, thus enabling it to run practically idle until the motor got into step with the generator on the surface. Where there were great differences in the make of water at different seasons, the second difficulty remained, but if there was sufficient lodge-room it could lie met by varying the number of hours of work, or, if pumping must be constant, by duplicating the plant. On the other hand, the alternating current had certain advantages, and there was no difficulty in using it for pumping purposes, if desired.

Prof. Louis also drew attention to the Riedler xpress-punip* with mechanically-governed valves, as suitable to be driven electrically, but the authors had been unable to hear of any important


example of the use of such a pump, or of any case of such a pump being placed underground. They had seen a small pump of this class which was running at about 150 revolutions per minute, it was in use on the surface for pumping water for boiler-feeding; the suction-valves only were mechanically-governed, being forced down by the ram on its return stroke; and the pump was working apparently satisfactorily with but one train of gearing, but the noise and jar were considerable. As to Riedler steam-driven pumps with mechanically-worked valves, the authors doubted whether the additional speed was worth the increased complication. The difficulty with all pumping-plant was to get the water rapidly enough into the pump, the only available force being the difference between the atmospheric pressure and the more or less perfect vacuum in the pump. In slow-running engines, this pressure would keep the pump solid, that is, the water would follow up the ram when it was moving at a moderate speed, but with high-speed pumps, special precautions, such as raising the water to or above the pump-level, with an auxiliary pump, had to be adopted. Mr. C. W. Martin expressed the opinion that where a large single valve failed to act, the consequent shock could be averted by the use of relief-valves, but the authors' experience did not bear this out. To be really effective in large pumps, the relief-valve must be placed on the ram-case, that is, on the pump-side of the delivery-valve. If then this relief-valve by any means got out of order, the pump was liable to draw air, and under such circumstances the pump might suffer a shock worse than the one which the valve was intended to obviate.

Mr. J. J. Prest expressed the opinion that for unwatering sinking shafts, rod-pumps were not suitable. Whether this be so or not, it was certain that some of the most heavily-watered sinkings had been effected by their use at a very low cost. Where special appliances were adopted for sinking and then pulled out and replaced by permanent plant, the cost of the double installation must necessarily be high. The authors believed that the system adopted at Clara Yale colliery of sinking with an engine, which at one time during the sinking raised 2,000 gallons a minute and was still working keeping the pit dry, was the most economical both in time and money. There was no difficulty in instantly varying the speed of pumping
or the length of stroke, and any duration of pause desired could be made between the strokes. Allusions had been made by speakers to the first cost of the different systems of pumping, and the authors regretted that they were unable in a few words to comply with the request for fuller information: in fact, to reply satisfactorily would require a paper on this subject alone. They might remark, in brief, that from an examination of the costs of the different systems as supplied by themselves, they found that the cheapest in first cost per horsepower was the steam-driven underground engine, next, the overground-engine driving pumps below by means of rods, while both hydraulic and electrically-driven pumps were more expensive in first cost than either of the two former.

Mr. F. R. Simpson (Blaydon-upon-Tyne) said that he had read the paper with great interest, but at the same time with some disappointment at the results of the working of the engines given by the authors. These fell considerably below the duty of the old Cornish engines, which, although cumbrous, were certainly economical. The writers quoted Mr. J. S. Dixon's statement that 10 pounds of fuel per indicated horsepower at collieries was very near the truth.* He (Mr. F. R. Simpson) had taken out particulars from six collieries, three of which were heavily watered, and found that this figure was about 8.5 pounds where high-class engines were adopted for pumping, and probably 10 pounds would be used where pumping did not bear a large proportion to the total horsepower. With regard to the percentage of output used for engines, their experience did not agree with Mr. J. S. Dixon's 7.39 per cent. as the following instance would shew:—At Clara Vale colliery, the average water-feeder, last year, was 1,578 gallons pumped to a height of 336 feet, and 215,810 tons of coal were raised (17 tons of water to 1 ton of coal); and the consumption of coal was only 4.9 per cent.: in this case a great proportion of the steam was used by a large compound condensing pumping-engine, actuating pumps by means of quadrants and developing 240 indicated horsepower at a consumption of 4.18 pounds of coal per horse-hour. He calculated from a trial which was made when the engine was running at half speed, and allowing for a little more economy when the engine was working at a larger load, that this engine would consume 4,021 tons of coal per annum out of a total of 10,500 tons, leaving only 6,454 tons, or 3 per cent., for two winding engines, two hauling-engines, fan-engine, electric lighting, screening and other auxiliary engines necessary for the production of 215,810 tons of coal. There were 5 Lancashire boilers 30 feet long and 7 ½ feet in diameter, working at a pressure of 80 pounds per square inch, and if the pumping-engine be omitted the colliery would be worked by 3 boilers. So far as economy of fuel was concerned, engines must necessarily be placed on the surface, but it must be remembered that convenience in many cases counteracts economy, and where large pump-spears are used there are considerable expenses in maintenance, which are almost entirely saved in the case of ram-pumps placed underground.

The remarks as to cutting-off steam at an early part of the stroke in the Cornish engine, applied also, in his opinion, to large engines of other types working pumps by means of quadrants; and cutting off earlier than three-quarter stroke was probably confined to 24 hours’ trials.

If his (Mr. Simpson's) calculations were correct, the Bradley engine was using 8.5 pounds per pump-horsepower, or 6.4 per indicated horsepower, and gave the low duty of about 20,000,000 foot-pounds, whereas the Moat engine, though slightly better, only shewed 72 pounds and 54 pounds, equal to about 31,000,000 foot-pounds: while the average duty of the old Cornish engine was said, to be 60,000,000 foot-pounds. He presumed that there must be some explanation of this low duty, even after making allowance for the low evaporating-power of the Staffordshire slack; if not, it need not be a matter for surprise that colliery-engines, which had to work under notoriously unfavourable conditions, except in pumping and ventilating, should get dangerously near the consumption of 10 pounds per horsepower-hour.

Smaller pump-valves had proved satisfactory, so far as their experience was concerned. In the Worthington pump, at Blaydon Mam colliery, that idea had been carried still further, and there were no less than 48 small valves, 4 inches in diameter in each pump, and these had worked, without trouble, for many years.

With respect to the length of stroke, in the Worthington engine this was only 2 feet, and the flow of water at the delivery was of remarkable continuity when 1,680 gallons per minute were being pumped (24 double strokes). The consumption of steam at underground pumps must necessarily be high, and their experience pointed to 7 pounds per indicated horsepower when the engine was placed at a depth of 270 feet from the surface.

He had found the use of hydraulic engines for pumping from dip-workings very convenient, though he did not favour taking the power-water from the rising main, but from a pond on the surface, so that in the event of any stoppage of the main engine the hydraulic motor could still be worked.

With regard to the low efficiency of electricity, he would draw the writers’ attention to the fact that, in the instance given the results were quite equal to those of the Moat engine and considerably better than those of the Bradley engine. The generating-engine only used half the coal consumed by the Moat engine, and the comparison was manifestly unfair to the electric installation.

As to the inconvenience caused by the movement of the floor, where engines were placed underground, they had never had the slightest trouble at any of the four engines which they had so situated at the Towneley collieries. In his opinion, it was of the greatest importance to have sufficient standage for water; and, where pumping-engines could be worked at night at their most economical speed and allowed to stand during the day, economy would ensue, and fewer boilers would be required, as the load-line throughout the 24 hours would be kept level, and there would be better opportunities of carrying out repairs necessary for the economical working of the engines. With a view to carrying out this policy, and having regard to the possibility of feeders increasing, engines were frequently erected of a capacity very much exceeding the volume of water to be pumped, and while this might cause a slightly lower duty, the wisdom of providing for contingencies was desirable. Mining-engineers were fully alive to the importance of the use of economical engines, but the difficulty in obtaining a
pumping-engine which could give a duty of 80,000,000 foot-pounds over a length of time was, as shewn by the paper under discussion, not an imaginary one.

Mr F Coulson (Durham) said that for pumping from the bottom of a shaft, probably a pumping-engine on the surface, with spears, and everything well balanced, except the quantity of water to be pumped, was the most economical, having valves so arranged that the water would pass readily through them, but that they would close quickly, and, if possible, mechanically. With regard to in-by pumping at a distance from the shaft, it seemed to him that there would be a great saving in using electricity, where such could be employed, and in other cases in using compressed air. The question of cables sparking was an important one, as they knew that gas could be ignited by sparks. He thought that there was a danger from the wires being taken in-bye, even when buried in the ground, for if there was any leakage it was not easily detected. He knew of one case where from such leakage a shot was fired, by one of the fuse-wires being dropped on the ground, when the other was connected with the shot. Where there was a danger from taking electricity in-bye, owing to the presence of gas, compressed air was the proper means to employ for pumping, and it appeared to him that in a colliery they could generate electricity and compress the air by a much higher class of engine, and save probably 40 to 50 per cent. in the quantity of coal used. In that case they would find that the efficiency both of electricity and compressed air would compare very favourably with other methods of pumping.

Mr. Henry Lawrence (Newcastle-upon-Tyne) said that the paper opened up a large field for discussion, though, as the principal methods were so well known to the members, he would not enter into any details of design or manufacture, but state generally that the best and most effective pump was that which would bring the water from the bottom of the shaft to the surface with the least amount of power; and in order to arrive at that satisfactory state he would say never, if it could possibly be helped, stop or divert the flow of the water; avoid also the use of ends and T pipes and badly-designed valves, with contracted areas, as they created much friction, and the pressure taken by a gauge at the bottom of the shaft, at the entrance to the air-vessel, was very much, and in many cases surprisingly, greater what was due to the statical load. Pumping water from dip-workings to the main pumping-machinery at the bottom of the shaft necessitated consideration, where the power required was much less than could he got from the hydraulic pressure due to the rising main. Hydraulic pumps had been in the past very much used: the power-water was taken underground to the site of the pump at the dip, and as the water subsided it could be easily moved nearer and nearer to the dip, but of course they had the expense of forcing the power-water back to the main pumping-engine; this method, however, was not frequently used at the present day, and then only under very favourable conditions. The most frequent method used at the present time was to work the in-bye pumps with compressed air. Compressed air, as a motive power was considered to be a very expensive one, but this had been very much exaggerated. Many colliery-owners, who had been using
compressed air very largely for pumping, coal-cutting, and other purposes for the last 35 years and were still using it, were quite satisfied with it. It was very useful and convenient, and the exhaust-air aided the ventilation of the mine. The most important motive power was electricity, but as he was not an electrical engineer he would leave that for discussion by electrical and mining engineers, and he hoped, as the matter was most important, that the discussion would be an exhaustive one.

Mr. W. C. Blackett (Durham) said it was not every engineer who would allow the statement as to the danger of an electric spark firing underground gases to go unchallenged; and it must not be admitted that there was a parallel between ordinary coal-gas and that found in mines. The conditions under which firedamp could be fired by a spark underground varied and did not always exist. He hardly thought that Mr. Meysey-Thompson should put forward that a coroner's jury ought to be accepted as the best judges of what would fire gas in the pit. His own experience of juries did not lead him to accept their decision as that of scientific experts. As to the power to be employed for pumping in-byes, he had had some little experience in that direction, and could not altogether give a very good character to compressed air. He agreed with Mr. Lawrence, who probably had in his mind one of their own collieries, when he said that compressed air had been advantageously used for many years, but it might be interesting to know that at a colliery with which that gentleman was familiar compressed air had been replaced by hydraulic power and a Lancashire boiler, in consequence, saved. Compressed air was convenient and easily handled, but it was expensive to instal and it was generally wasteful in use. Mining-engineers spent a large amount of thought and care in erecting air-compressing engines, fitted with efficient valves, and yet when they got the air down the pit it was far too often applied to defective engines and machinery. American engineers had adopted air-compressing machinery to a greater extent than engineers in this country: they employed displacement-pumps driven by the air, like a kind of steam-trap, and by applying these in stages they got a most economical form of expansive working.

Mr. H. Lawrence said he did not wonder that Mr. Blackett found the hydraulic engine more economical than compressed air. In compressed air they had to create the power, but hydraulic power was taken from the rising main or a pond, which was already made.

Mr. T. E. Forster (Newcastle-upon-Tyne) said that compressed air was very often compared with electricity, by taking out an old air-compressing plant and putting in a new electric plant, which naturally gave better results. A compressed-air plant really lasted a great deal longer than the average electric plant, and if interest on capital and depreciation at anything like a fair figure was taken, there was very little difference in the cost.

Mr. G. P. Lishman, with regard to the question of igniting pit-gases by means of an electric spark, said that he had frequently done this with a spark from a 5 volts accumulator at atmospheric pressure.
Mr. C. C. Leach wrote that he had a geared pumping-engine, on the surface, with a cylinder 16 ¾ inches in diameter by 9 feet stroke, geared 6 to 1, supplied with steam at a pressure of 100 pounds per square inch. It worked satisfactorily, and economically, and was pumping from a depth of 500 feet in two lifts: it had lifted 585 gallons per minute, and frequently pumped more than 500 gallons per minute.

Mr. J. Kenneth Guthrie (North Shields) wrote that most important feature about a pumping-plant is that everything should be of liberal design. From experience with these plants he had found that where the plant has been designed to do just the stated service, and has no margin in hand for an emergency, in most of the cases trouble has ensued and breakdowns have occurred. If an electrically-driven pump is to be installed it is necessary to see that the motor, which is to drive the pump, has a considerable output beyond its normal rating, so that there will be no danger of “burning-out” if the pump be called upon to do somewhat more than its rated capacity. With regard to motors it is well to understand that everything in a mine tends to reduce their efficiency: the temperature is higher, there are particles of dust flying about, and there is also a considerable amount of damp in the atmosphere. At the power-end of the pump, the bearings should be very ample: as when one erects a mine-pump of any capacity, it is with the idea that it will run continuously for ever and a day. The gearing, between the pump and motor, should be of the highest class, and the motor-pinion should be constructed of raw hide or fibre in preference to steel. Although a steel-pinion will outlast several of the rawhide type, yet a great gain is made in the reduction of the vibration and the quieter working of the pump. A raw-hide pinion will run without attention for 18 months, and if a steel-pinion were adopted it would probably last from 6 to 10 years.

The pump-end of an installation is probably the most important item. In the case of a steam-driven one, there is a certain amount of elasticity in the working, and if anything should happen to be wrong in the design of the water-end, or an obstruction takes place from any cause, in most cases the steam-end will adapt itself, at least to some extent, to the changed conditions. If, however, in the case of an electrically-driven pump, something were to go wrong with the valves, or if these were of too small an area, nothing could save the pump from working noisily, and perhaps it would damage itself. It is well, therefore, to be careful as to the pump-end, especially as regards the arrangement of the valves and the valve-area. If the valve-area is too meagre, it cannot be expected that the pump will work quietly, as an excessive speed of water will take place the passages, causing the valves to hammer.

In the planning of pumps it is generally advisable to adopt a design in which the water is flowing, as a general rule, in one direction, that is to say, coming in from the suction-side and flowing towards the delivery. This is not the case in many pumps, and any strictures of the passages through which the water is led means a restricted output, or at the best noisy working. The suction-end of a pump is by far the most important, and it is advisable to see that the pump is properly supplied with suitable pipe-connexion. On the suction-side, the level of the water to be pumped should not be more than 15 feet below the level of the pump-valves. The suction-pipe should be of somewhat larger diameter than the delivery and
provided with a foot-valve, which should have an area considerably in excess of that of the pipe. A strainer should be placed next to the pump so as to keep out all destructive matter, and an easy examination for cleaning can be made by removing the upper cover. The area through the strainer should not be less than four times that of the pipe. They are sometimes put in having the total area of the small holes drilled into the strainer, just the same as the pipe. As a matter of fact only about one-third of this area is effective, a great loss being caused by the friction of the water through the small openings. As the metal continues to corrode, one can understand how small a quantity will in due time reach the pump. This strainer dispenses with the danger of gags, mentioned by the authors, and in the Riedler pump, which he mentioned in the former discussion, even should a gag of a moderate size, say of the thickness of a lead-pencil, get into the valve, no damage is done to the gear, as there is a special buffer provided for the contingency.

A check-valve should be placed on the discharge-pipe, so as to relieve the pump of the weight of water held in the rising main. Beyond this check-valve, a charging-pipe should be led into the suction-pipe so that the pump may start with a load. There should also be placed in the delivery-pipe, or on the delivery-valve covers of the pump, suitable starting-valves to enable the air to escape from the pump while the water is flowing from the rising main. The operation of starting the pump should, therefore, be to open the charging- and starting-pipe valves some minutes before starting the pump. After starting the pump, the starting-valves should be closed so soon as the air has been discharged.

In his experience of pumps, where there has been trouble, almost in every case it has been found to occur on the suction-side of the pump, and it is due either to an obstruction in the pipe, or to the insufficient area of the foot-valve or strainer. In every case where the head against the pump is considerable a relief-valve should be fixed as near as possible to the pump on the delivery-side, and set at a pressure slightly in excess of the working-pressure. This accessory prevents the bursting of the pump, due to a valve being closed, or to a sudden stoppage in the discharge-pipe.

In the case of the water failing to reach the main pump or to a valve being held up, the governor should immediately come into action, thus preventing the racing of the engine and the bursting of flywheels. In a paper read in 1891, he mentioned in describing the Napier cat-governor on the Eltringham pumping-engine, that "on one occasion, with 14 inches setts, the ball of the governor was seen to fall, the engine stopped and then went quietly on: a man being sent down the shaft found that a spear of one of the setts was broken."*

As to the consumption of steam in underground pumps, of course there will always be a loss with a steam-pipe, but at two collieries in Scotland, the owners are erecting small superheaters in the flues of the boilers, sufficient to send the steam down the shaft in a dry state; this is more like effectual steam-drying than superheating.

He (Mr. Gruthrie) could not agree with the authors as to the great advantage of using surface-engines; facts spoke for themselves, the old system had of late been going out, underground force-pumps were being substituted for those worked from bank, and now that electrical power could be so economically transmitted they were coming still more to the front. He had had considerable experience with pumping since serving his apprenticeship with Mr. J. B. Simpson, who was then erecting a Hathorn-Davey horizontal underground engine, which he understood had since given capital results; and while he had known of several serious
stoppages of engines through breakages of spears, quadrants, teethed wheels, etc., he had seldom encountered serious cases with underground pumps. These in his experience had not been hidden away in holes and corners, but were,


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as a rule placed in roomy chambers near the pit-bottom, well lighted, and with all parts perfectly accessible, and he considered. if the cost compared very favourably with that of plants placed on the surface.

Mr V. H. Meysey-Thompson, replying to the discussion, said that the ordinary engineer wanted to know how many gallons of water could he raised so many feet high for each pound of coal, and in the paper they had tried to reduce everything to that one standard. In the Moat and Bradley engines, which had been running for nearly 20 years, the pounds of coal and the number of gallons were given, and it was easy to ascertain the foot-pounds of work, and the table at the end of the paper (Plate VI.)* reduced all the comparisons to one standard. Mr. J. S. Dixon practically agreed with Mr. A. M. Henshaw as to the consumption of fuel, and the reason for these figures being adopted as the standard was merely that they might be independent. It did not matter how they fixed a standard for the steam-engine, as they had to compare hydraulic with electric power, and if a more economical engine was used to produce electricity it should also be applied to the hydraulic motor. Mr. F. E. Simpson said that he had not experienced any difficulty from the shifting of the foundations of underground engines; and if some of their friends were in a similar position they would not have had so many difficulties to overcome. In some cases, it had been necessary to fix girders to support the engines, so that they did not rest upon the floor. As to overground engines cutting off at three-quarter stroke, the object of the second cylinder was to enable the high-pressure cylinder to cut off later in the stroke. The difficulty with the old Cornish engine was with an early cut-off: they required a high initial velocity to enable the engine to finish its stroke, and the object of the second cylinder was to secure the high expansion without this initial velocity. Mr. F. R. Simpson had found small valves satisfactory, but it was their later practice to enclose each valve in its own box, with the advantage that it could be easily taken away and replaced. The figures quoted by Mr. F. R Simpson as to the consumption of fuel by underground engines agreed very nearly with these given in the paper. As to the desirability


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for a plant working only for a few hours in the day, attention had been drawn to this in the paper, more especially as regards electric pumping-. If the power was purchased from a power-station, it was wellknown that the power-companies had a difficulty in providing power for only a few hours, and if the pumping could be done at a time when the station had a small demand the current would be supplied at a cheaper rate.
Mr. H. Lupton said that the duty of the Bradley engine was 25,500,000 foot-pounds, averaged over 13 years, including losses for banking fires, etc., and the average speed of the engine was rather under half the speed for which it was erected. The average duty for 10 years at the Moat engine was 31,000,000 foot-pounds, and that also included all losses for banking fires etc., so that these were not, in any respect, trial-duties. The coal used had an evaporative efficiency of 4 ½ pounds of steam per pound of coal; and the engines ought not to be compared with a modern engine working with high-pressure steam, as they were working at a pressure of only 60 pounds per square inch. If they took more comparable duties, that was, where the coals were of better quality, it would be found that at Yarlside, taken over a 5 days' trial, one surface-engine gave 53,000,000 foot-pounds, and a second engine, 51,000,000 foot-pounds, while the engine belonging to the Cleator Iron-ore Company gave 50,750,000 foot-pounds. These engines had a steam-pressure in each case of 80 pounds per square inch. An electric plant, at South Durham colliery, had a duty of 29,000,000 foot-pounds, very near the duty of the Staffordshire engines, but the coal was of a much better quality. It was a day's trial, and not a 10 or 13 years' trial, so that it was hardly comparable, and the 29,000,000 foot-pounds should be compared with the engines yielding 51,000,000 or 53,000,000 foot-pounds. He (Mr. Lupton) found that the cost in South Staffordshire over 10 and 13 years was £11 2s. 5d. per actual continuous day-and-night horsepower in the water lifted per annum, which was equivalent to a charge of 0.22d. per electrical unit: and he did not know that electrical units were sold anywhere at so low a rate. At Chamber colliery, where the engine was underground, and the steam taken down shaft, a trial gave a duty of 37,000,000 foot-pounds, and the consumption of coal was 6 pounds per pump-horsepower. So far as

the underground engine was concerned, the duty of the electric plant was very near the duty of the underground engine, but the cost of the electric plant was at least double the cost of the underground steam-engine.

Mr T. E. Forster pointed out that the electric plant at South Durham collieries was not working at its full power.

The President (Sir Lindsay Wood, Bart.) said it was quite possible to take electricity into mines where it would be absolutely safe, at any rate, in the main ways. The three-phase system, with properly constructed covered cables, would be quite safe. Of course in a gaseous mine they would not adopt it.

DISCUSSION OF MR. M. FORD'S PAPER ON "SINKING BY THE FREEZING METHOD AT WASHINGTON COLLIERY, COUNTY DURHAM."

Mr. W. B. Wilson (Easington) asked whether in sinking through the 41 feet of wet sand any difficulty was experienced in supporting the sides of the shaft.

Mr. E. Coulson (Durham) thought that it would be interesting to know something as to the ice-forming capacity of the plant at Washington, or more correctly speaking, of the heat-extracting power, and although Mr. Gobert said it was most satisfactory that the capacity was
taken in Centigrade degrees, it would be better if it were given in Fahrenheit degrees, with which they were more familiar, and he thought that the capacity of the plant might be given in British thermal units. It would also be interesting to know to how much greater depth the plant at Washington was capable of sinking. He believed himself that it was a question of time, and that the lighter plant required more time. Mr. Ford's paper also referred to the heat-conductivity of the clay, and this appeared to him to have an important bearing on the freezing of the pits. Taking the conductivity of the slate at 1,000, flag-stone would be 1,110, brick 730, clay 504, and cement as was 200. In freezing the alluvial deposits of clay and sand gravel, this seemed to have an important bearing, because having formed the ice-walls with a layer of slow conductivity


[260] between two layers of a higher conductivity, if the ice formed around, above and below the layer of slow conductivity, then, unless some means were taken to provide against it, this layer would freeze, and in freezing, if it contained much water it would expand to the extent of about one-tenth of its bulk and the expansion being irresistible, it would probably break through the ice-walls. In some cases, or even where there was a thick bed of clay over a bed of sand resting on the stone-head, the force of the ice would be so great that it would break the ice-walls. It would certainly find out the weakest place, and it might destroy the freezing-tubes. This can be provided against in some cases by putting bore-holes in the middle of the pit, and it occurred to him that they might, in some cases, with advantage freeze the bore-holes before freezing the side-walls. At Washington, all the tubes except the freezing-tubes were withdrawn, but, in some cases, light tubes were inserted to protect the freezing-tubes. At Washington, there was an accident from the explosion of a gelignite-cartridge; and it might or might not be caused by the freezing. For some unknown reason, odd cartridges of gelignite were occasionally found not to have exploded. He considered that compressed powder was the best and safest explosive, and it would give the best results in a sinking pit. There was no necessity to use gelignite in frozen ground, as its great advantage was found in wet pits, where there was difficulty in drying the holes. It seemed to him that it was absolutely necessary to bore to the stone-head, because the form of the frozen ground at the bottom of the shaft was like the bottom of a bottle and left a weak place. And there was also uncertainty as to how the sand-beds lay in alluvial deposits. A short distance from the pit, the sand-beds might occur, and in all cases where there was no knowledge of the thickness of the sand, or the direction in which it lay, it would be desirable to bore and freeze down to the stone-head. There was another system, which might be applicable, not so much in quick-sands as in shales and in the Coal-measures where water was encountered, if it could be relied on that the partings were all horizontal and would be reached by the bore-holes: this was by forcing in what was called "cement-broth," which would flow almost anywhere where water would flow. If this method were successfully carried out, it would replace and render tubbing unnecessary. A vertical

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gullet might be met with, however, which was not touched by one of the bore-holes and they could not force cement into it.

Mr. Mark Ford, replying to the discussion, said that no difficulty had been experienced in sinking through the wet sand, the sides were quite solid, and with the exception of the 6 feet length inserted near the surface, nothing was used to support the sides of the shaft. With regard to the ice-forming capacity, the quantity of water supplied to the condenser was 4,000 gallons per hour and was heated 18° Fahr., equal to 720,000 British thermal units per hour. It was noted that the clay was more or less frozen into the centre of the pit, while the wet sand was in the ordinary condition in the centre of the pit. Further, the frost seemed to endure longer in the clay than it did in the sand, that portion of the shaft-walling backed with clay was wet for several weeks, while the walling which kept back the sand was dry during the same period of time; and the water that came from the freestone into the pit, and filled it to a height of 20 feet from the bottom, was, for 5 or 6 weeks after freezing ceased, only 5° or 6° Fahr. above the freezing-point. The clay sunk through was of a very tenacious character: bellite was tried, but with rather poor results, and better results were got from gelignite. Diversity of opinion still existed as to the necessity for freezing the clay, and even the German operator confessed that the clay at Washington was not thoroughly understood by his firm; they did not realize that it was of so tough a nature, and evidently thought that it resembled the clay referred to by Prof. Louis in the previous discussion.

Mr. W. C. Blackett (Durham) thought that it was not a question of the conductivity of the clay and sand, so much as the conductivity of the water in small bulk and water in large bulk. They had water in clay in small bulk, but the water in the sand was of greater bulk than that in the clay, and possibly capable of circulation, and as water was such a well-known non-conductor of heat, the water in the clay would freeze more quickly because it was of lesser bulk and less free to circulate. Then there was an anomaly in Mr. Ford's statement that whereas the clay showed that it conducted heat quickly while freezing, yet while thawing it conducted it more slowly; this was difficult to understand.

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Mr. M. Ford said that the behaviour of the clay as mentioned by Mr. Blackett would be accounted for by the specific heat of the clay and the fact that the ice-wall had penetrated further into the clay than into the sand.

DISCUSSION OF MR. T. ADAMSONS PAPER ON "WORKING A THICK COAL-SEAM IN BENGAL, INDIA."

Mr. R. R. Simpson (Calcutta) wrote that, as one who had seen and studied the methods of working the thick coal-seam at the East Indian Railway Company's collieries at Giridih, he was unable to agree with those critics who had expressed the opinion that the method of working was unsafe; on the contrary, the very opposite was the truth. At the present moment, he was unable to refer to the statistics of accidents to workmen employed in extracting coal by this method, but he was convinced that they would compare most favourably with those for other methods of working in India, and still more favourably with those for those districts in Great Britain in which thick coal-seams were worked. The inspectors of mines in India thoroughly
approved of the system and were accustomed to hold up the methods in vogue at Giridih as an example to the rest of Bengal. The secret of the success of the system was two-fold: (1) The sandstone-roof is an excellent one, and an area, 500 feet square, has been known to remain suspended for some considerable time after the coal has been extracted. The roof, when it falls, breaks off sharp, and very little coal is lost by crushing. Working is safely resumed alongside a fallen area on the day after the fall has occurred. (2) Excellent discipline is observed at the Giridih collieries, and the officials and workmen are thoroughly trained to appreciate and guard against the dangers incidental to mining operations. The Special Rules of the collieries, which are strictly enforced, far exceed the requirements of the Indian Coal-mines Act, 1901; and an elaborate and carefully-checked system of written reports is also in operation. The testing of the roof and sides was carried out in a manner which he had no seen surpassed in any British colliery.

The chowkidars, or "watchmen," left in the goaf, vary from


10 feet square, the original pillars are 100 feet square with roads 8 feet wide: and four chowkidars are thus left in an area 108 feet square. The loss in working from chowkidars, therefore, varies from 2.2 to 3.4 per cent.: adding to this the 4 per cent. loss in thin ribs, the total loss in working is seen to average from 6.2 to 7.4 per cent. He thought that this small loss combed most favourably with the loss incurred in working thick seams by longwall, in two or three carries, and certainly a much larger percentage of round coal was obtained.

Mr. Thomas A. Ward (Giridih, India) wrote that the impression evidently left by the reading of Mr. Adamson's paper was that the system described was dangerous. This impression was, he thought, due to the omission of the writer to make it clear that the heavy blasts of air, caused by roof-falls, are not inherent in the particular system described, but are common to all the systems which had been tried—even to the "rabbit-warren system," to quote Mr. J. P. Kirkup's apt expression—and are due to the massive character of the roof. The sandstone is not laminated and hardly any, and no regular, bedding-planes can be distinguished. The intercalated seams of coal are the only regular dividing-planes up to which it is usual for large areas of roof to break. An accident in which several lives were lost occurred last year, in the Raneeganj coal-field, from this cause. The system of working was the "rabbit-warren," and the pillars were being brought back. The air-blast killed men who were a long way back from the face.

In 1885, in this coal-field, the pillars in a seam only 8 feet thick, which had been opened out on the pillar-and-stall system, were being brought back. The mine was worked from the outcrop by adits. The miners had been withdrawn because the roof was uneasy, and three had seated themselves at the entrance to the mine. They were not under cover, but they were killed, one body being thrown about 100 feet. A small party, just before engaged in drawing timber, were actually in the mine at the moment that the roof fell, but as they were not in the direct current, they escaped uninjured.
These instances—which could be multiplied—show that there is no increased danger from this source when working the system described. The substantial pillars, or chowkidars, which are left,

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help, in fact, to cause the roof to break up in falling and diminish the force with which the air is displaced. These chowkidars are spaced 30 feet apart, and not 40 feet, as stated in Mr Adamson’s paper.

The system is really a modification of the method by which the Thick coal-seam of South Staffordshire is won. The sides of work, there, are laid out, nearly always, with 30 feet openings. The main difference in working has arisen from the fact that the coal in India has no partings, so that it cannot be “cut in” in layers, as in South Staffordshire, but has to be brought away en bloc as described. The openings are not so dangerous as in South Staffordshire, as the ground is in every respect much stronger.

Mr. T. Adamson (Giridih, India), replying to Mr. A. L. Steavenson, wrote that the result of over 12 years working at the collieries of the East Indian Railway Company was that 70 per cent. of the total output (which in 1902 amounted to 614,000 tons) was wrought by the system described in his paper, without a fatal accident having occurred directly from the system, and this proved that it was not a dangerous one. The conditions were altogether different at Giridih, to what existed in the county of Durham. The Giridih seam usually comprises 21 feet thick of good coal, without a single stone-band in it. The floor and roof are hard sandstone and a roof better adapted for the working of the system is not, perhaps, to be found. The knobs are blasted out, and are not left to fall out “at random,” as stated by Mr. Steavenson. The Giridih seam occurs in the Coal-measures and not in the Mountain Limestone.

The area wrought before a fall of roof takes place, varies from 150 feet by 150 feet to a much greater area. He (Mr. Adamson) knew of a goaf, 800 feet by 200 feet, where all the coal had been removed, without even a tell-tale being left in it, which stood for 3 or 4 years before it came on. As the blasts caused by large goaf-falls are great, it was found advisable to leave the tell-tales or indicators as stated in the paper.

With reference to the system worked by Mr. T. E. Forster in Australia, he (Mr. Adamson) had seen mines, which were worked 15 years or more ago, in Bengal, in the same way. The whole of the area from the shaft to the boundaries was cut into pillars.

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(square or rectangular). The pillars were made small, and the roads were driven wide. In recent years, attempts had been made to remove these pillars, with the result that, when a few pillars had been removed, the roof instead of breaking down (on account of its great strength, like the roof over the Giridih seam) settled upon the remaining pillars and crushed out several acres of them.

The coal is of a somewhat hard nature, with thin dirt-partings (2 to 4 in number in the seam 21 feet thick), and the undergoing is made up to one of these partings. The coal rests directly upon hard sandstone, and there is no under-clay. Traces of plant-remains have been found in the beds above the seam, but they are very rare.
An area took fire over 20 years ago, which had been worked on the old Bengal pillar-and-room system, the pillars being made small and the galleries wide. As the pillars were too small to maintain the roof, the latter collapsed, and buried a large area of crushed coal, which after a time took fire, and the fire-area was enclosed by masonry-dams.

No fires had taken place since the system described in his (Mr. Adamson's) paper was introduced. A fire on a large scale could not occur, as there was so small a quantity of coal left, the tell-tales being spaced 40 feet apart, and the ribs 200 feet or more apart. If there was a fire, it would only be necessary to build 2 stoppings in the gate-ways through the ribs, and shut off the fire from the rest of the mine-workings.

The old system, referred to by Mr. J. P. Kirkup, was introduced for dropping the top portion of pillars that had been formed before the dropping system was introduced. As the galleries had been driven, in most cases, to the full height of the seam, chatnies were not required to be driven, and a less percentage of the seam was dropped than when the roads were driven in the bottom portion of the seam, and narrow chatnies driven in the upper portion of the seam. Therefore, the advantages were less than those accompanying the present system, and it was not so safe, as a large portion of the roof was exposed at an early stage, and needed constant attention. The roof is an unusually good one, and enabled 90 per cent. of the coal in the seam to be obtained.

The 15 feet of dropped coal was mostly in large pieces, and

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had sometimes to be broken with picks, before it could be loaded into tubs. The coal may be sampled as follows:—Steamcoal and rubble (rubble is 1½ inches cubes) 85 per cent. and less than rubble (smithy and dust) 15 per cent. The smithy is consumed under the colliery-boilers and the dust-coal is all made into coke.

**DISCUSSION OF MR. S. J. POLLITZER'S PAPER ON THE UNDERLAY-TABLE.**

Mr. James Henderson (Truro) wrote that Mr. Pollitzer's apparent object is to show that by means of the underlay table a base-line, run at the surface, can be accurately transmitted down an underlying shaft; and that the system he recommends is preferable to that adopted by mine-surveyors generally. Having read the description of the above instrument and its applicability to underground surveying, the writer is desirous of making the following comments thereon. It appears that as the length of a base-line afforded by the underlay-table cannot exceed 2 feet or thereabouts, the survey of a diagonal or underlie-shaft, would be a very hazardous business as to accuracy, and even if this base-line could be extended to a greater length, the time occupied in the repeated fixing of the instrument and the suspension of the necessary plumb-lines, would be so great as to render its adoption practically useless. While, on the other hand, by means of a miner's theodolite or the Henderson rapid traverser, in both of which the vertical limb so overhangs the horizontal circle or plate as to render the reading of the vertical angle from 0 to 90 degrees perfectly easy, the various changes in the vertical and horizontal deflections in a shaft can be taken and recorded with accuracy and rapidity. If it be assumed that the measured draft-line down the shaft is, say, 100 feet in length, and the underlie is 60 degrees, which is of frequent occurrence in metalliferous mines, it would seem that the underlay-table would require to be placed in position no less than 25 times, with the probable result that the operator's mind or temper would not be in a very
enviable condition when in the drawing-office calculating or plotting his work afterwards. By the same rule, an underlying shaft of 70 degrees would require 17 fixings of

† Ibid., 1893, vol. v., page 199.

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His instrument: one of 80 degrees 8 fixings, and so on; the only angle suitable for one fixing would be 88 degrees 51 minutes, or 1 degree 9 minutes from the perpendicular. An unnecessary number of draft-lines is what every surveyor should avoid, whether at the surface or underground and he (Mr. Henderson) failed to see what advantage would be gained by the use of the underlay-table, when the traverse of a shaft of any angle of underlie could he so readily and accurately ascertained by means of the instruments before referred to.

DISCUSSION OF DR. E. D. PETERS’ PAPER ON THE “TREATMENT OF LOW-GRADE COPPER-ORES.”

Mr. J. J. Muir (Tasmania) wrote that Dr. Peters, in referring to low-grade disseminated sulphide-ores of copper, in a siliceous matrix, and of a character similar to that of the Australian ores investigated by himself (Mr. Muir) emphasized his dissent from the necessity of a preliminary concentration. He fully agreed with Dr. Peters on this point, but his contention for this operation as a preliminary to lixiviation, was especially provided to meet an objection peculiar to Australian mining investors, namely:—That to raise capital, for the development of copper-mines, it is essential to show the immediate return of a sufficient amount of metal to pay the working expenses of the mine; and the profits that are obtained from the deferred process of lixiviation are then acceptable. In his (Mr. Muir’s) paper† on the subject, he made a special effort to provide this condition, and no doubt Dr. Peters would agree that, under the local circumstances, his advocacy was legitimate. In following out his investigations on these ores to a metallurgical conclusion (which he had finally completed since writing his paper on the subject) he had fully established the great advantage of preliminary dry crushing and roasting of the ore. He was gratified to hear that the same result had been independently arrived at by Dr. Peters. The operation of roasting, after the ore had been crushed fairly fine, imparted to it a physical change, and fully bore out what Dr. Peters claimed for it. The ore assumed granulated form, and was amenable to quick percolation and

† Ibid., 1902, vol. xxiii., page 517.

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perfect leaching. As the final outcome of his (Mr Muir’s) extended researches on Australian ores, as described his paper, he had devised an original forced process, whereby the copper was extracted, and precipitated in 12 hours, on any tonnage up to the capacity of the plant that he had designed. In the circumstances of the ores under discussion, it appeared that the only possible solution of the problem, was a method based on the lines that he had indicated—
utilizing the chemical conditions of the ore itself in the process, and finally melting the precipitates into coarse copper-bars at the works. In the method that he had finally adopted for his personal operation, the cost, under general Australian conditions, were 15s. per ton of crude ore for the complete operation: and from Dr. Peters' description of the conditions prevailing in the United States, he saw no reason why similar results should not be easily arrived at in that country.

Mr. Horace J. Stevens (Houghton, Michigan, U.S.A.) wrote, in explanation of the existence of Lake Superior copper-mines successfully extracting the metal from ores averaging less than 1 per cent. of copper, that it might be said that the Lake Superior mines were all very low grade under ordinary circumstances, the richest mine returning less than 3 per cent.; there were no gold-values, and the silver-values were so small as to be scarcely worth consideration. The Lake mines, however, were unique because they mined native copper exclusively. In most copper-districts, more or less native copper was found in the alteration-zone, especially in association with cuprite, but outside the Lake Superior mines native copper was mined upon a scale of importance only in the Coro Coro district of Bolivia, and from one or two mines in Eastern Canada, although extensive and possibly workable deposits of native copper, disseminated in igneous and sedimentary rocks, were known to occur in Australia and elsewhere. The Lake Superior mines possessed a great advantage, by reason of the remarkably simple and inexpensive process of reduction required. The metal was won by crushing the rock and concentrating the copper-values, while smelting was simple requiring merely the addition of limestone for flux and the necessary fuel-charge. The complex smelting conditions noted in many copper-districts were entirely lacking. In addition to the advantages already enumerated, the Lake superior mines possessed the great advantage of being able to draw on almost unlimited capital, and the equipment of the larger mines was upon a scale of magnitude paralleled only by the mining operations on the Rand of South Africa. For the reasons already set forth it was unsafe to use the figures of values from Lake Superior copper-mines in estimates of the possibilities of other fields.

The conditions in Australia were much the same as in certain important cupriferous fields of the United States and Mexico, although perhaps more aggravated. The drawbacks to the operation of low-grade ore-deposits included aridity, lack of adequate transportation-facilities, and scarcity and high prices of fuel. Without good water or rail-transportation, and without adequate supplies of coal or coke of fair grade at a reasonable price, smelting was too costly with low-grade ores in Australia as elsewhere. Many people had thought otherwise, but the results had proved them to be mistaken.

The tendency of copper-production seemed against the suggestion of Mr. Muir, that ores should be transported to the seaboard for smelting. Under exceptional circumstances this plan was feasible, but ordinarily the process of reduction should be carried on as far as possible at the mine. Fifty years ago, the bulk of the world's copper-production was shipped to Swansea as ore, for reduction. Since that time, the tendency had been toward smelting at the mines. It was true that a large part of the American copper-production was smelted in the western half of the United States, and that the blister-copper, produced by the local smelters, was sent to the Atlantic seaboard for electrolytic refining: but in this case the impurities carried in the blister-copper averaged only 1 or 2 per cent., and the excess freight on such impurities was
so trivial a matter that it was much more than offset by the superior advantages offered for electrolytic plants along the sea-coast.

In the way of direct smelting of low-grade ores, some remarkable results had been secured in the United States and Canada during the past few years. In the Deadwood district of British Columbia, the cost of smelting had been reduced to 1.35 dollars (5s. 7 ½ d.) per ton of ore. This location, however, afforded advantages in the way of transportation-facilities and fuel that were entirely lacking in the more remote districts of Australia.

It would seem, from the examination of available data, that direct smelting was out of the question in the case of many or most of the low-grade deposits of Australia. A combined reduction-process of mechanical concentration, followed by smelting of the concentrates was a highly satisfactory process where conditions were favourable. This system, however, called for a large and steady water-supply, which was often lacking in the interior of Australia, and it should also be borne in mind that not all low-grade ores were adapted to economical concentration. While certain ores were being successfully concentrated 20 into 1 at the present time, 3 or 4 into 1 was nearer the average of what was considered successful practice, and even in such cases the losses in fines was very considerable, although much reduced latterly by the very general use of concentrating tables of the well-known Overstrom, Wilfley, or Bartlett types.

It seemed to him (Mr. Stevens) that lixiviation held forth the greatest promise for the low-grade ore-deposits of Australia, and of many other cupriferous fields suffering under somewhat similar disadvantages. The highly successful results secured by comparatively inexpensive processes of lixiviation in Spain and Portugal, and more especially at the Rio Tinto mines, were worthy of careful study. Mr. Eissler's comprehensive little work on the Hydrometallurgy of Copper contained a great fund of information and might be studied to advantage by those interested in the treatment of low-grade ores.

The Neill leaching process was now undergoing its initial test at the Coconino mine in Arizona, and the results secured, while not final, owing to the short time during which the method had been employed, were highly satisfactory and very promising. This process was based on the solvent action of sulphurous acid upon copper oxides, carbonates and silicates, in the presence of water and an excess of the acid. The copper in the oxidized ores went into solution as a sulphite, which, though insoluble in water, was soluble in an excess of sulphurous-acid solution. When the excess of sulphurous acid was driven out by heat the cuprous sulphite was precipitated as cupro-cupric sulphite, a finely crystalline, dark red salt, carrying 49.1 per cent. of copper. The precipitate was smelted to blister-copper, practically without fluxing. The sulphurous acid was made from roast-gases, and would dissolve more copper than sulphuric acid, while being weaker, it did not dissolve other metals which fouled the solution and absorbed sulphur. The process, as applied to the oxidized ores of the Coconino mine, was briefly, as follows: The ore is reduced by crushers and rolls to pass through a 20 meshes screen. The crushed ore is charged into a covered wooden tank containing wash-water, carrying a little sulphurous acid, 2 tons of this
watery solution being used to 1 ton of ore. The washed sulphurous-acid gas is forced by an air-compressor through the charge in the leaching-tank entering near the bottom. The process can be completed in one tank, but tanks in series are preferable. The pulp from the last leaching-tank is drawn into another tank and forced into a filter-press under air-pressure. The cuprous solution from the filter-press is conveyed by pipes to steam-tanks and the pulp remaining in the press is re-washed. The cuprous solution is heated by exhaust-steam to boiling-point, thus expelling the free sulphurous acid. Part of the copper is precipitated by gravity, under heat, the balance of the solution being drawn off into other tanks and the copper precipitated therefrom by scrap-iron or lime. The process is adapted to low-grade oxidized ores carrying neither gold- nor silver-values. It is also applicable to sulphide ores, previously roasted to drive off sulphur, and oxidized in the process. If gold- and silver-values are carried in the ore, these can be secured by chlorination after leaching.

Mr. H. Lipson Hancock (Moonta Mines. South Australia) wrote that, with the low price now ruling for copper, the treatment of low-grade sulphide-ores in a profitable manner was a perplexing and difficult question, and required all the skill that could be centred on it in order to bring it to a successful issue. The friendly discussion on the subject should, therefore, be helpful in possibly throwing some further light on an important matter. As far as his experience in the matter of low-grade copper-ores was concerned, he endorsed Dr. Peters' comments relative to concentration preceding the wet treatment, where mining costs are very low. Mr. Muir's paper,* however, relative to this part of the subject seemed to present a rather extreme case, as his tailings appeared to be nearly as rich as the crude ore.

At the Wallaroo and Moonta mines concentration is chiefly accomplished by Hancock jigs, and the quantity passed over each


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machine per week (working one shift of 8 hours per day) totals from about 500 tons at the Moonta mines to a little over 1,000 tons at the Wallaroo mines, or equal to the rate of 1,500 to 3,000 tons each machine per week for full time. At the Moonta mines the crude vein-stuff contains from 2.5 to 3 per cent. of copper, the tailings being reduced to under 1 per cent. At the Wallaroo mines, where the crude vein-stuff—the matrix of which is of higher specific gravity—represents an average copper-content of a little over 4 per cent., the tailings contain between 1 and 1.5 per cent. of copper. Both these cases indicate a fair recovery of copper by concentration.

The tailings from the dressing machinery at both mines are passed on for cementation. At the Wallaroo mines, the latter work is not sufficiently advanced to describe the results, but at the Moonta mines, where over 1,000,000 tons are in process of treatment, copper is being extracted for £25 or £30 per ton. The concentration has paid all costs of these heaps being placed in position. In this way it has, in addition to profit, saved huge expenditure as capital-cost which would otherwise have been necessary, had the vein-stuff been placed to cementation direct, which capital-cost most likely would have prohibited the adoption of the hydro-metallurgical process.
It is, of course, well known that the sulphides of copper are scarcely dissolved with weak acid, and oxidation is required to make the work a success. Mr. Muir appears not to have expressed himself on this point: and experience here has shown that, without oxidation, the application of weak acid under the circumstances is of very little avail. The action of wind and weather opens the way for the use of acid, but the judicious and systematic application of ferrous salts, which gradually become converted more or less into the ferric state, extraordinarily hastens the process and promotes good oxidation. The addition to the liquors at this stage of a very small percentage of sulphuric acid dissolves the oxides of copper which have been formed, and tends to make a very satisfactory leaching proposition under the conditions described. If a larger proportion of iron-pyrites be associated with the sulphides of copper, the proposition should be an easier one for leaching, although it would militate more or less against the success of the concentration problem according to the proportion of the iron-pyrites present.

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Of course, it is impossible to set out a process equally applicable to all cases, even should the copper-ores and matrix be somewhat similar, as even the minerals themselves appear to assume different characteristics in different localities. He (Mr. Hancock) would suggest, however, that unless the grinding or roasting could be done very cheaply, it might be a heavy tax on the cost of extracting the copper, and as the grinding of the ore produces a slimy portion, this latter would be likely to interfere with a percolation-treatment of any depth, even though the roasting should improve the porosity of the mass. In the case where concentration precedes cementation, the finer slime-products are, of course, kept separate for purposes which are manifest.

Mr. C. Fernau (Alston) wrote that, in discussing in general terms the treatment of low-grade copper-ores, a distinction must be drawn between copper-ores, where the copper is the main or only valuable metal present, and copper-ores, the value of which is enhanced by the presence of gold and silver in appreciable quantities. Where copper alone is the object of treatment, the problem is one that, only in exceptional cases, admits of more than one solution. Low-grade ores are those containing a maximum of 3 per cent. of copper. Leaching requires either exceptional ores, decomposing in the presence of air and moisture, as in the case of the Rio Tinto ores; or exceptional circumstances in the way of the cheap supply of salt and acids. The capital required is large, and in the case of the Rio Tinto ores, the time required for the completion of the process is very great—10 years or more. After the first 10 years, the process no doubt becomes continuous, and about as much copper is obtained in any one year, as the amount of copper laid down. The percentage of extraction is in the long run very high, higher probably than by any other method, but the ores suitable for such treatment do not occur very generally. Nor does it often occur that mines are so situated as to permit of the cheap handling by means of acids that other leaching processes require. Smelting is a method more generally applicable, and gives a fairly high extraction. Still, the loss is appreciable, and rarely is less than 0.50 per cent. of copper left in the slag. He (Mr. Fernau) had obtained slags from pyritous material, smelting with charcoal.

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with a low blast, as low as 0.25 per cent., and had seen million tons of slags in Spain, smelted by the Romans, containing only 0.12 per cent. How the smelting was done, however he had no accurate knowledge—probably in hearths not much larger than blacksmiths' forges, and with a blast produced by a bellows. He considered that 0.50 per cent. in modern practice was not bad it would be unsafe to reckon on less. No doubt a highly siliceous slag can be allowed in a blast-furnace, but, as a general rule at the expense of fluidity in the slag. In one case, he smelted with 45 per cent. of silica in his charge, and obtained slags containing 1.20 per cent. of copper. This was reduced to about 0.70 per cent. on reducing the silica-contents to 28 per cent. The higher loss, however, paid better, as the flux was very costly Assuming a loss of 0.50 per cent., it requires cheap fuel and labour to make a 3 per cent. ore profitable, as well as cheap ore. The cost of smelting, including fuel, flux and labour only will rarely be below the value of 1 unit of copper and the loss ½ unit, leaving only 1½ units for the cost of mining and reducing the matte to copper or sending to market. As a general rule, the writer considers that a 3 per cent. ore is too low for smelting, that is to say, that for a low-grade ore, smelting is rarely possible.

There remains the process of concentration followed by smelting. This process is more universally applicable, and is the one most generally in use. Whether it will pay or not will depend on the nature of the ore, and the percentage of recovery. With a good recovery, most 3 per cent. ores ought to be profitable, if the ore be regularly supplied, and the cost of mining be not exceptional. Concentration can be accomplished in a well-designed plant at an exceedingly low cost per ton. In one instance in his (Mr. Fernau’s) experience, it was as low as 1s. 1d., and he is now concentrating lead-ore in the North of England, at about 1s. 6d. per ton. The question to be determined is, therefore, how much the ore costs to mine, and what proportion of recovery can be obtained. The recovery in the case of copper-ores is not so good as in the case of lead, tin, or even auriferous iron-pyrites. When the ore is chalcopyrite, its flakiness occasions loss, and when bornite, its liability to slime. When in the metallic state, as in the Lake Superior district, the recovery is very high indeed, but that kind of ore is limited in distribution. On the whole, in his (Mr. Fernau’s)

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experience, concentration is the process most generally adapted for low-grade copper-ores. If copper be not the only valuable metal present, the problem alters completely. Smelting and lixiviation then become much more serious competitors, as the losses in concentration, especially of silver bearing ores, are sometimes very heavy. The field of enquiry also widens very much, and embraces considerations, which are out of place in a discussion of the treatment of low-grade copper-ores.

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DISCUSSION OF MR. S. J. POLLITZER’S PAPER ON "A MEASURING-TAPE, AND ITS USE IN MINE-SURVEYING."

Mr. James Henderson (Truro) wrote that great credit was due to Mr. Pollitzer for his explanation of the use of a steel measuring-tape of an unusual length, and for the description which he gave of a very successful application of the same in a complicated survey.

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Mr. D. G. Kerr’s paper on “Air-compression by Water-power: The Installation at the Belmont Gold-mine,” was read as follows:--
AIR-COMPRESSION BY WATER-POWER: THE INSTALLATION AT THE BELMONT GOLD-MINE.
By D. G. KERR.

The water-power is situated in the township of Belmont county of Peterborough, Ontario, about 3 miles in a northwesterly direction from the Belmont gold-mine. At the outlet of Deer Lake, there are falls and rapids which give a head of 75 feet in a distance of 1,600 feet; and still farther down the river, there is another drop of 25 feet. Deer Lake is about 4 miles long by 1 mile wide, and holds a splendid reserve of water for a dry season. The lake is fed by a chain of smaller ones, which extend northward about 100 miles, and it makes an ideal situation for a power-plant.

After the water-power was acquired, the question of electricity or compressed air was considered. The generation and transmission of electricity would have cost less at the powerhouse and to the mine: but it would have been necessary to have erected a motor-driven air-compressor at the mine to supply the rock-drills with compressed air and to apply motors to the hoists and engines. This would have brought the first cost of the electric installation to a higher figure than that of a large air-compressor plant; and besides, the attendance, etc., at the motor-driven air-compressor at the mine would swell the working costs. By installing a large air-compressor at the water-power and carrying the compressed air in pipes to the mine, branching it off in all directions to the shafts and mill, without having to make any alterations to any of the engines or hoists, all that was then required to be done was to shut off steam and turn on air to the engines, hoists and pumps without any loss of time while air was turned on at the powerhouse. This left the steam-plant, boilers, etc., with all their connections as a reserve of power, in the event of anything going wrong with the air-power. And further, this arrangement permitted of the utilization of all machinery that was only two or three years old.

An important point was the erection of an air-compressor plant large enough to do the mining work for many years to come. As the underground requirements for air increased, more power could be developed at the falls by electricity to work the surface-machinery. There would also be ample time for considering the proper size of motor-driven machinery for handling the quantity of ore, as it would then be better understood.

The outlet of Deer Lake consisted formerly of two channels, 300 feet apart, through a fine-grained diorite-rock. The southern channel was closed with a concrete-and-cement-masonry dam, 85 feet long, 9 feet wide at the top, 16 feet wide at the base, and 15 feet high at the deepest part. On the top of the dam, small piers, 18 feet apart, are erected for bridging with timbers for a passage across. Underneath this bridge and over the top of the dam, the surplus water passes when stop-logs are placed in the slide-way on the northern dam. The northern dam is 75 feet long, with a slide, 25 feet wide, for the passage of logs. In front of tin.1 northern slide, is a forebay with a 30 feet rack; and this is the point where the water is taken out of the
lake for the power, through an opening, 7 feet square, in the dam, with a gate on the side next to the lake. This gate is worked by means of rack-and-pinion wheels and a worm-shaft and wheel. The water-intake to the flume is reduced from the square to a cylindrical shape by means of steel-work, with flanges and fasteners for the wooden staves of the flume-pipe. On the top of the dam, behind the gate and going down into the water-entrance of the flume-pipe, is a man- or air-hole: and without this, the shutting-down of the gate at the dam, allowing water to pass through the wheel, would create a vacuum in the flume, causing a tendency to collapse or disturbance of the staves, resulting in much trouble and annoyance through leaks when the water was again turned on.

The flume-pipe, 1,550 feet long and 6 feet in internal diameter, is made of pine-staves, 2 ½ inches thick and 6 ¼ inches wide, with radial edges and butt-joints, with saw-drafts cut 2 inches into both ends, in which is placed a steel-plate, ¼ inch wider than the stave, so as to embed it in the staves on both sides. No two joints come together, as they are made at irregular intervals, the staves being cut in 12, 14, 16 and 18 feet lengths, cramped with 2,000 steel-bans, 3/16 inch by 2 inches, and fastened with grip-fasteners. The pipe is carried on timbers, 12 inches square, shaped to take the outside circle of the flume, and these bearer-timbers are 8 feet apart, centre to centre. The steel-bands are spaced 3 inches apart at the lower end and 24 inches at the upper. There are two curves in the flume, each of 20 degrees. The staves 6 ¼ inches wide, were too wide and rigid to be sprung into place on the outside of the flume, and, in consequence, one-third of the top staves going round curves are made 3 ½ inches wide.

The bed for the flume is cut through ridges of rock for 900 feet from the dam, 3,960 cubic yards of rock-excavation being made by a steam-drill in the winter season. At the lower end, there is 217 cubic yards of stone-piers to carry the flume over a low piece of ground before arriving at the power-house, and inside the powerhouse a steel-tube takes the place of the wooden flume.

The cost of the wooden flume, made of pine, is 3 dollars (12s. 6d.) per foot, while the estimated price of a steel-flume, was 15 dollars (£3 2s. 6d.) per foot. The power-house building lies north and south, and the part which contains the air-compressor is 50 feet long and 40 feet wide. Southward of this, is the cooler-room, 43 feet long and 16 feet wide, and northward of the main part is the water-wheel section, 64 feet long by 35 feet wide. The water-wheel is a double bronze Leffell wheel, 50 inches in diameter, fitted with a double discharge; and when running at 210 revolutions per minute, it has a capacity of 800 horsepower, and takes 7,500 cubic feet of water per minute. The water-gates of the wheel are made of cast-steel, and the casing of ½ inch steel-plates, with cast-iron heads. The water-wheel is carried on a steel-shaft, which is extended at one end for the transmission of the power, by means of a rope-pulley, 5 feet in diameter and 6 feet 4 inches across the face, and fitted with 30 grooves for 30 cotton ropes, 1 ¾ inches in diameter.

On the top of the wheel-casing is a dome, 2 feet in diameter and 10 feet high, with a valve, and just above this valve are two pipes 12 inches in diameter, fitted with spring-valves, leading into the draught-tubes. This is an arrangement for the relief of any undue pressure from the water-ram, such as might be caused by the water-wheel gates on a long flume, through which water is travelling at a certain rate, being shut quickly. This arrangement takes the place of a
stand-pipe; it costs less, and there is no danger from freezing, as it is placed under cover. On the wheel-case is a

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Gauge shewing the water-pressure and head in feet, and on the draught-tube is a gauge giving the vacuum in inches.

The water-wheel, wheel-casing, etc., were furnished by the William Hamilton Manufacturing Company, Peterborough.

Underneath the wheel is the tail-sump, and from that the tail-race passing into the river. This was excavated out of solid rock a depth of 20 feet, and it has cement-masonry walls with steel-beams and bolts, by which the wheel-casing is held in place. This tail-sump is carried westward underneath the wheel, in order that it may take the water from another wheel of 350 horsepower, and provision is made for its water-supply by means of a T piece on the steel part of the flume. When this second wheel is at work the water-velocity through the 6 feet flume will be increased to about 10 feet per second. It is intended to apply this 350 horsepower to the generation of alternating current by means of a direct-driven dynamo.

The horizontal compound air-compressor, made by Messrs. Walker Brothers, Wigan, has a high-pressure cylinder, 30 inches in diameter, a low-pressure cylinder, 48 inches in diameter, and a stroke of 4 feet. The cylinders are water-jacketted, with accessible inlet-valves, and fitted with metallic packing on the piston-rods. It is rope-driven by means of a pulley, 20 feet in diameter, and 6 feet 4 inches across the face, weighing 60,500 pounds, and built in sections on massive concrete-and-cement foundations, 14 feet high. When running at 65 revolutions, or a piston-speed of 520 feet per minute, it will have a capacity of 6,500 cubic feet of free air per minute. The low-pressure air-cylinder intake is connected by a branch pipe from the 3 feet pipe to the external atmosphere. This 3 feet pipe lies horizontally on the top of the low-pressure air-cylinder, one end going to the southern and the other to the western end of the building. The air is compressed in the low-pressure cylinder to a pressure of 30 pounds, and is then discharged through a pipe, 14 inches in diameter, to the inter-cooler; thence, after being cooled, to the high-pressure cylinder, from which after being compressed to a pressure of 100 pounds per square inch, it passes into the after-cooler. The inter-cooler and after-cooler are filled with brass tubes, through which flows cold water, and the compressed air passes and repasses over the outside of the tubes, and is cooled down to within 10 degrees of the temperature of the water used. In this cooling

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process, considerable moisture is deposited, as it is only by cooling the air to the lowest temperature attainable that a high extraction of moisture can be obtained.

The air leaves the after-cooler through a 12 inches pipe or ordinary oil-well casing, having fine screwed couplings and tested to a pressure of 600 pounds per square inch. An air-receiver placed ½ mile away from the air-compressor, to collect any moisture, which may have passed the after-cooler; and this moisture is drawn off daily.

The 12 inches pipe-line, from the compressor to the mine is 15,000 feet long. At the end of this pipe-line, at the mine another air-receiver is placed to collect any moisture, which may have been carried into the pipe-line. The only time of the year when any moisture is expected
to be carried this distance is when spring sets in, and the heat of the sun drives off any moisture from the inside of the pipe. This will be very little, as the air-receiver near the air-compressor lies in a low swamp, and the air-line leaving it for the mine has a gradual rise of 50 feet in 2,000 feet, thus draining the moisture back into the receiver. The pipe-line has 18 expansion-joints, and is mostly buried in sand, so as to maintain an equable temperature, and thus prevent expansion or contraction.

The plant started running in August, 1902, but has not yet been driven up to its full capacity, and the loss of pressure in transmission has not been determined. The loss of pressure, at present, is less than 1 pound, but using the full quantity of air, it is expected to reach 3 ½ pounds. The writer has found it impossible in the short time that the plant has been running to make a complete comparison, between summer and winter, of the temperature at which the air is taken into the compressor, the amount of moisture extracted, and the temperature of the water used in the coolers.

During the past winter, there has only been one shut-down owing to freezing, and it was caused by the moisture in the air-receiver, ½ mile from the compressor, being allowed to freeze, as had not been drained off every day. The ice formed in a honeycomb form, until it interfered with the air-pressure at the mine, reducing it to 65 pounds, while there was 105 pounds at the air-compressor. After taking out the honey-comb ice, the air-receiver was covered with a shed, and banked so as to protect it from the intense frosts, and thus permitting of the moisture being drained off.

There has been no difficulty at the mine from freezing, except with a Corliss engine and a Duplex pump; but engines fitted with slide-valves gave no trouble, as the air is not expanded in the cylinders.

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DISCUSSION OF MR. E. GOSSERIES’ PAPER ON "THE GUIBAL FAN COMPARED WITH A DYNAMO."

Prof. A. S. Herschel (Slough) wrote that he had read Mr. Gosseries’ paper, and appreciated its value very highly; but seeing that it turned on two things which were to him entirely problematical: —(1) That for a given rate of revolution of a Guibal fan there is a particular supply of air at which it shows a maximum water-gauge: with lower water-gauges for any greater or less air-flow; and (2) that the laws of air-flow under a driving-head are just the same as those of an electric current under a potential difference or electromotive force—he would have replied immediately that want of familiarity with fans and fan-theories for the last 10 or 12 years quite disqualified him from holding any opinion at all, either pro or con, upon the merits of the paper. But before writing, he read, with considerable scruples of conscience for having disregarded them before, two papers by Mr. H. W. Halbaum on “The Equivalent-orifice Theory treated Graphically”† and “An Extension of the Equivalent-orifice Theory;”‡ he also read again Prof. A. Rateau's "Remarks on Mr. M. Walton Brown’s Report on Mechanical Ventilators,”§ and this now stirred him up to read Mr. M. Walton Brown's admirable expose of theory and practice, with more care and leisure than he had been able to give to it before, since it had evidently roused mining-engineers in every country to express their views most skilfully, and to discuss the fan-question in a series of most able papers. He was very sensible
now, with the little reflection that was needed to understand these recent papers, how immensely far ahead of all

† Ibid., 1900, vol. xx., page 404.
§ Ibid., 1902. vol. xxiii., page 47-2.
ǁ Ibid., 1899, vol. xvii., page 482.

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his previous notions of it the art of mechanical ventilation had advanced.

In regard especially to Mr. Halbaum's two papers on the equivalent-orifice theory, the latter had done a great deal more than merely translate Mr. Murgue's views into graphic language. He had shown their meaning by a feat of composition (fairly rivalling, he considered, in manner and in matter, Fourier's work on heat-conduction), and his first paper, at least, was rhetorically as well as geometrically, a most brilliant performance. The rhetoric was indispensable to the establishment that he effects of Ohm's law in air-flow and in all streams of fluids, because rather large concessions and revolutions of one's natural ideas have to be made to take in the truth of the conception:--Airhead, square of discharge, and square of clear-voidance (rather than thin orifice) of an air-channel, answer in just the manner of Ohm's law to potential-difference, current-quantity and electric conductivity of an electric lead or cable. As regards the discharge or volume-output of the flow, no notice whatever need be taken of any velocity that it may possess at the point of measurement of its water-gauge and volume, since any such terminal velocity is just exactly one individual part of the whole series of similar velocities, which the head essentially produces all along the channel to be killed by friction; and it belongs, where the water-gauge was measured, to the friction of the mine. The air's faster inrush into the mouth of the fan is similarly one individual part of the fan's internal friction or resistance, since it is produced by a later and lower water-gauge than that measured at the drift-mouth, and would also be killed if the fan cannot transform some or much of it into backpressure. The velocity of the discharge's escape into the open, in leaving the fan, is again just similarly a part of the fan's internal frictional resistance; because, although blades can produce pressure, only fluid-pressure can produce fluid-motion, and some head of pressure must therefore have been spent uselessly in the fan, on the discharge, to produce a velocity in it, which is bound to be killed in the open air. There may perhaps be tracts, at times along a mine, that act like embouchures or tie expanding chimney of a Guibal fan, to recuperate, here and there, some of the flow's velocity and transform it into back-pressure to the relief of the final water-gauge, and they are, so

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far, little fans; but in so far as they are permanent and persistent, they may be lumped together into the mine's whole conductivity or temperament for the time being, and do not, like the mechanical fan, need a separate consideration. These were the modern through-and-through views of a mechanical air-draught that he gleaned from the above-named papers: but besides skilful rhetoric and geometry Mr. Halbaum had also used examples (as when, in his second
paper, he differed from Mr. Murgue on a rather fundamental point), when argument failed to prove his case, with great practical experience; so that his share in the thorough clearing up of the orifice-aspect of the subject struck him (Prof. Herschel) as a remarkably original and substantial one. Considering that a thin orifice has a very uncertainly known vena contracta, and does not therefore flow full any more than a mine does, he (Prof. Herschel) could never imagine why Mr. Murgue chose it as a proper representation of a mine's discharge, or as an equivalent description, with its own peculiar obstruction, of the mine's impeding action. It seemed to be rather a simple practical form of scale by which to measure and describe the air's flow than anything theoretical, as it was hardly probable that the vena contracta of a thin orifice and the airway of a mine would constantly match each other well at all water-gauges. If a theoretically equivalent, and not merely a conveniently definite form of aperture, was really meant, it should be a full-flowing one, giving the discharge freely and fully through it with the theoretical gauge-speed, not through a fraction of it only of hardly fixed amount for all depressions. The choice of a true equivalent to the mine being a purely theoretical one, it seemed absurd to take a practical one, especially a not very perfectly explored practical one, to represent it; therefore, he (Prof. Herschel) never credited Mr. Murgue's equivalent orifice with any claim to theoretical significance. But once it was allowed that a mine's limitations to its air-discharge's free and full response to an aspirating-pressure was simply a limitation of aperture, it then seemed quite natural to suppose that the aperture which defines and denotes the limitation should flow as full as it could to give the resulting limited discharge through it at the velocity due to the water-gauge. He (Prof. Herschel) would call it the "free outlet," or voidance, as the square root of the conductivity, and its reciprocal, the "barrage" of the mine,

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as the square root of its resistance.* This is just Mr. Halbaum had done; for though he termed his papers expositions and applications of the orifice-theory of mechanical ventilation, he nowhere used the name "orifice" for his constants M and F, that denote them for the mine and the fan throughout his papers, and the consequence was that one saw at once through the very perfect theory that he was trying to expound and illustrate: while he (Prof. Herschel) had read through Mr. Murgue's book† at different times, treating of the substitution of an airway by the technical device of a thin-plate orifice, without being ever led to suspect that with its use he was clearing the way (as had thereby come to pass) for a recognition of Ohm's law in ventilation-currents. He (Prof. Herschel) had often tried to find a solution of that problem, but always unsuccessfully as without the useful hint of an equivalent free orifice in an airflow, no one would ever dream of taking the square of the discharge as the quantity of flow in a current produced by a driving head through the square of a limiting free aperture as a conductivity, or against the reciprocal of that square as a resistance. If Mr. Murgue had set forth that consequence of his proposition, divesting it for that end of its technical shape, and expressing it more simply and abstractly, he (Prof. Herschel) thought he could hardly have overlooked the appearance of so notable a discovery in Mr. Murgue's book as the Ohm's law one, nor, he thought, would Mr. Murgue have failed to mention it, if that all-important and invaluable consequence and conclusion from his proposition had been obvious to him; but he would read Mr. Murgue's work on mechanical ventilation again more carefully, and see whether it promulgated the law distinctly.‡ Mr. Halbaum, himself, nowhere stated it
A note of some rather more suitably adapted terms for conveniently denoting and dealing with the several new quantities that require to be considered in the conduction-like view of an air-flow's maintenance, will be furnished hereafter, to more fully elucidate and illustrate the principles of that somewhat novel and surprising aspect of the subject of aerial and other fluid currents.


‡ The writer must here correct a mistake, which was indeed a pardonable one, in the pronunciations which he was led to make originally in his remarks (since they were not, in fact, written originally with a view to then published): that the work above said to have been read through at different times, which his memory imperfectly recalled as having, many years ago, a him most valuable instruction in the theory of mine ventilation, was not actually Mr. D. Murgue's "Essai sur les Machines d'Aerage," in the Bulletin de la Societe d'Industrie Minerale, 1873-1880, at all, nor the translation into English by Mr. A. L. Steavenson (which he had not seen yet) of Mr. Murgue's work on The Theory and Practice of Centrifugal Ventilating-machines, but the very useful handbook, Ventilation des Mines (Mons, 1875), by Mr. A. Devillez. He must therefore retract the quite mistakenly presented estimate expressed above of Mr. Murgue's really most complete indication of the law of resistance and conduction found to be always governing aerial currents, since it is most definitely and distinctly laid down as he found it represented and propounded in the first division of Mr. Murgue's "Essai," published in 1873; for, in a note there given, on the fitting capabilities and mode of calculation of the equivalent orifice of an air-flow, the two different descriptions of resistance, by surface-friction and by constriction of a current-channel, are shown to act quite similarly in impairing in a constant manner in a given channel, the driving head's power of producing squared discharge of volume through it; and the law thus shown to hold in two, at least, of the most important forms of current-friction (though sudden deflections also form another serious source of obstruction to a flow), in a fluid at least (like air in ventilating currents), of practically constant density, provides at once the fullest and a perfect means of solving problems of air-flows' distributions through ramified and varied channels by exactly the same rules as those which Ohm's law supplies to answer similar questions of distribution of galvanic currents. The same law is recognised and used, but in a less general way, as it is only proved and affirmed exactly with regard to the effects of surface-friction, without numerical estimates other forms of friction, along any series of branching and successive airways, in Mr. Devillez' rather later book.

Generally, but, simply accepted it, and used and applied it unreservedly throughout his papers. In a supplementary note to Mr. Gosseries' paper on a case of resemblance between a Guibal fan and a dynamo-machine, Prof Macquet stated that if \( u \) be the velocity of discharge produced by a water-gauge depression through a hole in a thin plate of area, \( S \), \( Su \) is the volume of the discharge.\(^*\) Now in his Applied Mechanics,\(^†\) on flow of gas from an orifice, Prof. W. J. M. Rankine wrote:—"Let the pressure of a gas within a receiver be \( p_1 \) and without, \( p_2 \); let \( A \) be the effective area of an orifice with thin edges; that is, the product of the actual area by a coefficient of contraction, whose value is 0.6, nearly . . . ;" and further on:—"For small differences
of pressure, such that $P_1/P_2$ is nearly equal to 1, the following approximate formula may be used . . .

$$v^2/2g = p_0 t_1 (p_1 - p_2)/\xi_0 \tau_0 p_1$$

for the velocity $v$, "and the flow of volume is $Q = vA$ at the contracted vein." This showed that engineers may disagree about the properties of flow through a thin orifice, when they write thus about it; and be the contracted vein or equivalent free aperture of a thin-plate orifice what it may, at different depressions (for it is hardly likely to be constant) no one who has seen smoke-rings produced in that way round the issuing jet, will be ready

† Article 687, page 581.

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to believe that the outflow of a gas from a thin-plate orifice is as free from eddies that affect water-gauge depression, as its ideal outflow is; and hence not the whole but only an unconsumed part of the working pressure can act over the area of the orifice to produce velocity through it, or the full speed through the orifice is less than the theoretical speed for the depression, or the discharge is necessarily less to some (not well-known) extent than the free-flow discharge with the full theoretical air-speed through the whole open area. It is a pity that mining engineers have introduced this idea of a thin-plate orifice into the question of fluid-flow resistance, as a right conception of such a resisted flow's natural discharging power may easily be obscured and made difficult to apprehend in consequence.

Prof. Macquet spoke also of a Pitot tube.* He (Prof. Herschel) had seen it in use, and the process of summing up its readings for a mean resulting water-gauge; and he was much inclined to think that considerably more errors were likely to occur in its use than might arise by simpler means without it: especially when a sufficient ball of cotton-waste or wool was tied over the open end of a water-gauge tube, which performed exactly the part of a Pitot tube, without demanding a multiplicity of water-gauge readings and averaging of figures. Possibly, two brass tubes might be bent like S hooks, and fixed as shewn in Fig. 1,

[Diagram: Fig.1.]

on either side of a straight brass mouth-tube (closed at its upper end) attached to the water-gauge tube; both the straight and curved tubes having pretty wide-open side-holes for communication, where they meet and cross, and are there soldered to each other. An air-draught from the left, would then enter the two S tubes at their top-ends, and would leave them at the bottom; and as their two currents would oppose each other where they cross and communicate with the straight water-gauge mouth-tube, they would baffle each other there in their action of aspiration, or otherwise, on the air in the straight tube, and would obviate the necessity of pairs of readings and averages with a Pitot tube; but the device would be a poor

make-shift, he suspected, for the well wool-padded end of an ordinary water-gauge tube.
The radial velocity, which Prof. Rateau considered,* in his comments on the report on "Mechanical Ventilators," should be superadded to the blade-tip speed in some fans (that is, open-running ones) in calculating their theoretical effects, can hardly be great and surely must scarcely exist at all in a cased-in Guibal fan, so that there it must be negligible. In open-running fans it might more depend, perhaps, as a correction to the blade-tip speed, on the volume passed by the fan than on slight forward curvatures of the blade-tips in some fans. He (Prof. Herschel) did not follow Prof. Rateau's mathematics there, and in the rest of his comments, from having failed to read his other papers.

Dr. Henry Stroud (Durham College of Science) wrote that it might not be superfluous to draw the attention of members to the article on "Warming and Ventilation" by Dr. W. N. Shaw, in Messrs. Stevenson and Murphy's Hygiene and Public Health, in which was given a method of treatment suggested by Mr. Murgue's work on The Theory and Practice of Centrifugal Ventilating-machines, translated by Mr. A. L. Steavenson. In that the resistance of a mine in a given condition was constant, whatever the flow, there was an analogy to the electrical case where the resistance of a conductor in a given condition was constant, whatever the current; but since the square of the air-flow through a mine was proportional to the head, it seemed doubtful whether any further assistance could be obtained by attempting to pursue the analogy.

Prof. A. Macquet (Ecole des Mines du Hainaut, Belgium) wrote that Prof. A. S. Herschel began by avowing himself absolutely unqualified to express an opinion for or against Mr. Grosseries' paper, the great merit of which he is, however, pleased to recognize. This does not prevent him from, embarking upon the most curious and fantastical definitions, of the equivalent orifice (as he conceives it); of the pressure and motion of a fluid: of the recuperation of energy due to the Guibal expanding chimney; of the orifice in a thin plate; and of the contraction-vein, etc. Next, Prof. Herschel took him (Prof. Macquet) personally to task, because he wrote, Q, = Su, terming Q the volume of flow through the section, S, at a, velocity, u, this volume being reckoned at


the pressure proper to the fluid in the section, S. He however, with Prof. Rankine, who writes Q = vA, for the volume of flow under the same hypothetical conditions, that is through the contracted section of the effective surface, A, at a velocity, v. In what do these formulas differ? He (Prof. Macquet) failed to see it. Wherefore, he took the liberty of attaching significance to the Professor's remark that "this showed that engineers may disagree about the properties of flow through a thin orifice, when they write thus about it." He preferred to leave Prof. Herschel on the watch for "smoke-rings produced round the issuing jet" of a fluid through "a thin-plate orifice" and to leave him to the pity with which he is filled for the engineers, adepts in the theory of orifices in thin plates.
Nor did he (Prof. Macquet) propose to insist upon the remarkable instance cited by our esteemed controversialist, who has had the opportunity of seeing the Pitot tube in use, as he thought that such opportunities were common among mining-engineers. Engineers, at all events, would hardly forgive him for lecturing to them on matters of which he did not understand a syllable, even were it on a certain "Pitot tube."

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THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

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GENERAL MEETING,

Held at the Keswick Hotel, Keswick, June 10th, 1903.

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Sir LINDSAY WOOD, Bart., President, in the Chair.

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The Secretary read the minutes of the last General Meeting and reported the proceedings of the Council at their meetings on May 30th and that day.

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DEATH OF MR. A. L. COLLINS.

The following letters were read:

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Newcastle-upon-Tyne,

7th February, 1903.

Sir,

The Council desire me to call your attention to the death of Mr. Arthur Launcelot Collins, a member of this Institute, who was murdered at Telluride, Colorado, United States of America, in November last.

The Council trust that the British Ambassador to the United States may be instructed to use every endeavour in order that the perpetrators of this murder may be brought to an early trial.

I enclose herewith, for your information, an account of "The Tragedy at Telluride," taken from the Engineering and Mining Journal (published in New York) of November 29th, 1902.*

I have the honour to be, Sir,

Your obedient Servant,

M. Walton Brown,

Secretary.

The Right Honourable the Secretary of State, Foreign Office, London, S.W.

* The Tragedy at Telluride.—Just after going to press last week, our correspondent in Colorado telegraphed that Mr. A. L. Collins, the manager of the Smuggler Union mine, at Telluride, had been shot in his house, with results that were fatal within 36 hours. The act was that of an assassin who had fired buck-shot through the window of the library, in which Mr. Collins sat with two or three friends.

Throughout the membership of that profession which Arthur Collins adorned by his high intelligence and earnest work, this sad news will provoke a feeling of great pity that a useful and honourable career should be terminated in such a tragic manner, and to this pity will be
added the bitterness of resentment that an unoffending man of high character should be sacrificed to the spirit of lawlessness which has prevailed at Telluride for the past two years, and of which is the logical outcome. Our readers will remember that in July 1901 there was a strike among the workmen at the Smuggler Union mine, consequent upon the introduction of the contract system; they will also recall the fact of a murderous attack made by a body of strikers, in the course of which the latter shot discriminately into the dwellings and office buildings at the mine, killing eight men and severely wounding many more. Nothing whatever was done by the county or the State to punish this outrage, and not a single individual has suffered any punishment for this act of cowardly ruffianism. In July of the present year, a marble monument was erected to the memory of the single member of the attacking party who was killed in that assault, and at the unveiling of this monument to the murderer a number of flowery orations were spouted by local politicians. Amid these happenings, Mr. Collins, as manager of the mine, stood out fearlessly for the maintenance of law and order, and when the Sixteen-to-one Miners' Union, of Telluride, sent him a list of scabs, or non-union men, warning him not to give them employment, he immediately inserted a paid advertisement in each of the local newspapers promising work to any man on that list so long as he was manager of the property then under his control. In speaking of this incident he would exclaim, with indignation, that the names on that list "could be pronounced!" That is, they were men of American and English extraction, in contrast to the bulk of the miners in the district who are Austrians, Slavs, Italians, etc., with enough hot-headed ag'in-the-government Irish to lead these foreigners into devilry.

Throughout these troubles, the local and State authorities have been shamelessly negligent of their duty to the community in the enforcement of the law. The present Governor of Colorado is an ordinary political accident, and has permitted the exigencies of corrupt politics to tie his hands. It may be necessary to explain that the Miners' Union is influential in politics, not only locally, but also through its affiliations with similar organisations throughout the State, and the members as a body belong to the political party which of late has been dominant in Colorado on account of the socialistic and anarchistic tendencies developed by the agitation following the fall in silver. The Smuggler Union mine is owned by Boston capitalists, who are likely to cease operations at the mine and keep it shut down until there is better evidence of protection to life and property in this particular district; they will doubtless be glad to meet the heavy expenses of a thorough investigation, and will spare no effort toward the arrest of the criminal, even though the county and State prove as supine as heretofore. Whether this culminating tragedy will arouse the State authorities to action we do not know, but if it does not it appears to us that it is high time for the civic spirit of Colorado to awaken and to see to it that punishment awaits the perpetrators of this and other crimes committed at Telluride.

From considerations such as these one turns again sadly enough to realisation of the cost of all this frontier lawlessness and political expediency. Arthur Collins was a member of an old Cornish mining family. He was barely 40 years of age, with a young wife and two lovely children. He was well travelled and extremely well-informed in technical matters. A few years ago he had been adviser in mining to the Ameer of Afghanistan, and had been placed amid surroundings requiring a high type of courage. As manager of mines first at Central City and then at Telluride, he had evinced great energy and capacity. He seemed destined to occupy a very honourable place in the profession, and he could look forward to a career of domestic happiness and professional distinction. This---citizenship of the very best---is suddenly and without warning wantonly destroyed because local politics have made it inexpedient to enforce the administration of the law.
Foreign Office,
April 21, 1903

Sir,

With reference to the letter from this office of the 16th of February last, I am directed by the Marquess of Lansdowne to inform you that a despatch has been received from Sir Michael Herbert, His Majesty's Ambassador at Washington, on the subject of the murder of Mr. A. L. Collins, at Telluride, Colorado, in November last.

Sir M. Herbert has received a report from the British Vice-consul at Denver, who was instructed to make enquiry into the steps being taken to bring the murderers of Mr Collins to justice, and has been in communication with the Governor of Colorado with that object. The latter has furnished a full statement of the measures taken by the United States authorities for the purpose of investigating the murder, from which it appears that after an investigation lasting nearly three weeks, during which time a grand jury, specially empanelled, examined a large number of witnesses, no clue has been obtained as to the identity of the assassin. The Governor states that every effort, without regard to cost, has been made to clear up the mystery, and that every resource at his command will be devoted to discovering the perpetrators of the crime and securing their conviction.

I am, Sir,

Your most obedient humble Servant,
F. H. Villiers.

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AWARDS FOR PAPERS.
The Secretary read the following list of papers, communicated during the year 1901-1902, for which prizes of books had been awarded by the Council to the authors: —

"A Method of Socketing a Winding-rope, and its Attachment to a Cage without the Use of Ordinary Chains." By Mr. W. C. Blackett, M.I.M.E.
"Mechanical Undercutting in Cape Colony." By Mr. John Colley, M.I.M.E.
"Electric Pumping-plant at South Durham Collieries." By Mr. Fenwick Darling, M.I.M.E.
"Some Silver-bearing Veins of Mexico." By Mr. Edward Halse, M.I.M.E.
"Apparatus for Closing the Top of the Upcast-shaft at Woodhorn Colliery." By Mr. C. Liddell, Stud.I.M.E.
"Standardization of Surveyors' Chains." By Prof. Henry Louis, M.I.M.E.
"A Visit to the Simplon Tunnel: the Works and Workmen." By Dr. Thomas Oliver.
"The Carboniferous Limestone Quarries of Weardale." By Mr. A. L. Steavenson, M.I.M.E.
"Auriferous Gravels and Hydraulic Mining." By Mr. W. S. Welton, M.I.M.E.
"Tapping Drowned Workings at Wheatley Hill Colliery." By Mr. W. B. Wilson, jun., M.I.M.E.

The Secretary read the balloting-list for the election of officers for the year 1903-1904.

The following gentlemen were elected, having been previously nominated: —

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Members—
Mr. Denys Leighton Selby Bigge, Electrical Engineer, 27, Mosley Street, Newcastle-upon-Tyne.
Mr. Emile De Hulster, Engineer, Easington Colliery, Castle Eden R.S.O., County Durham.
Mr. John James Jones, Mine-manager and Quarry-manager New Westminster, British Columbia.
Mr. Charles Hesterman Merz, Consulting Engineer, 28, Victoria Street, London, S.W.; and Collingwood Buildings, Newcastle-upon-Tyne.
Mr. William Cuthbert Murray, Colliery Manager, Clifton House Sherburn Colliery Station, near Durham.
Mr. Percy Clement Campbell Phillips, Mining Engineer, Wallsend Colliery, near Newcastle-upon-Tyne.
Mr. Norman M. Thornton, Mining Engineer, South Pelaw Colliery, Chester-le-Street, County Durham.
Mr. William Henry Walton, Land-surveyor and Mine-surveyor, Bridgewater Offices, Walkden, near Manchester.

Associate Members—
Mr. Frederick Tillotson Walker, 70, Pilgrim Street, Newcastle-upon-Tyne.
Mr. Thomas Welford, Wallarah Colliery, Catherine Hill Bay, New South Wales.

Student—
Mr. Charles Southern, Mining Student, Heworth Colliery, Felling, R.S.O., County Durham.

Mr. W. E. Walker's paper on "Hematite-deposits and Haematite-mining in West Cumberland" was read as follows:-

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HEMATITE-DEPOSITS AND HAEMATITE-MINING IN WEST CUMBERLAND
By W. E. WALKER,

Introduction.—The writer believes that it is a long time since a paper relating to haematite-deposits and haematite-mining in West Cumberland has been placed before the members, and as discoveries of great importance have been made in recent years in West Cumberland, it occurred to him that the subject might be one of interest to members of the Institute.
When the writer commenced haematite-mining over thirty years ago, the ore being worked was, with very few exceptions, at a, comparatively speaking, shallow depth. Horse-gins and small combined winding-and-pumping-engines were employed at the shafts, and horses were, in several cases, used underground for the purpose of drawing the ore along inclined roads.
In those primitive days, many shafts were sunk to the rise of the ore-deposit for the purpose of reaching it as quickly as possible, regardless of future cost in working. As this ore, after a time, was much reduced in quantity, it became necessary to prospect for other and deeper deposits by means of boring, some of the bore-holes going down to the slate-rock. Several of these bore-holes were unsuccessful, while others found ore in such quantities as to revolutionize iron-ore mining in West Cumberland. From 200 to 300 feet was formerly looked upon as a fairly deep shaft, whereas the deep bore-holes, above referred to, have necessitated the sinking of pits from 700 to 900 feet in depth. Even that depth is now being far exceeded, south of Egremont, by the Wyndham Mining Company, who are sinking a shaft to a dep of over 1,200 feet; and by the Beickermet Mining Company, who are sinking a shaft near to Winscales, about 1 mile south of Egremont.
The former system, of sinking the shaft to the rise of the deposit, naturally led to great expense in pumping water and drawing

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of the ore from the dip workings. Now, all this has been changed, for, after the discovery of the dip of the "sole," that is, the floor of the deposit, by means of bore-holes, the shaft is sunk to the dip, and thus gravitation aids the conveyance of both ore and water to the foot of the shaft. There is no comparison in the cost of boring, sinking and providing plant with the cost as it stood formerly: for instance, where £2,000 would cover the whole expense in olden days, £10,000, £20,000, and even £30,000, do not always cover it now. Many firms spend thousands of pounds in boring alone, before they feel justified in sinking a shaft, and it has sometimes happened that the boring-operations have been entirely unsuccessful.

Accidents.—In opening out, developing, working and robbing an iron-ore mine, the first consideration of the owner and management is the safety of the men employed, and the efficient ventilation of the mine. During the whole time that the writer has been connected with haematite-mining, he has been brought into contact with accidents, to workmen, of all kinds, but he has never known of one where any blame whatever could be justly charged to default on the part of either the owner or the management. Every accident, so far as he is aware, has been caused either by the workman not obeying the instructions of the manager, or by utter carelessness; or, in such a way, that it was entirely impossible for anyone to foresee such dangers as "slips" from smooth joints, which, when sounded by the inspector and miners, showed no indication that movement was likely to take place.
After the safety of the miners, the next consideration is to obtain as much ore as possible from the mine, clean, and at as low a cost as possible, seeing, at the same time, that the workmen employed receive proper remuneration for their labour. It is the universal custom in the district for the miners to take contracts, which are regulated according to the selling-price of the ore.

Machinery.—At present, the large winding-engines and pumping-engines, employed on the surface, are worked by steam, but, in the not far-distant future, the writer hopes to see electricity (undoubtedly the power of the future) used for this purpose. He also anticipates that the hand-drills used for boring shot-holes, both in ore-workings and limestone-drifts and sinkings, will be supplanted by more scientific and efficient methods, which will be of the greatest advantage, both to mine-owners and miners, by producing an increased output at practically the same all-round cost and with much less manual labour.

Dip-workings are, of course, occasionally necessary even now. The ore from them has to be drawn by haulage and the water removed by steam or hydraulic engines in a way, arranged in detail, according to circumstances.

Spain as a Competitor.—As the members are no doubt aware Spain is the chief competitor of the iron-ore mines in West Cumberland and North Lancashire. In Spain, the ore has simply to be quarried from the hill-side, and it varies in thickness in the Bilbao district from about 3 feet to about 40 feet. Some years ago, when the writer was visiting one of the largest mines in that neighbourhood, about 20,000 tons of ore were sent away weekly, the total cost being less than 4s. per ton free-on-board ship in the Bilbao river. At that time, about 1,500 work-people were employed: six Englishmen directed the drilling of shot-holes, about 200 women carried the ore in small baskets on their heads from the bank to the railway-wagons; and the remainder were Spanish labourers employed in breaking ore, filling baskets, and lifting them on to the heads of the women, as they passed by, all working with the regularity of a machine.

The men were paid, at that time, from 2s. to 2s. 4d. per day, and they lived chiefly in wooden sheds on the mountains, 20, 30, and even 40 men frequently sleeping in one of these, their beds each consisting of a sack laid on the ground. Needless to say that such wages and mode of life would be inapplicable to the English miner. During the summer, these men work from 5 a.m. to 8 p.m., with 1 hour for breakfast and 2 hours for dinner and siesta. In the autumn, winter and spring, they work from daylight until dark, and, although they live on the poorest of fare, the amount of work that they perform is astonishing.

The main part of the Bilbao hematite-deposit has now been worked out, and mine-owners have to go farther into the country for their supplies of ore. This implies increased cost and an increase of capital that will gradually bring the Spanish mines more on to a level with those of this district. There is no concealing the fact, however, that the iron-ore resources of Spain are enormous, though the quality of the ore, taken as a whole, is not so good as formerly.
The writer simply mentions these matters regarding Spanish iron-ore to show what we, in this district, have to compete with. If labour in Spain were put on anything approaching the same footing as it is here (and the writer believes that it is gradually moving in that direction) it would bring the cost of Spanish iron-ores nearer to a level with those of West Cumberland and North Lancashire. We must, however, not lose sight of the fact that if Spain had not been sending iron-ore to West Cumberland and North Lancashire for some years past, neither West Cumberland nor North Lancashire could have kept the number of furnaces in blast that they have done.

Ore-deposits.—In some parts of the haematite-district of West Cumberland there are four deposits of ore underlying each other. The No. 1 bed of ore is found in the first limestone; the No. 2 bed in the second limestone, about 30 feet beneath the first bed; the No. 3 bed occurs in the third and fourth limestones, about 250 to 300 feet below the second bed; and the No. 4 bed is found lying on the slate-rock or on calcareous limestone, which is occasionally found immediately above the slate-rock. If the ore be lying on the calcareous limestone it is much more easily worked, because the calcareous limestone, being of a hard and strong character, allows pillars of ore to stand for the purpose of supporting the workings without much expense in timber, whereas, if the iron-ore pillars are immediately on the shale, they are liable to shrink, thus necessitating extra labour and the use of artificial support to the workings.

These four deposits extend over a considerable area, though the main part of the first and second deposits, so far as is known, has been worked out. The quality of the ore is good, particularly in, the top or No. 1 bed, which generally reaches 60 per cent. and over of metallic iron, and is low in silica.

In searching for haematite in a new field, the first bore-holes may be termed "sporting"; they, however, as a rule, provide information which can be used profitably by the mining engineer, such as the location of faults in the Carboniferous Limestone, where the ore is nearly always found. The writer may mention, However, that indications as to the neighbourhood where faults

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may occur in the Carboniferous Limestone may frequently be traced from the mountainous district, or in quarries or outcrops in the district where you are desirous of boring. It may be added that if there were no faults, there would be no haematite ore, because there would have been no spaces in which the iron-ore could have been deposited.

When, by boring, a sufficient body of ore has been proved shaft is sunk, if possible clear of the deposit, thus leaving the shaft stable and free from injury, when all the iron-ore is worked out. There are, however, exceptions to this rule, for instance, in some mines the deposit is so extensive and the dip of the sole so great that a second shaft is sunk for the purpose of working the ore lying to the dip of the first shaft; and also for the purpose of robbing the first mine of the last remnants of ore; and, in this case, the position of the first shaft is not of such vital importance as if it had to be the only one.

Furness.—In the Furness district of North Lancashire, at Ronhead, Mr. Myles Kennedy has recently proved a very large deposit of haematite-ore, near the shores of Duddon Bay. The
depth of the ore is not yet known, but, so far, it has been proved up to 60 feet, and a level has been driven through over 300 feet of iron-ore.

West Cumberland.—North of the Duddon estuary, there is the great deposit of iron-ore worked by the Hodbarrow Mining Company, who have in hand the building of a huge sea-wall. This, when completed, will enclose a large area of the deposit, which they would not otherwise have been able to work.*

To the north of Frizington, the ore occurs in vein-like deposits, lying at a steep angle, with a general trend a few degrees to the west of north, and many of these have been traced from the outcrop to nearly the great fault, which runs between the Coal-measures and the iron-ore measures, through the Frizington an Arlecodon districts. The writer believes that these deposits will be found to run up to and abut against the fault; and it possible, and more than probable, that they may widen considerably before approaching the fault.


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To the north of Lamplugh, and extending towards Eaglesfield, about 3 miles from Cockermouth, is a large area of Carboniferous Limestone still unproved. About 24 or 25 years ago, a little "scratching" for surface-ore was done near Eaglesfield, and a few hundred tons of haematite were procured; but when it was found that the lease had been inadvertently taken from the wrong party, the undertaking was abandoned. Since then, nothing has been done, although iron-ore can be seen cropping out through the Carboniferous Limestone, and, no doubt, this part of the district will be again prospected. The borings made in the neighbourhood of Lamplugh Cross were not successful, and it is mainly for this reason that the above-named district has not been further explored. Narrow veins exist at Lamplugh Cross: there is no reason, however, why they should not widen out to the north, and bear a considerable amount of payable ore. About 25 years ago, some engineers thought that, long ere now, all the West Cumberland haematite-deposits would be exhausted. Those years have dropped into the past, but haematite still remains.

New haematite-fields are being opened out to the south of Egremont, two shafts have been sunk, one by the Ullcoats Mining Company, Limited, and the other by the Millom and Askam Iron Company, Limited, and large quantities of haematite are being raised. The Ullcoats Mining Company, Limited, are sinking a second shaft; the Beckermet Mining Company, Limited, are sinking a deep shaft; and the Wyndham Mining Company, Limited, are sinking a shaft to about 1,300 feet in depth near to the town of Egremont. Then, farther northward, the Winder Pit, belonging to Messrs. Ainsworth, is producing a considerable quantity of iron-ore; but, as this ore, like a few other bottom-deposits in West Cumberland, lies on the slate-rock, the writer believes that it is difficult to work, necessitating extra labour and the use of a very large quantity of timber.

Bigrigg and Moor Row districts, the writer believes, have a bright future in store, and he has no hesitation in saying that, so far as it is possible for any human being to judge, the mining of haematite in West Cumberland is only in its infancy. He has no doubt that, by employing
economical methods of working, with proper railway-facilities and fair royalty-rents, West Cumberland

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will be able to hold its own against all competitors for many years to come.

The writer believes that large deposits of haematite will be found extending through Haile, Calderbridge and Gosforth, because the same geological conditions exist there as to the south of Egremont; and that they will connect, by the narrow veins of the Eskdale and Irton Hills, with the great Hodbarrow deposit. At Haile, Calderbridge and Gosforth, in the near future the writer hopes to see still another haematite-district prospected and developed, and it will be of the greatest importance to the future welfare and prosperity of West Cumberland.

Mr. Cedric Vaughan (Hodbarrow Mines) wrote that Mr Walker, in his interesting paper on haematite-deposits, stated that "if there were no faults, there would be no haematite-ore." He agreed with him so far, but not in the reason which he gave for this conclusion, namely, "Because there would have been no spaces in which iron-ore could have been deposited." This would imply that the ore had been deposited in cavities or hollows previously existing in the Carboniferous Limestone, a view which he (Mr. Vaughan) frankly admitted had at one time attractions for him. However, during the working of the Hodbarrow deposit certain phenomena had presented themselves, and to his mind they were quite inexplicable except by a theory of substitution; and having again read that portion of Mr. J. D. Kendall's book, in which he deals with the origin of haematite,* he (Mr. Vaughan) had come to the conclusion that his theory of the replacement of limestone by haematite is the only one by which these phenomena can be explained.

With regard to the presence of fossils in haematite-ores, he (Mr. Vaughan) had three fossils which were found in the Hodbarrow mine, one especially being a perfect pseudomorph of pure haematite, which could not possibly have been produced by any other means than that of replacement or substitution. Again, detached pieces of limestone are occasionally found in the body of the ore-deposit, that have apparently resisted the action of the salt of iron, and so remained unchanged. If, as Mr. Kendall suggests, this salt of iron came from below in a gaseous condition,


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through the then recently formed faults in the Carboniferous Limestone, and coming into contact with water farmed a solution of perchloride of iron, then, as he has shown, the whole of the facts become simple and easily understood by the chemical formula which he gives. Moreover, in some parts of the Hodbarrow deposit there are traces of the action of heat, whereas in other parts of the same deposit there are none, which might be accounted for by the fact that considerable heat is evolved when perchloride of iron is dissolved in water, but the solution thus formed would cool down while acting upon the limestone. In other words, the
parts affected by heat must have been near the vent, where the gaseous emanations from below came in contact with water and formed the solution which acting upon the limestone caused peroxide of iron (haematite) to be deposited in its place.

The difficulty, however, still presents itself that a given volume of limestone so acted upon would not produce an equal volume of haematite, and as the Hodbarrow ore is very compact and comparatively free from "loughs" and foreign matter, he (Mr. Vaughan) could not quite fall in with Mr. Kendall's calculations on this point.

Mr. J. D. Kendall (London) wrote that, in discussing Mr. Walker's paper, the first observation that one felt called upon to make was with regard to such tautological expressions as "haematite-ore" and "calcereous limestone." Haematite is a red ore of iron, therefore it is unnecessary to speak of "haematite-ore," while limestone is of necessity calcereous, even when most impure.

When Mr. Walker speaks of haematite-mining in West Cumberland as being "only in its infancy" one feels that there ought to be an arriere-pensee which would associate that infancy with second childhood. Compare the district as it is to-day with what it was 25 to 35 years ago. Then, new and important deposits were being found in all directions; now, it is the rarest thing to hear of the discovery of a new deposit. The last ironworks erected in the district are now 24 years old. Then glance at the production. In 1882, it was 1,725,478 tons; in 1892, 1,335,007 tons; and in 1901, 1,009,869 tons. To-day, the output is probably not more than 50 per cent. of what it was 20 years ago.

Beneath the large area of Permian rocks south of Egremont, there may be an extensive tract of Carboniferous Limestone, which may contain many unknown deposits of Haematite, but exploring for them must be very costly and uncertain work; and when deposits are found, they will, from the great thickness of water-bearing strata, by which they are overlain, require large sums of money to develop and equip them. Whilst afterwards, they must be more costly to work than the shallow and comparatively dry deposits that occur to the north of Egremont. The area north of Rowrah has been much more fully explored than Mr. Walker appears to be aware of. As was pointed out to the Institute many years ago* that area is very little intersected by faults, and therefore deposits of haematite are less likely to be found in it than in the area between Rowrah and Egremont which has been very severely faulted.

Mr. Walker's idea of the deposits in the Carboniferous Limestone south of Egremont being connected with the immense deposit in the same rocks at Hodbarrow, by the narrow veins in the granite at Eskdale, is something like suggesting that the Cretaceous Coal-measures at Crows Nest Pass in British Columbia and seams on the same geological horizon in New Mexico are connected by the Carboniferous Coal-measures of Pennsylvania.

Mr. Joseph Adair (Egremont) wrote that, being only an amateur in mining matters, it might be considered out of place for him to make any remarks beyond saying that so far as Mr. Walker's sketch extended, it seemed to be in accordance with the generally received opinions on the subject. It was over 30 years since a party of adventurers, of which he (Mr. Adair) was the active member, endeavoured to take royalties in the Pardshaw and Dean district, but after a year's endeavour to take a royalty the attempt was abandoned. He (Mr. Adair) had the idea
that there was ore there. It was after their fruitless endeavour to take a royalty that the scratching to which Mr. Walker referred took place near Eaglesfield. It had been held as an opinion by some mining engineers for many years, that the deposit of ore extended from Egremont to Hodbarrow. The members of the


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Institute would see on their visit to Egremont that the trend of exploration was in a southerly direction, but whether ore would be found all the way through south-west Cumberland was problematical.

Mr. W. E. Walker (Whitehaven), replying to the discussion, remarked that Mr. Cedric Vaughan wrote on a subject very much discussed in past days, that is, as to whether or not there were spaces where the haematite-ore could have been deposited. To his mind, there were such spaces and, occasionally, spaces had been and still were met with in many of the mines. Some of the spaces, when holed into, were found to contain water, others shewing plainly, by their water-worn state, that, at one time, water passed through them. Heat might have acted and he (Mr. Walker) believed that it did act, to a certain extent, on haematite-ore, but this happened after the deposition took place. He (Mr. Walker) had found several fossils in the mines, but always at the junction of ore and limestone; and, although these fossils were mostly coated with haematite-ore, they, when broken, were found to contain limestone, and the coating of haematite-ore was very thin. He had never found a fossil consisting of haematite-ore only, nor did he ever find one in the body of the ore.

Before he wrote his paper, he had perused the journals of all the bore-holes put down north of Lamplugh as far as Eaglesfield, and they were, comparatively speaking, very few in number. As to the water in the Haile district, to which Mr. Kendall referred, if they were successful in finding haematite-ore there they would erect plant to cope with what water might be encountered. The water-question was an insignificant matter, and he had never known nor heard of any mining-engineer considering a few thousand gallons of water per hour to be a stumbling-block. The chief point was to ascertain whether haematite-ore was there in quantity; if so, the rest was a simple matter for those experienced in such work as might be required to be done.

The President (Sir Lindsay Wood, Bart.) moved a vote of thanks to Mr. Walker for his interesting paper.

Mr. T. E. Forster seconded the vote of thanks, which was cordially approved.

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THE GEOLOGY OF THE ENGLISH LAKE DISTRICT
By J. POSTLETHWAITE, F.G.S.

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Introduction.

Introduction.—The central portion of the English Lake District is composed of Lower Palaeozoic rocks, which all geologists agree in dividing into three separate groups. These Lower Palaeozoic rocks are almost entirely surrounded by a girdle of Carboniferous strata, and these again by an outer girdle of deposits of Permian and Triassic ages. The tripartite grouping of the rocks, which form the central portion of the area, was first recognized by Mr. Jonathan Otley, of Keswick, and his views were recorded in a paper, contributed to the Lonsdale Magazine in 1820, in which the groups were named, in descending order:—Greywacke, Greenstone and Clayslate. These divisions were afterwards described in fuller detail by Profs. Sedgwick, Phillips and Harkness, and still later by Prof. Nicholson, by whom they were classified as Skiddaw Slates, Green Slates and Porphyries, and Coniston Limestone, Flags and Grits. In 1876, Mr. J. Clifton Ward's Memoir of the Geology of the Northern Part of the English Lake District was published, and in 1897 The Physical History of the English Lake District, by the same author. In these, and in papers contributed to learned Societies, the various formations in the Lake District were described and illustrated in a very full and able manner, and all later workers are more or less indebted to him for the result of his labour during the six years that he was employed on the Geological Survey. Mr. J. C. Ward renamed the Green Slates and the Porphyries the "Volcanic Series of Borrowdale;" and he also adopted the Falcon Crag section as being typical of the whole volcanic area.

The most recent contribution to the literature bearing on the geology of the Lake country, which comprises the result of many years of patient, laborious and painstaking work, accomplished by Mr. John E. Marr and Mr. Alfred Harker, including microscopic examination and chemical analysis of the rocks, was written by Mr. J. E. Marr, and read by him to the members of the Geologists' Association on July 6th, 1900, in preparation for their excursion to the district in the latter part of the following month, in which he occupied the position of director.*

In some important points, Mr. Marr dissented from Mr. Ward's mapping, and to these points further reference will be made later. In this paper the old name, "Green Slates and Porphyries," is again given to the Volcanic Series, and the three great divisions of strata are described under the apppellations of Lower Slates, Middle Slates and Upper Slates.

The Skiddaw Slates.—The Skiddaw Slates are exposed in the north-western portion of the Lake District, where they cover an area of about 200 square miles, but the presence of isolated patches on the south-western and eastern margins are indications that there is very probably a more extensive area buried beneath strata of later date, and it was no doubt once continuous with the sedimentary rocks of the Isle of Man and those of North Wales.

The base of the Skiddaw Slates is nowhere visible, being surrounded or overlain on every side by rocks of later age, namely, on the western, north-western and eastern boundaries by Carboniferous Limestone; on the north and north-east by the volcanic rocks of the Caldbeck mountains; and on its south-eastern margin, which extends in a somewhat irregular course from Swinscale Beck, near Penruddock, by Mellfell and Threlkeld Common to the foot of Walla
Crag, thence along the eastern shore of Derwentwater, and over Maiden Moor, to the northern end of Honister Pass; it is succeeded, as far as the western side of Mellfell, by conglomerate, and from that point onward to Honister Pass by rocks of the Volcanic Series; and on the south from the northern end of Honister Pass to Dent Hill, near Egremont, it is bounded partly by the Buttermere and Ennerdale Granophyre and partly by the Volcanic Series.

The Skiddaw Slate-rocks consist of a series of beds of soft shale, or slaty mudstone interstratified with occasional bands of grit. The slaty mudstone, which forms the most important part of the series, is a soft dark-grey rock, sometimes almost black, and frequently containing oval-shaped ferruginous nodules of various sizes. This rock has been cleaved, crumpled and distorted by lateral pressure, and most of it breaks up into long splintery fragments; but, in localities, where the cleavage coincides with the bedding, it splits readily into thin leaves.

At one time, attempts were made in these localities to quarry the rock for roofing-slate, and portions of old farm-buildings may still be found in the neighbourhood of Keswick, and near the Skiddaw group of mountains, that are wholly or partly roofed with Skiddaw Slate. The ruins of the Earl of Derwentwater’s mansion on Lord's Island, of which the foundations only and some mounds of rubbish remain, afford proof that it, too was either wholly or in part roofed with Skiddaw Slate. This slate cannot, however, compete with any possibility of success with slate of volcanic origin, being defective in hardness and durability and inferior in colour; nor with the sedimentary rocks of North Wales, in the quality of lightness, or capability of being split into very thin leaves.

The beds of grit are in some cases of considerable, but irregular, thickness, generally more or less micaceous, and of a hard and durable character. Occasionally, the grit is coarse and sandy, breaking up into square or oblong blocks, and in some localities it passes into a true conglomerate; in other cases it is formed of finer materials, and is of a flaggy nature. The flags are frequently ripple-marked, or show a structure similar to ripple-marking, which may have been caused by earth-movements subsequent to the deposition of the rock. These beds have also suffered from the lateral pressure which acted on the softer strata, but in a much less degree.

These alternating beds of fine and coarse mud and sand, hardened by age and pressure, which probably attain a thickness of from 10,000 to 12,000 feet, represent old marine-deposits of river and current-borne materials. There are no indications of deep-sea deposits, but rather those of shore-conditions. To allow of such an accumulation of deltaic deposit, there must have been a continual depression of the area of deposition during a very long period of time. The thickening of the beds towards the west, or a little to the north of west, would indicate that the continent, which supplied the river-borne materials, in that direction, and that the river, which brought down, and deposited the materials, must have been a large one to form delta of such width and thickness. During the deposition of the
Skiddaw Slates, the Ordovician sea obeyed the Divine command and "brought forth abundantly the moving creature that hath life," and the moving creatures thus produced were mostly of a very low type, but some were a little more highly organized. There was vegetable life, too, in the shape of sea-weed and marsh-plants, but the species recorded are few in number, and their preservation often imperfect. Considering their frail and perishable nature, and the vast lapse of time since they were buried in those ancient deposits of sand and mud, we need not be surprised at their imperfection, but rather that any trace of them still remains. The forms of animal life, which were fossilized in those ancient mudstones, were of a much more enduring character, as they were enclosed in chitinous or calcareous cases, which would resist the ordinary decay of nature much longer, and thus afford greater facilities for fossilization. The animal-remains thus preserved in the Skiddaw Slates were chiefly graptolites, the characteristic fossils of the Ordovician age. About 120 species of graptolites have been found in the Lower and Middle Ordovician rocks of Great Britain, and of these upwards of 60 have been obtained from, the Skiddaw Slates. Numerous impressions of worm-tracks also occur in the Skiddaw Slates, both in the flaggy beds, and also in the softer and finer mudstones.

Next to the graptolites, the most numerous and persistent of the Skiddaw Slate fossils is the bivalved phylopod, Caryocaris wrightii. Its remains occur in almost every locality where graptolites are found.

A small number of trilobites (probably not more than 30) have been found in the Skiddaw Slates, and most of these differ from all known species; indeed the trilobite-fauna of the Skiddaw Slates may almost be said to stand alone.

The fossil mollusca also stand alone. The remains of molluscs are scarcer than those of trilobites, indeed it is probable that the Skiddaw Slates have not yielded 20 specimens, and these there is not one that agrees with any known species. In addition to the alteration caused by lateral pressure, extensive areas of Skiddaw Slate have been metamorphosed by proximity to, or contact with, intrusive masses of igneous rock. The amount of alteration around the larger masses of granite, microgranite, granophyre, picrite, diabase, etc., is very variable, while the slate around the smaller bosses and dykes is often very little altered. In many places, the slate is traversed by mineral veins, and by strings of white opaque quartz, and it is generally much hardened along the sides of the veins and where the strings are numerous.

The most interesting example of metamorphism in the Skiddaw Slate area occurs round the Skiddaw Granite. It measure about 6 miles from east to west, and 5 miles or more from north to south. On approaching the metamorphosed area, the first indication of change observable in the slate is the appearance of small undeveloped crystals of chiastolite. Proceeding in the direction of the granite, the white crystals of chiastolite become larger and more numerous, measuring where they are best developed upwards of 1 inch in length. The chiastolite-slate passes into a hard schistose, foliated, and sonorous rock of a darker colour, in which dark oblong spots composed of andalusite mixed with flakes of mica, take the place of crystals of chiastolite in the former. Proceeding onward, the spotted schist gradually passes into mica-schist, a brownish granular, foliated rock, containing a considerable quantity of mica. This rock is in contact with the granite.
The Volcanic Series.—The Volcanic Series consists of a vast accumulation of bedded volcanic ashes and breccias, interstratified in some parts with sheets of lava. It attains a thickness of from 10,000 to 12,000 feet, and occupies an area of about 400 square miles. This area is bounded on the north and northwest by Skiddaw Slate, except where it abuts against the Buttermere and Ennerdale Granophyre. The south-western boundary is formed partly of Permian Sandstone, partly of Eskdale Granite, and partly of the Skiddaw Slate of Black Combe. On the northeast, it is succeeded partly by Carboniferous Limestone, partly by conglomerate, and partly by Skiddaw Slate, and the south-western margin is formed of Coniston Limestone. The ashes and breccias compose the largest portion, probably nine-tenths of the rocks of the Volcanic Series; they are alike in being formed of materials that have been ejected from volcanoes, but differ with regard to the size of the fragments which they contain. The ash properly so-called, varies from a rock containing fragments of the size of walnuts, which is considered a very coarse, to a rock formed of fine impalpable powder. Breccias are of all degrees of coarseness, from rocks made up chiefly of fragments about the size of walnuts, to those in which they measure 5 or 6 inches across, and in some cases they contain huge blocks several feet in diameter. In both coarse ashes and breccias, the fragments are generally angular and unworn at the edges, but in some rare instances they are water-worn like a conglomerate. In colour, the ashes and breccias vary from dark green to light grey, or sometimes purple. The green tints, which are very prevalent, are due to the presence of chlorite diffused through the rock, in a greater or less degree, while the red and purple tints are due to haematite. There is generally more or less stratification discernible in the ashes, shown in some cases by clearly defined bands of lighter and darker colour, and in others by finer and coarser materials. These alternating beds or layers of finer and coarser ash are often very irregular, some layers thinning out and others thickening; and occasionally very clear examples of false-bedding are seen among the finer varieties. Sometimes, a fragment of an older ash of considerable size, showing all its original structure and stratification, may be seen embedded in a newer ash, the stratification of the fragment being at a different angle to that of the rock in which it is enclosed. The best section of lavas, ashes and breccias exposed in the Volcanic Series occurs on the eastern shore of Derwentwater, extending from the margin of the Lake to the summit of Bleaberry Fell, a height of 1,691 feet. The lavas, of which there are 12 distinct sheets, are mostly very hard and compact, of a grey or bluish-green colour, and often contain crystals of altered augite, garnet and other minerals. The sheets differ greatly in thickness, varying from 15 to 150 feet, the upper and under surface in each case being more or less vesicular and cinder-like, while the remainder is massive and compact. Messrs. Marr and Harker have, however, shown that this section is typical of a very small portion only of the Volcanic Series, which they classify as follows, in descending order: —(1) Shap rhyolites; (2) Shap andesites; (3) Scawfell banded ashes and breccias (Kentmere-Coniston slate-band); (4) Ullswater basic-lava group (Eycott group); and (5) Falcon Crag and Bleaberry Fell andesites.
The Ullswater basic group, or Eycott group, is well developed on the western side of Borrowdale, on the north and south of Lake Ullswater, and on the north and north-eastern side of the Caldbec mountains, from Berrier, or Eycott Hill to the neighbourhood of Cockermouth. Also on the west and south-west of the volcanic area, from the head of the Vale of Ennerdale to the Duddon Estuary.* At Eycott Hill, a series lava-flows of this group occur, interstratified with thin beds of ash, one of the lavas being, with the exception of Shap Granite, the handsomest rock of its kind in the Lake District; it consists of a general porphyritic base, containing dark green spots and large crystals of felspar, many of them an inch or more in length.

The Scawfell banded ashes and breccias, or Kentmere-Coniston slate-band, cover a much smaller area than the Eycott group, but form some of the highest mountain-masses, extending from Scawfell to Dunmail Raise; from Helvellyn summit to near Haweswater, and thence westward to the Duddon Valley. This group consists principally of ashes, lavas being few in number.

The Shap andesites and Shap rhyolites occur as rather narrow bands, extending from Shap to a point a few miles northwest of Coniston, where they abut against the Coniston Limestone.† The andesites consist of more or less vesicular lavas, probably made up of a succession of comparatively thin flows, interstratified with ashes and fine agglomerates. The rhyolites consist of lavas, compact, and often of a flinty appearance; some are laminated, and others coarsely nodular; and associated with the lavas are a series of rhyolitic ashes and breccias.

The Coniston Limestone Series.—The Coniston Limestone consists of a dark-greyish blue, hard and compact limestone, in which the calcareous element is very poorly developed; it is also less jointed than most rocks of its kind. The limestone is a good deal mixed up with cleaved shales, some of which are calcareous. On the eastern side of Kentmere, there is a bed of


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contemporaneous felspathic rock of a reddish colour, interstratified with the beds of limestone and shale; some of the latter are also mixed with volcanic ashes. The whole of the beds, which are somewhat irregular, make up an average thickness of about 300 feet.

The Ordovician river-delta, which afterwards hardened into Skiddaw Slate, sank at the close of the volcanic period, and the Coniston Limestone was deposited in a moderately deep sea, but the large river still brought down great quantities of mud, which were carried far out to sea, and became mixed with the calcareous ooze, rendering it very impure, while fitful outbursts from the expiring volcano scattered showers of fine ashes, which also mingled with the calcareous ooze and river-borne mud on the bed of the Ordovician sea.

The Coniston Limestone forms a band stretching across the Lake country, from Millom, by Broughton, Coniston and Low Wood (near Ambleside), across the valleys of Kentmere
and Long Sleddale, to Wasdale Crag (near Shap), where it is partly cut off by the granite. It is again seen on the opposite side of the Shap Granite, then passes beneath the conglomerate and Carboniferous rocks to re-appear once more at Keisley, where it forms part of the Cross Fell inlier. There is also a small exposure of Coniston Limestone in the Furness district, near Dalton, where it is brought up by an anticlinal fold. In the Lake District, it overlies the rocks of the Volcanic Series with perfect conformity, dipping to the south-south-east at high angles. In some places, it is much disturbed and shifted by faults. Although there is no want of conformity between the Ashgill Shale, the uppermost bed of the Coniston Limestone Series, and the superincumbent strata, there is complete discordance between the fossil-remains found in them; therefore, it is at this point that the line of division between the Ordovician and Silurian systems is placed.

The Coniston Limestone is no doubt the equivalent of the Bala Limestone in North Wales, the same characteristic fossils being found in each of them. Deposits of much the same age, as shown by their included fossils, also occur at one point, amongst the rocks of the Volcanic Series, north of the main area of the Skiddaw Slates. This section is exposed in Drygill, between Carrock Fell and High Pike.

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Stockdale Shales (Lower Silurian).—At the commencement of the Silurian age, the seabottom was again elevated, and the formation of the river-delta was resumed. The sea again swarmed with graptolites, but they differed greatly from those which were entombed in the Skiddaw Slates. During the long ages that elapsed, while the rocks of the Volcanic Series and the Coniston Limestone were being formed, changes had occurred in the graptolite-fauna, but whether of progression, or retrogression, it is not easy to determine.

The Stockdale Shales succeed the Coniston Limestone with perfect conformity; they consist of a belt of highly fossiliferous shales or mudstones, measuring from 250 to 400 feet in thickness and extending from the Duddon Estuary to Shap Fells, where they disappear beneath the basement-bed of the Carboniferous series. They re-appear again, however, near Knock, in Westmorland, as part of the Cross Fell inlier. There is also another small exposure of Stockdale Shales, on the eastern side of the Duddon Estuary, near Dalton-in-Furness.

Coniston Flags and Grits (Lower Silurian).—The Stockdale Shales are succeeded on the south-east by the Coniston Flags and Grits, which attain a total thickness of about 6,800 feet of flags and lower grit-beds, and 4,000 feet of upper grits, the beds being somewhat thinner on the eastern side of the district. The flags consist of dark-blue laminated sandy mudstones, which split into moderately thin flags, where the cleavage is well developed. The lower part of the flags has yielded a considerable number of graptolites, trilobites and encrinites, but in the upper beds fossils are somewhat scarce.

The grits consist of thick beds of tough grit or sandstone, interstratified with flaggy beds. They, too, have yielded a considerable number of fossils, one bed near the base being remarkably prolific.

The flags and grits occupy two separate areas—one where they succeed the Stockdale Shales and older rocks, in regular order, between the Duddon Estuary on the south-west, and the Shap Fells on the north-east; and the other where they occupy the high ground around Howgill and Langdale Fells on the east side of the Lune, and on Grayrigg Common and
Whinfell Beacon on the west side of the Lune. There is also a considerable area of flags and grits in the northern part of Furness.

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Bannisdale Slates and Kirkby Moor Flags (Upper Silurian, Ludlow Series).—The Coniston Flags and Grits are succeeded on south and south-east by rocks of the Ludlow formation, comprising beds belonging to both the lower and upper divisions of that series, namely, the Bannisdale Slates and the Kirkby Moor Flags. They attain their greatest development between Kendal and Kirkby Lonsdale, where they measure about 11 miles across the outcrop of the beds. This area is bounded on the north by the Coniston Grits, on the east by the Lune-valley fault, and on the south-west by Carboniferous Limestone. The Upper Ludlow rocks re-appear from beneath the limestone in a narrow strip on the eastern side of Kendal Fell, and there is an outlier of the same rock, extending in a narrow band from about ¾ mile north-west of Staveley to Borrow Beck, near Hollowgate. The Bannisdale Slates (Lower Ludlow) consist chiefly of sandy mudstones, interstratified with beds of grit and thin bands of hard sandstone. Rough and inferior slates are sometimes obtained from these beds, but they rarely yield even a tolerable quality. The mudstones are, however, extensively quarried for paving and building-stone, and for rough slabs. The Kirkby Moor Flags (Upper Ludlow) consist chiefly of thick beds of hard concretionary sandstone, interstratified with thinner beds of fine-grained sandstone of a flaggy nature. Fossils are scarce in the Bannisdale Slates, but are very plentiful in the Kirkby Moor Flags, consisting chiefly of brachiopods, lamellibranchs and gasteropods.

Deltaic conditions prevailed, and a gradual sinking of the land and ocean-bed continued during the deposition of the Silurian rocks; then the downward movement became more rapid, and the Lake District suffered extensive denudation; while at no great distance, on the west and north-west, still more drastic changes occurred, resulting in the total and final submergence of the continent from which the great river had, during so many ages, worn away and emptied into the Ordovician and Silurian seas, its burden of mud and sand. We have seen that, during the deposition of the Coniston Limestone, the mud far exceeded the calcareous element; but the Carboniferous Limestone was formed almost entirely of calcareous matter, and the rocks of later age, which surround the Lake country, bear no record of deltaic deposits, such as those which prevailed during the deposition of the Lower Palaeozoic rocks.

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Carboniferous Rocks.—The Lake District is almost surrounded by Carboniferous strata, extending in a continuous belt from Egremont on the west around the northern and eastern margin to Ingleton on the south-east, thence in detached patches to Silecroft, on the western side of the Duddon Estuary; the remaining 20 miles being the only important break in the circle. The Carboniferous strata, in descending order, include:—(1) Coal-measures; (2) Millstone Grit; (3) Yoredale Series; (4) Carboniferous Limestone Series; (5) Lower Limestone-shale Series; and (6) the Basement Conglomerate. These divisions are not continuous, and they vary considerably in their development at different points." One of the most important of the divisions, from an economic point of view,
is the Coal-measures; indeed, it contains in its fossil fuel one of the most valuable mineral assets associated with the Lake country. The West Cumberland coal-field covers an area of about 100 square miles, and it has been yielding its wealth, and providing employment for a large number of men, since the early part of the seventeenth century.

On the eastern margin of the Lake District, at Argill, near Brough, there is a small area of workable coal, discovered by Mr. T. G. Goodchild, and on the south-eastern margin, a more extensive area, about 20 square miles in extent, namely, the Ingleton and Burton coal-field, which has yielded a considerable quantity of coal.

A narrow strip of Carboniferous Limestone, in West Cumberland, extending northwards from Egremont, about 8 or 9 miles, and measuring from 1 mile to 1 ½ miles in width, has been, and is still, a repository of vast mineral wealth. The south-eastern edge of this strip of limestone reposes on Skiddaw Slate, and its north-western edge is overlain partly by Permian breccia, partly by Millstone Grit, and partly by Coal-measures. The deposits of haematite in the area here described are of immense value, and the members of this Institute will have an opportunity during their stay in Cumberland of visiting some of the mines. Similarly rich deposits also occur in the Carboniferous Limestone in South Cumberland, near the mouth of the Duddon Estuary, at Hodbarrow and Whicham mines: indeed, the output

* The Carboniferous rocks have been very ably described by Mr. J. D. Kendall, Trans. N. E. Inst., 1883, vol. xxxii., page 319; and 1884, vol. xxiv., page 125.

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At the former probably exceeds that of any mine in Cumberland. Equally rich deposits occur in connection with the Carboniferous rocks of Low Furness. The deposits here are very irregular, but the largest masses of ore are found at or near the junction of the slate-rocks and the Carboniferous Limestone.

The Carboniferous rocks, as their name indicates, are remarkable, above all other geological formations, for the profusion of contained fossil-vegetation, but they are also rich in fossilized remains of animal-life. The graptolites, which were so numerous in the Ordovician and Lower Silurian rocks, had disappeared, and trilobites were dying off, but the remains of shell-fish had largely increased, while ganoid fishes, corals, encrinites, and a higher class of amphibian mammalia had appeared, together with insects of various kinds.

Permian and Triassic Rocks (New Red Series).—The outer girdle of Permian strata which succeeds the Carboniferous rocks, covers a much larger area, but in all probability its thickness is not far in excess of the latter. On the north and north-east the New Red rocks extend from Maryport to a point about 3 miles from Netherby, and from Bowness-on-Solway to Kirkby Stephen, being cut off on the east by the Pennine fault. On the south of the Lake District, there are detached patches in Cartmel and Low Furness, and on the west a strip extending from the Duddon Estuary to St. Bees Head: but they attain their greatest development between Penrith and Carlisle, and in the valley of the river Eden. The lowest bed of the series is the Penrith Sandstone, coarse-grained, and of a dark red colour, with its underlying and overlying breccias (locally called "brockram"). Above the upper brockram is a series of alternating beds of pale yellow sandstone, with thin films of clay between, of reddish dolomitic sandstones, marl-slate bands and shale. The yellow sandstones, clays and shales
are crowded with carbonized Plant-remains, mostly in a very fragmentary condition. These are overlain by gypseous marls, red shales and micaceous flags; these again by a great thickness of red sandstones with white and mottled bands, which are known as the St. Bees and Kirklington Sandstones.

The Permian and Triassic rocks, which girdle the Lake country, are not so prolific in the remains of animal-life as those

of Carboniferous age. The Magnesian Limestone yields its ganoids, shell-fish and reptilian remains, and some of the stones and shales give evidence of an abundance of vegetable life, but the thick masses of New Red Sandstone are singularly barren. The conditions under which they were formed were probably not favourable for fossilization, as the footprints only of certain animals are left to show that animal life did exist these localities and at that time.

Surface-deposits.—Many of the valleys beneath the highest mountain-masses contain numerous irregular mounds of moraine-material, some of which have been cut through by streams. The rocks on the mountains, and on the sides of the valleys, are in many places rounded and grooved by glacial action. In the valleys, there are also numerous patches of Boulder-clay, containing occasionally striated and grooved boulders. On many of the Skiddaw Slate mountains, notably Latrigg, the eastern end of Skiddaw, Blencathra, Newlands Hause, etc., are perched blocks of ash and trap from the Volcanic Series, at all elevations up to 1,500 feet, and the river-courses in the Skiddaw Slate valleys are filled with boulders that have been transported from the mountains of the Volcanic Series.

Numbers of peat-mosses and bogs on the mountains, and in some of the valleys, mark the sites of old tarns and lakes; numerous masses of drift-material also occur in the valleys, consisting of sub-angular gravel and beds of sand, often strati-tied and false-bedded.

Igneous Rocks: Eskdale Granite.—This is the largest exposure of granite in the Lake District, covering an area of about 35 square miles. It lies at the south-western margin of the area occupied by the Volcanic Series, and is succeeded on the western side by New Red strata. Generally the rock is rather coarse, but in some parts there are bands of fine-grained granite. It consists of quartz, orthoclase and triclinic felspar, and dark brown mica; in some portions of the fine-grained granite mica is absent. The felspar is more or less impregnated with haematite, which gives a reddish tint to the rock, and that tint is more apparent on a weathered surface than where it has recently fractured; as the haematite, when liberated from the decomposed felspar, overspreads the whole surface of the rock. There are also three small exposures of granite, which are no doubt connected with the Eskdale mass, namely, at Burnmoor Tarn, at the foot of Wastwater, and the foot of Scawfell. The first-named is rather coarse, and the two latter fine-grained, but all have the reddish tint which characterizes the Eskdale Granite.
Shap Granite.—On the opposite margin of the Volcanic Series, near Shap, is a much smaller, but in some respects, a more interesting exposure of granite. The rock consists of a base made up of grains of white felspar, crystalline quartz and black mica; in this base are embedded large oblong crystals of pink felspar (orthoclase), which are often of gigantic size, and form the distinguishing feature of the granite. It is much altered where it is in contact with the surrounding rocks, the latter also being greatly metamorphosed. The mass, as it now exists, measures about 2 miles in length by 1 ¼ miles in width, but large quantities of it have been removed by denudation, multitudes of boulders of all sizes being scattered over the country to the south and east of the parent mass, some of them having been carried to a distance of 60 miles from their original home.

Skiddaw Granite.—A small mass of Skiddaw Granite is exposed in Syning Gill, near the base of Blencathra, and a larger mass at the upper end of the Caldew valley; there is also a third exposure a little lower down the course of that river, which is connected, on its northern margin, with the igneous rocks of Carrock Fell. The granite is composed of white opaque felspar (both orthoclase and triclinic), dark-brown or black mica, and quartz containing numerous liquid cavities; also some grains of magnetite. The three exposures in the localities named doubtless form portions of a continuous mass, which extends over a large area at a very short distance beneath the surface. The metamorphosed Skiddaw Slate surrounding and overlying it covers an area of about 30 square miles.

Buttermere and Ennerdale Granophyre.—This mass of granophyre occupies a large area, extending from Buttermere on the north to Wastwater on the south, a distance of 9 miles, and for

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a great part of the distance forms the boundary between Skiddaw Slate and the Volcanic Series. The rock is generally of a pale-red colour, sometimes changing to dark-grey, and is fairly uniform in appearance. It consists of pink felspar (plagioclase and orthoclase), transparent quartz, dark hornblende, chlorite, and a little mica.

St. John's Microgranite.—This rock occurs in two masses occupying both sides of the lower end of the Vale of St. John. Each of these masses measures about 1 mile from north to south, and from ½ to ¾ mile from east to west; they are each bounded on the east, west and north by Skiddaw Slate, and on the south by the Volcanic Series. It is probable that the fault which separates the two formations may have been the channel through which the mineral matter of these masses, as well as the Buttermere and Ennerdale Granophyre, welled up from beneath in a molten state.

The microgranite consists of orthoclase and microcline-felspar, quartz, calcite and schorl, also some epidote and serpentine; part of the last-named has probably replaced mica. The colour is generally grey, but in some places it assumes a reddish tinge. The rock is very much jointed, and frequently contains masses of considerable size that are greatly altered; in some of the joints crystals of galena and blende have been found. Close to the junction with the Skiddaw Slate, the microgranite is slightly altered in appearance and becomes more brittle; the Skiddaw Slate is also hardened, and contains irony spots.
Igneous Rocks of Carrock Fell—On Carrock and the adjoining mountain, Great Lingy, there is a series of igneous rocks, consisting of (a) granophyre, (b) gabbro, and (c) diabase. The granophyre is a coarsely grained rock, very hard and tough, and of a pale red or brownish-grey colour, with a number of greenish crystals, which show a spherulitic structure, scattered through it. The gabbro is generally coarsely crystalline, but sometimes fine-grained. The base of this rock consists of large crystals of opaque white felspar (plagioclase) and interstitial quartz, and through it are scattered crystals of dark olive-green diattacite, which is very nearly allied to hypersthene; also occasional grains of magnetite and apatite. Large blocks of lava of the Eycott Hill series are here and there enclosed in the gabbro. The diabase is also coarsely crystalline, of a dark-green colour, and in some parts shows distinct lines of bedding.

Hornblende-picrite of Little Knot.—This is a coarsely crystalline rock of a dark olive-green colour: it is largely composed of hornblende, but there are also present in small quantities, quartz, felspar (plagioclase), iron peroxide, epidote, apatite, olivine and calcite. The rock occurs in an oblong mass, about 1,800 feet in length by 120 feet in width, and extends from Little Knot, at the northern end of Longside, down nearly to the bottom of Barkbeth Dale.

Dioritic Picrite of White House and Great Cockup.—This rock is very nearly allied to the hornblende-picrite of Little Knot; it is exposed on both sides of Hause Gill, which separates White Hause from Great Cockup. The exposure on the former measures from 36 to 45 feet square, that on the latter mountain being somewhat smaller. The two masses are about 1 mile apart, and are doubtless connected beneath the till which forms the floor of the little valley.

The dioritic picrite is a coarsely crystalline rock of a dark olive-green colour, consisting of several varieties of hornblende, also quartz, felspar, calcite, serpentine, iron peroxide, and probably a little apatite, ilmenite and viridite. Olivine is also probably represented by some of the serpentinous mineral, but its presence cannot be clearly determined.

Sale Fell Minette.—At the summit of Sale Fell, is a minute exposure of a very beautiful rock. It consists of a pink crystalline felspathic base, in which are numerous crystals of dark-green mica. The base is chiefly composed of orthoclase, but some triclinic felspar is also present. There is no quartz visible to the naked eye, but small crystals may be detected under the microscope: there is also a little hornblende present. The rock is very hard and tough, and in lithological character is unlike any other rock in the neighbourhood.

Igneous Rocks of Seatoller Fell.—On Seatoller Fell, Borrowdale, there is a dyke of diorite lying between two masses of intrusive
diabase. The masses of diabase together measure about 1 mile in width. The rock is very compact, and of a dark blue colour; it consists of a felsitic base, in which there are crystals of triclinic felspar, quartz, augite, and some magnetite. The diorite, which is much altered, is made up of numerous small crystals of felspar, hornblende, magnetite and chlorite. The dyke is about 1/3 mile in length and 40 or 50 feet in width. It is in connection with these masses of blue diabase, the dyke of diorite, and the adjoining ash-rocks, that the rich deposits of graphite have been found. The ash all round the igneous rocks is much altered.

Garnet-bearing Rocks, below the Banded Ashes of Scawfell.—These rocks attain their greatest development beneath Scawfell and the adjoining mountains, and extend in a narrow band, from 1 ½ miles to 2 miles in width, from near the head of Wastwater to Dunmail Raise, and in a narrower band from Scawfell to the upper part of Langdale valley. They also occur in another area around and to the west and north-west of Haweswater. The rock is generally of a greyish or greenish colour, with a compact base in which crystals of felspar and augite occur; in some places it appears to pass into ash, and occasionally into breccia. The garnets are sometimes small, and very sparsely scattered, and in others they are numerous and of considerable size. Formerly these rocks were regarded as contemporaneous lavas and ashes, but Messrs. Marr and Harker consider that the evidence, on the whole, points to the intrusive character of most of them.

Dolerite of Castlehead, Keswick.—This mass of dolente, although not remarkable for beauty, is in some respects one of the most interesting of the igneous rocks of the neighbourhood, as it probably represents the last expiring effort of the great volcano from which flowed, or were ejected, all the lavas, breccias and ashes of the Falcon Crag and Bleaberry Fell series. On this last occasion it succeeded only in raising the lava part of the way up the vent, where it solidified, and at some period, long afterwards, became exposed through the removal of the cone by denudation. The rock is highly crystalline, and is composed of augite and pale felspar, with crystals of a soft dark-green pseudomorphous mineral, in which both serpentine and chlorite are present. Small veins of quartz and calcite occur in it; also flakes of brown mica, and some magnetite.

Armboth Dyke.—This dyke is a quartz-felsite or microgranite, being precisely the same in chemical composition as the St. John's microgranite. It is a very beautiful rock, consisting of dull red felsitic base, studded with numerous crystals of pink felspar and transparent quartz, also a little serpentine, and occasional grains of green mica. The dyke is from 20 to 30 feet in width and extends in a north-north-westerly and south-southeasterly direction across Armboth Fell, where it may be traced for a distance of about 1 ½ miles. It may be seen in the wood above Armboth House, and appears again on the opposite side of the valley, near the seventh milestone on the road from Keswick to Ambleside, and extends in a south-easterly direction beyond the crest of Helvellyn.

In addition to those already described, there are small bosses and dykes of igneous rock on Skiddaw Dodd, Seathwaite Howe (near Embleton), Wythop Fell, Robin Hood, Burtness
Combe (near Buttermere), Hindscarth, Swirrel Edge, Helvellyn, Langstrath (in Borrowdale), Troutbeck, and on Matterdale Common.

Faults and Mineral Veins.—The faults and veins of the Lake District belong to two systems, one having a prevailing east-north-easterly and west-south-westerly, and the other a north-north-westerly and south-south-easterly direction. The former coincide with the strike of the older rocks, and are much older than the latter, as they do not affect any strata of later date than the Upper Ludlow formation. No date can be assigned to the newer, or north-north-westerly and south-south-easterly system. The best known example of this system is the Pennine fault, which dislocates the strata to the extent of not less than from 6,000 to 7,000 feet, and forms that important geographical feature known as the Pennine Chain. In the Lake District, the most important fault of the newer system is one that extends from Skiddaw Forest, through the Glenderaterra and Thirlmere valleys, thence through Dunmail Pass along the depression occupied by Grasmere, Rydal and Windermere lakes. Its presence can be detected near Ambleside by the shifting of the Coniston Limestone to the south. Another parallel fault probably extends through the depression occupied by Bassenthwaite and Derwentwater lakes, through Borrowdale and the valley in which Coniston Lake lies. This has also shifted the Coniston Limestone at Coniston Waterhead. A third fault probably passes along the valley of Lorton, through Crummock and Buttermere Lakes, terminating in the Duddon Estuary. It is also probable that there are faults in the Shoulthwaite and Watendlath valleys, and many more of minor importance.

Of the older or east-north-easterly and west-south-westerly system, it may be noted that one fault probably extends from the coast of West Cumberland, up the valley of Eskdale, and is prolonged through the Grisedale Valley and the depression of Ullswater Lake; but the most important of this older system is no doubt the great boundary fault between the Skiddaw Slates and the Volcanic Series, which extends in a zigzag course from near Egremont to the eastern side of Mellfell. The nature of this boundary has given rise to some divergence of opinion amongst geologists. Mr. Clifton Ward mapped it as a faulted boundary or junction, and with the dip or hade of the fault approaching the vertical, corresponding in amount with that of the mineral veins of the district. He shows, moreover, that the main east-north-easterly and west-south-westerly fault is complicated by the intersection of a number of north-north-westerly and south-south-easterly faults, the two frequently meeting at right angles with each other, and letting down the newer rocks between them. On the other hand, Sir Archibald Geikie, in The Ancient Volcanoes of Great Britain records his entire disbelief in the existence of such a fault, and furthermore states that he went over most of the ground with Mr. Ward, heard his arguments in favour of it, and yet remained unconvinced. He does not, however, offer any alternative theory to account for the present position of the rocks. Messrs. Marr and Harker hold that there is a fault, which they describe as a "lag-fault," at the junction, not almost vertical, as Mr. Ward mapped it, but nearly horizontal: and that a similar lag-fault forms the boundary between the Ordovician and the Silurian rocks. They have stated as their opinion, "that the folding and faulting which

* Vol. i., page 229.
affected the Lower Palaeozoic rocks of the district are primarily due to the pushing forward of the rocks in a general northerly direction by a force acting from the south. Further, that the rocks moved forward at unequal rates, and that so far as the main mass of rocks now exposed is concerned, the Skiddaw Slates moved farthest forward, causing the Green Slates and Porphyries [Volcanic Series] to lag behind, and the Upper Slates [Silurian] in turn to lag behind the Green Slates and Porphyries. As the result of the lagging, a fault, whose fissure approaches the horizontal, was formed between the Skiddaw Slates and the Green Slates and Porphyries, and a similar fissure between these volcanic rocks and the Upper Slates.*

The few sections, however, where the junction can be inspected seem to support the theory of a nearly vertical fault, rather than of one that is nearly horizontal.

If an observer takes his stand near the junction, between Castle Head, Keswick and Walla Crag, and faces the south, he looks toward the high mountains of the Volcanic Series; in the foreground he has Bleaberry Fell, High Seat and Armboth Fell; in the distance Langdale Pikes, with the Scawfell group a little to the west, and Helvellyn, Fairfield and others a little to the east. Then if he turns round and faces the north he has in front of him Skiddaw, with Saddleback on the east, and Lord's Seat and other Skiddaw Slate mountains on the west. It will be seen that the older mountains of sedimentary origin have their summits practically on a level with the newer mountains formed of volcanic materials; and on looking back into the past history of our Lake country, bearing in mind the fact that the rocks of sedimentary origin are and have been wearing away at a speed at least ten times more rapid than the volcanic rocks, he will see that there was a time in the past when the Skiddaw Slate mountains must have been several thousands of feet higher than those of volcanic origin: whereas, according to their age and the general sequence of the strata, they should have been buried to the extent of some thousands of feet beneath them. This then is the condition of things that is so hard to understand, and which has caused such divergence of opinion.


All geologists, from Mr. Jonathan Otley downward agreed that there is an anticlinal axis, or an axis of elevation, of which the Skiddaw Slates are the centre. Mr. Otley regarded the Skiddaw Granite as the original nucleus and uplifting agent, and believed that the newer rocks were wrapped around it like a mantle.

It is more probable, however, that at a time when the Skiddaw Slates were entirely covered by volcanic, and possibly also by Silurian strata, the granite welled up as a molten magma, into a portion of a huge cavern formed by the upward bending of the superincumbent strata into an arch of vast dimensions, having its ridge in an east-north-easterly and west-south-westerly direction: and that the upward bending, caused by lateral pressure, resulting from the contraction of the earth's surface while cooling, continued until the arch broke open along the ridge. The Skiddaw Slate, which was then in a plastic condition, yielding to the immense pressure of the superincumbent strata, began to flow toward the opening thus formed, and...
upwards through it, pushing the walls of the fracture more widely asunder, the upward flow continuing until a vast mass accumulated far above the then existing surface. This theory is to some extent supported by the fact that the bedding-planes of the Skiddaw Slates are almost everywhere in a more or less vertical position. Then at the close of this movement the irregular fissure was formed, as mapped by Mr. Ward (which let down the strata on the south-eastern side), and it probably penetrated downwards until it tapped reservoirs of molten rock, which welled upwards and crystallized into what are now the Threlkeld microgranite and the Buttermere and Ennerdale granophyre. An immense thickness of rock has since that time been removed from the district by denudation.

Mineral veins are very numerous in the Skiddaw Slate rocks; many of them are large, and they are filled with a variety of metallic and non-metallic minerals; but the deposits of metallic minerals or metalliferous ores are irregular, occurring in detached sops more frequently than in continuous pipes. Veins are not so numerous in the Volcanic Series as they are in the Skiddaw Slates, although some of them have been more productive, and the deposits of ore are more persistent and extensive. But the most valuable and extensive deposits of metalliferous ore occur in connection with the veins in the Carboniferous Limestone—of haematite in West Cumberland, South Cumberland and Furness, and of galena in the Cross Fell Range.

Mr. J. L. Shaw (Whitehaven) wrote that he had had some experience of the occurrence of iron-ores in the Skiddaw Slates of Kelton Fell and Knockmurton. In other districts than the above in West Cumberland, many bore-holes had been put through the Carboniferous Limestone rocks into the Skiddaw Slates below, but when the latter are reached the almost universal practice is to stop the boring under the belief of its being useless to proceed further. Shafts, also, are often sunk into the Skiddaw Slates, but more for convenience of working the mine than for any other purpose. There was no doubt, common sense in the above idea, but in his (Mr. Shaw's) experience of upwards of 30 years he had never been able to see why a vein of iron-ore in the deeper Carboniferous Limestones should necessarily cease on reaching the Skiddaw Slate. He knew cases of both: for instance, in the Egremont district, in the No. 4 Pit of Gillfoot Park, the vein-ore swept out on the flat at a depth of about 600 feet, on the top of a layer of shale covering the upturned edges of the Skiddaw Slate, but did not penetrate into the slate below this depth; while in the Falcon Pit of the Wyndham mines, which was not quite 1,800 feet to the southeast of the No. 4 Pit already named, a vein of ore (but not on the same fault as above) did descend from the Carboniferous Limestone through a bed of grit (7½ to 9 feet thick and even thicker in places) the stratification of which was parallel with the limestone, into the Skiddaw Slate-rock below, ore having been proved in the last named rock, on the 624 feet level, to be 3 feet wide at one side of this level, and 18 inches wide at the other side: and it probably descended deeper though not yet proved to do so. The sole of the 624 feet level was some distance below the top of the Skiddaw Slate.

The Skiddaw Slates are frequently ripple-marked. An example was and probably is still to be seen, near Foxfield station, but he (Mr. Shaw) had no new facts to give in reference to Silurian
fossils. The strike of the bedding of these slates is north-east and south-west in the Kelton mines, the dip being to

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the north-west, at an angle varying from 58 to 65 degrees, as taken in the cross-cuts.

Another point might be mentioned with reference to the surface of Silurian strata having been proved at Millom. These rocks crop up at the Moors farm, and on the fore-shore at Hodbarrow mines were proved to lie at a depth of 994 feet.

In the Volcanic Ash-rocks, veins of iron-ore also exist, but their general inaccessibility prevents them from being wrought. A mineral vein is shewn upon the map of the Geological Survey between Scaw Fell and Bow Fell. It was a good many years since he (Mr. Shaw) visited it, but there were then hundredweights if not tons of good blast-ore lying about in its immediate neighbourhood, although no attempt had been made to prove its value in capacity or even in width.

He (Mr. Shaw) had also had some experience of the Coniston Limestone at Waterblean, near Millom, where he found its thickness as deduced from actual measurement to be 145 feet, lying in one band. Mr. Postlethwaite takes no notice of an important break in the band near Graystone House, excellently described by Prof. Sedgwick in his "Structure of the Cumbrian Mountains."* as an "enormous fault." Now, it was a matter for surprise that this excellent position for iron-ore had never to his (Mr. Shaw's) knowledge been tested with boring-rods; and his method would be to test both broken ends of the limestone-band, where these abut upon the fault.

At Waterblean, where the colour-pigment was mined for some years, the ore lay in pockets, not much exceeding 20 feet in diameter, these pockets being joined by joints in the limestone generally carrying a little ore, but in some cases the junction consisted of the mere joints in the rock alone. The best ore for colour-making was found lying closest to the surface, being there freest from silica; and at a greater depth, which did not exceed 40 or 50 feet, the ore became so largely impregnated with silica as to be unfit for pigment and was even very poor blast-ore. It had not been proved that there were no more pockets of ore at Waterblean, and the ground appeared to deserve further trials by boring.


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With reference to the Carboniferous rocks it was scarcely correct for Mr. Postlethwaite to state that the break in the continuity of these rocks was 20 miles wide, because no one knew how far south from Egremont either the coal from near to the sea at St. Bees or the limestones extended. Further proof of this was very much wanted, but Carboniferous Limestone was known to lie below the Permian rocks to the south of Egremont. It had not been proved to extend within his (Mr. Shaw's) experience, to the north-west of the Whicham mines, or rather, farther in that direction than the Arrow Hill, but this was by no means the same thing as saying that it extended no farther.
Mr. D. Burns (Carlisle) wrote that the members were to be congratulated on having added to their Transactions such an able epitome of the geological features of Lakeland, by one who had not only mastered all that had been done by others in the district, but who had been a patient and successful searcher for its many hidden treasures, resulting in important additions to the life-records of its oldest sedimentary rocks. Mr. Postlethwaite traced a steady succession of beds from the base of the Ordovician to the top of the Silurian, without any break in the deposition, and hence without any unconformity. The Ordovician strata he estimated at 24,300 feet, and the two lower members of the Silurian at 11,000 feet. He did not give the thickness of the uppermost section of the Silurian, namely, the Bannisdale Slates; but as their outcrop measured 11 miles across, they probably represented a greater thickness. He considered them identical with the Ludlow Series, or Upper Silurian, and Sir Archibald Geikie gave the Ludlow group as 1,950 feet thick, and the whole Upper Silurian group at 5,050 feet.* There was thus a total thickness of say 35,000 feet or approximately of 7 miles of steady deposition, beginning and ending in an estuary within a few feet doubtless of the sea-level. In the middle of this tranquil subsidence, but not extending throughout it, beginning with a burst and ending with spasmodic ash-showers over the calcareous sea; but not till 12,000 feet of pure volcanic products had been spread over an area extending an indefinite distance in excess of 400 square miles, did the Castlehead volcano subside into aesthetic quietude. Mr. Postlethwaite states that at the close of the Silurian period, the downward movement became more rapid, resulting in


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the denudation of the Lake District. It is difficult to see how an increased downward movement could have this effect. A slow uprising exposed to the full beat of the ocean-waves would be more likely to have the denuding effect now noted. Thus, long after all traces of volcanic action had left the district, the whole of the rocks round the Lake mountains were tossed up here and down there, followed by denudation slicing obliquely across the formations, and giving rise at the beginning and towards the close of the Carboniferous period to the most violent unconformities. One could easily understand that there would be a steady and great depression of surface over an area that recognised Castlehead as a centre, while 1,000 cubic miles at least, and probably several times this amount of volcanic material was being ejected. But this seems not to have perceptibly affected the depression that had continued for long ages before, and was destined to continue long ages after. There was clearly much to learn in such matters, and the evidence of Mr. Postlethwaite’s paper was to the effect that, contrary to received opinion, volcanic action, as evidenced by the outpouring of volcanic rocks, was quite an insignificant factor in producing the changes of level of the earth’s surface required to explain the stratigraphical evidence presented.

With regard to the disputed fault between the Skiddaw Slates and the Volcanic Series, Mr. Postlethwaite some considerable time ago took him (Mr. Burns) to see the junction in Borrowdale. He could not see at that spot conclusive evidence of a fault, although in newer rocks the evidence would have been most conclusive, as the line of junction approaches the vertical. Certainly it had no "lag" about it. Mr. Postlethwaite’s argument for a fault, based on
the relative perishability of the rocks on the Skiddaw range, would not carry wide conviction. The many and large faults that upset the calculations and plans of the colliery-manager, and which gave no indication of their presence at the surface, were the greatest trouble of his (Mr. Burns') professional work. Unless a fault had been large enough to determine the course of a river or glacier it had little effect on the relative levels of the rocks on its two sides. The Pennine fault and Stublick dyke were in places apparent exceptions, but they were extreme cases in several ways, and glacial action had been in each case at work. Indeed, denudation was extremely slow on the mountain-tops, and when the mountains were covered with forests, it would be nearly infinitesimal. At Walltown Crags, north-west of Haltwhistle, there was a good instance of the differentiation of denudation. At this point the Whin Sill altered its horizon and traversed a limestone. On the slope, above the influence of running water, there was at one point a dip-slope of whin and in line with it to the east a dip-slope of limestone. Assuming that at the close of the Glacial period these two slopes were reduced to one plane (and certainly the limestone-plane would not project beyond the other), it was evident by the striae on the whin that it had not been denuded 1/64 inch since Glacial times, and that the limestone had only suffered about 1 foot and that almost entirely by chemical action.

Mr. J. D. Kendall (London) wrote that Mr. Postlethwaite had described the rocks of the Lake District with considerable fulness of detail, especially those in the neighbourhood of Keswick, but he had not noticed, except incidentally, a most interesting piece of ground in Low Furness. Within 1 square mile, just south of Ireleth, occurred the following formations and series:—(1) Carboniferous Limestone; (2) Basement Conglomerate; (3) Stockdale Shale; (4) Coniston Limestone; (5) Borrowdale Volcanic Series; and (6) Skiddaw Slate. These formations and series were all shewn on the very imperfect geological map published by the Geological Survey, but so inaccurately and incompletely, that it was impossible to make out the geological structure of the ground therefrom. He had tramped over the area many times, and was not satisfied that he had yet unravelled its structure, but of one thing he felt quite certain, namely, that the Geological Survey map gave no clue to it. Two separate and distinct bands of Coniston Limestone were shewn on that map, separated by Skiddaw Slate, but there was no evidence of more than one band. From the structure of this piece of ground, it was quite clear that the Skiddaw Slate and the Volcanic Series had been subjected to a considerable amount of faulting and denudation before the deposition of the Coniston Limestone, for that formation was found resting on the Skiddaw Slate at one point, and at another, quite close to it, on the Volcanic Series. It also shewed that the Volcanic Series was thinning out rapidly in that direction, the thickness of these rocks there not being more than about 700 feet.

Under the head of "Faults and Mineral Veins," Mr Postlethwaite had described three main north-west and south-east faults as running respectively through Windermere, Coniston Lake, and the estuary of the Duddon; and a north-east and south-west fault as running from
the coast of West Cumberland through Grisedale valley to Ullswater Lake. The only evidence referred to as a basis for these statements was the shifting of the Coniston Limestone near Ambleside and Coniston. At both these places, however, the direction of the shifting faults was about north 10 degrees east, and therefore they did not come within the system of north-westerly faults referred to by Mr Postlethwaite. But apart from that, the suggestions were at variance with all the results obtained in careful mapping; and the fault which shifted the Coniston Limestone near Ambleside did not pass down Windermere, but about 2 miles to the west of that lake.

The boundary between the Skiddaw Slate and the Volcanic Series from Honister to Great Mell Fell was probably only a faulted boundary in part. The facts could be explained without assuming either the complicated system of faults adopted by Mr. Ward, or the drag-fault of Messrs. Marr and Harker, by looking upon the boundary as the outcrop edge of the Volcanic Series, shifted here and there out of its regular course by a number of intersecting faults.

Mr. Alfred Harker (London) wrote that of especial interest from the point of view of mining were the intrusive igneous rocks of the district, since it was probably with these that the metalliferous deposits (excepting perhaps those in the Carboniferous formation) were directly or indirectly connected. It was clear that the ore-deposits belonged to more than one epoch, though they had not, he believed, as yet, been classified from this point of view. Mr. Marr had recently shewn that there were metalliferous veins older than the Shap Granite, and therefore of Lower Palaeozoic age: while many of the veins in the district were doubtless younger.

Two, and probably three, distinct suites of igneous intrusions were to be recognized in the Lake District:—The first included rocks which belonged to the same period of igneous activity as the Borrowdale Volcanic Series, though they were somewhat later

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than the lavas and tuffs with which they were associated. Here the Buttermere and Ennerdale granophyre might be placed, with some other acid rocks, such as those of St. John's, Armboth, etc., also most of the basic intrusions of the district, including the Castlehead and other dolerites, and the rocks which have been termed picrites. To what extent the garnetiferous rocks intercalated in the Volcanic Series were intrusive was a somewhat doubtful question. The second suite of intrusions, connected with the principal crust-movements of the district, and therefore of Mid-Paleozoic age, embraced the granites of Skiddaw, Eskdale and Shap, with a number of acid dykes and others of minette and allied types. Other igneous intrusions in the district, and in particular those of Carrock Fell and of the Caldbeck Fells, were perhaps to be referred to a distinct later epoch, being younger than the great crust-movements. Indeed, a comparison of the rocks themselves with known rocks in the Western Islands of Scotland suggested that the Carrock Fell intrusions, and consequently the associated ore-deposits, might be of Tertiary age.

It seemed doubtful whether the different directions of the lodes could be used with any confidence for classifying them according to age. The movements with which faults and lodes were connected were apt to recur on the same lines at widely separated intervals of time; and the displacement along a given fault-line—probably, too, the infilling of a given lode—must often have been accomplished at more than one epoch.
Mr. J. Postlethwaite wrote that his (Mr. Postlethwaite's) statement that there is a break in the girdle of Carboniferous rocks in South-west Cumberland, 20 miles in width, is made because of the absence of any direct evidence that these rocks exist in that area. They may extend beneath the Permian strata, over a considerable part of, or possibly the whole, distance between the points named; but, so far as he is aware, there is no evidence to prove it. With regard to the omissions in his paper referred to in the discussion, he (Mr. Postlethwaite) might explain that his aim was to give a description of the geology of the Lake Country, which would be concise, and at the same time as comprehensive as the space allotted to such a paper would allow; consequently many interesting features had necessarily to be Passed over unnoticed, while in other cases, the descriptions had to be materially curtailed. He (Mr. Postlethwaite) thought that Mr. Kendall would confer a favour upon all future students the geology of the Lake District by embodying in a paper the results of his examination of the structure of the interesting piece of ground in Low Furness.

The President (Sir Lindsay Wood, Bart.) moved a vote of thanks to Mr. Postlethwaite for his valuable paper.

Mr. W. Leck (H.M. Inspector of Mines) seconded the resolution, which was cordially approved.

Mr. Wm. H. Bohlase's "Description of the Lead-ore Washing-plant at the Greenside Mines, Patterdale," was read as follows:

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DESCRIPTION OF THE LEAD-ORE WASHING-PLANT AT THE GREENSIDE MINES, PATTERDALE.

By Wm. H. BORLASE.

Adit-level.—The vein-stuff, comprizing quartz, baryta, copper-pyrites, iron-pyrites and galena, is brought from the mine through a long adit-level by an electric locomotive, and the wagons are discharged into stone-made hoppers or kilns, sloping gradually toward the fronts, at the bottom of which are fixed two steel-barred grids or grates, one over the other. The roughs on the top grate are hand-picked for conveyance to the stone-breaker; the stuff on the second grate is small enough for the roll-crushers; the stuff passing through is sized sufficiently for treatment at the Green plunger-jiggers: while the fines, slimes, etc., are caught in settling-tanks (Figs. 1 and 2, Plate XIII.).

First Floor.—This point (the picking grates) being 150 feet lower than the site of the crushing-and-dressing plant, the several sizes are taken, in turn, as required, up the incline in self-
tipping wagons, which the writer claims to have erected, the first of its class made in this country, in 1873, at the Ruthers iron-mine, Cornwall, from a design of his deceased father. The power employed in working the incline is derived from the No. 1 vortex-turbine of 20 horsepower. The tip is arranged so that two hoppers are served at one point (Fig. 2, Plate XIII.): the first with rough stuff for the stone-breaker, and the second with the smalls for the crushing-rolls. The stone-breaker is driven by the No. 2 turbine of 15 horsepower, and is fixed, so as to allow the stuff passing through it to join the smaller stuff, being conveyed to the crushing-rolls, and the whole can be rushed together or separately as desired.

The crushers, driven by an overshot water-wheel, 80 feet in diameter and 4 ½ feet wide, taking the exhaust-water from the No. 1 winding-turbine, comprise three sets of rolls (Fig. 2, Plate XIII.), each 16 inches in diameter and 17 inches long.

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The top set of fluted rolls, made of specially chilled iron, further crushes the stuff before dropping it on to the two sets of plain rollers below.

[Photograph: Fig. 3. -- View of Washing-plant and Surface-arrangements at Greenside Mines.]

Below the rolls, there is a revolving screen-cylinder. A, of 2 ½ square meshes to the lineal inch, and the roughs separated by this operation, commonly called "raff" (which in most crushing-plants is elevated by "raff-wheels" and returned again the same crusher), is taken to another crusher, with large Cornish

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rolls, and crushed alone. This method, in the writer's opinion, is much to be preferred, the stuff, being composed of smalls, varying from ½ inch to 1 inch cube, when mixed again with larger stuff, escapes the rolls, and consequently may be several times so returned to the crushing-rolls, thus seriously reducing the work of the crusher.

The stuff passing through this screen, A, is conveyed by water and shoots to the screen, B, with 8 holes to the lineal inch. The stuff, passing to the end of this sizer, feeds into the No 1 plunger-jigger, with four compartments: the perforated

[Photograph: Fig. 4. -- Electric Locomotive.]

plates being made of steel sheets of No. 10 wire-gauge with 3/8 inch round, punched holes. The plunger runs about 140 strokes of ½ inch per minute, and makes four grades of quality. The first grade consists of about 75 per cent. of galena; the second, of lead, baryta and blende-ores; the third and fourth is chats, composed of stone, quartz, etc., with particles of the before-mentioned ores attached.

The next screen or sizer, C, meshed to 4 holes to the inch, receives the stuff passing through the meshes of screen, B, the rougher size going to No. 2 jigger, also of four compartments,

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with steel plates and \( \frac{1}{4} \) inch punched holes, and the plunger runs 140 strokes of \( \frac{1}{2} \) inch per minute. The results are similar to those of the No. 1 jigger, excepting that the first compartment produces almost pure galena.

The next screen, D, contains 6 holes to the lineal inch and its rough stuff supplies the No. 3 jigger of 3 compartments, fitted with copper-plates and conical punched holes of No. 7 Cornish gauge. The plunger makes 180 strokes of \( \frac{3}{8} \) inch per minute. The results comprise three qualities of stuff: the first, equal to about 80 per cent. of metallic lead; the second, of lead-ore baryta, pyrites and blende-ore; the third, portions of the same ores mixed with quartz, etc.

From this point, the classification is continued through four spitzkasten boxes, E, (Fig. 2, Plate XIII.), each supplied with clean water from the pressure-pipe, P (this pipe also supplies the extra water required for the jiggers), and each supplying separate jiggers of three compartment-capacity, according to the grade of the stuff.

The No. 4 jigger is fitted with copper-plates having conical punched holes of No. 14 Cornish gauge, and produces results equal to those of the No. 3 jig. The plunger runs at a speed of 200 strokes of 5/16 inch per minute. The No. 5 jigger is fitted with copper-plates with conical punched holes of No. 18 gauge, and the plunger runs at 220 strokes of \( \frac{1}{4} \) inch per minute.

The No. 6 jigger, with holes of No. 23 gauge, runs at a speed of 230 strokes of 1/8 inch per minute. The No. 7 jigger, with holes of No. 29 gauge, runs at a speed of 250 strokes of 1/8 inch per minute. The results at each jigger are as follows:—The first compartments contain 80 per cent. of metallic lead; the second, a mixture of lead-ore, baryta, blende and pyrites; the third, small particles of ores attached to fine quartz, sand, etc.

Second Floor. From this point, the overflow from the last classifier is taken by way of the downfall-launder, F, to a large spitzkasten, G, where the heavy portions, dropping to the bottom, supply alternately two automatic buddles, H, of the convex type. The overflow from the spitzkasten, G, goes to the classifier, I, which supplies two other automatic convex buddles with finer grade stuff (Fig. 1, Plate XIII.). The overflow from the classifier, I, is then caught in settling-tanks for further treatment in other buddles on the slime-floor, below, when sufficient stuff has accumulated.

The whole of the above plant is being supplied with stuff, which has been only once handled at the crusher.

[Photograph: Fig. 5.—Electric Locomotive entering the Adit-level.]

The automatic buddles, H, of simple construction, are capable of dealing with a large quantity of stuff of low grade. Their diameter is 24 feet, with a head or centre 8 feet in diameter. The only bearing is an upright iron bar, with a top turned to a pivot-point, J, on which the cover, K, rests, acting as a coupling to the pipe, 1 \( \frac{1}{2} \) inches in diameter, encasing the upright bar, and carrying the whole of the moving parts (Fig. 2 Plate XIII.). Outside the iron pipe is fixed the bell-mouthed
receiver, L, conveying clear water for the sprays, fitted a flange at the bottom and four waterways, M. The flange is secured to the bottom of the larger receiver, N, into which slimes and water to supply the buddles are conveyed by feed-launders, O. Into this receiver, N, four short arms are screwed, having T pieces screwed to their ends, through which the stuff flows unto the head of the buddle, The resistance, or check of the flow at the T pieces and at the sprays in the long arms or pipes for the clear water, the outer ends being plugged, supplies sufficient power to give a rotary motion to the moving parts of the machine, which, as before mentioned, simply rests on the pivot-point of the upright bar. Each buddle is capable of treating the fines from the crushers escaping the jiggers for a run of 200 tons of stuff, requiring little or no attention beyond the blocking or "stepping" up of the outlet or tail as the head of the buddle is gradually filled. The contents of the buddle are divided into four qualities, the tails being run direct to a classifier and another buddle on the waste-floor. The second and third partings are hand-fed to a small buddle, while the heads are treated in a small, mechanically-driven buddle, where the ore is brought up to the standard.

Second Floor.—The writer must now return to the treatment of the stuff caught in the hopper at the end of the first screen, A. The stuff is conveyed by a tram-wagon to a Cornish crusher for further crushing, and is afterwards classified for four jiggers in a similar manner to that already described in the first-floor jigging-house. Both sets of jiggers on the first and second floors are driven by the No. 3 vortex-turbine of 12 horsepower.

The ore caught in the first compartments of the jiggers, Nos. 1, 1a, 2, 2a and 3, is separately conveyed to the cleaning-jig, No. 12, of another type, and thence to the ore-bings. The ore of the first compartment of the jigs, Nos. 3a, 4, 4a, 5, 6 and 7, is severally tipped into a trunking-box or rectangular buddle, through which a clean stream of water is passed to run through the stuff, as it is being thrown against the sloping head of the trunk. The water washes back any small impurities which may have happened to pass through the perforated plates of the jiggers. The produce is lead-ore, containing from 82 to 84 per cent. of metallic lead.
gauge and a plunger-speed of 280 strokes of $\frac{1}{4}$ inch per minute. The results are practically standard galena in the first compartment of each jig. The second compartments contain baryta and blende, with a fair amount of lead-ore, and requiring further jigging. The third compartments contain a very complex mixture, which must be further reduced in the stamps, while the overthrow is exceedingly poor in any mineral. This plant is driven by a Pelton wheel, 12 inches in diameter, under a fall of 400 feet, and capable of running at a speed of 1,400 revolutions per minute.

Fourth Floor.—The third compartments of the whole of the jiggers of fines, Nos. 3, 4, 5, 2a and 3a, are further reduced (as in the case above-named) in the small stamps battery, and classified; the rough portions are jigged, the fines passing on to Luhrig horizontal jigging-tables (Fig. 1, Plate XIII,). These tables also treat the stuff from the third compartments of jiggers, Nos. 6, 7 and 4a. The contents of the fourth compartment from jiggers, Nos. 1 and 2, and the third compartment of jiggers, Nos. 1a and 2a are taken to No. 4 crusher, and crushed, classified and jigged: the fines being sent to the Luhrig tables. The table-house is equipped with a very fine jig, running at a speed of 280 strokes of $\frac{1}{16}$ inch per minute, fitted with conical punched holes of No. 36 gauge. The overflow of the classifier supplying this jig passes successive spitzkasten-classifiers, each supplying a table. These tables are doing excellent work, and it is intended to erect more of them, so soon as practicable, to treat the slimes, etc., now caught in the zig-zag settling-pits, and now treated by mechanically driven buddles of the old type on the slime and waste-washings.

The writer need not point out the advisability of arranging any washing-plant to avoid as much as possible the handling of the stuff, so as to dispense as far as practicable with labour and to reduce the charges to a minimum. The writer does not claim to have, as yet, accomplished this object in the plant under review, having met with too many drawbacks by way of old appliances and fixtures, which (to prevent a stoppage of the whole of the work) have had to be considered, and consequently stood in the way of the desired reforms. It would have been better for the installing of an improved plant, had the ground been cleared of all such obstacles. As far as practicable under existing circumstances, the plant is on the principle of continuous ore-dressing, to the extent that at least 70 per cent. of the produce is being delivered to the ore-bing ready for the smelt-mill, with only two handlings on the shovel after passing through the stonebreaker. The settling of the fine-slimes in the pits for clarifying the water in some instances entails more cost than the value of their contents.

The total labour-costs, including the picking of the crude stuff at the grates (containing about 7 per cent. of lead-ore) to the delivery of the ore (containing 82 per cent. of metallic lead), to the smelt-mill, is 10s. 6d. per ton of ore.

A dynamo, for supplying the washings, smelt-mills, workshops, offices, etc., with electric light, is fixed in the No. 1 turbine-house, and is connected to the turbine (belt-driven) by clutch-gearing.
The President (Sir Lindsay Wood, Bart.) moved a vote of thanks to Mr. Borlase for his valuable paper.

Mr A. D. Nicholson (H.M. Inspector of Mines) seconded the resolution, which was cordially approved.

Mr. Geo. H. Bragg's paper on "Granite-quarrying, Sett-making and Crushing; and the Manufacture of Concrete-flags and Granitic Tiles," was read as follows: —

GRANITE-QUARRYING, SETT-MAKING AND CRUSHING; AND THE MANUFACTURE OF CONCRETE FLAGS AND GRANITIC TILES.

By GEO. H. BRAGG.

Granite.—Granite is perhaps a painful subject to the inhabitants of large towns. As a material for road-making, and electric-tramway paving it is very familiar, and the frequent upheavals of our thoroughfares makes its presence somewhat disagreeably felt. The Lake District abounds in granite, slates, and many other minerals, but this paper will chiefly deal with the working of the Threlkeld quarries, St. John's-in-the-Vale, where over 800 men and boys find employment.

Mr. Frank Rutley stated that the "Threlkeld rock is closely allied to granite in composition, although it differs from it in structure; its fineness of grain and poorness in mica rendering it really a quartz-felsite, the mineral constituents being felspar, quartz, calcite, a little epidote and serpentine, some of which has apparently replaced mica. A general idea of the hardness of the rock may be realized from the fact that felspar is almost as hard as steel, while quartz is harder." The specific gravity is 2.63, the weight per cubic foot is 164 pounds, and the crushing-strain, as certified by Mr. Kirkcaldy, is 31,912 pounds on the square inch, or 2,052 tons on the square foot.

Site of Quarry.—In opening a quarry, much expense is saved if particular attention be paid to the position of the joints, which should be the first consideration in selecting a site on the side of a hill, instead of going in an haphazard fashion. Very often, a quarry has been opened in such a position that the rock has to be lifted against solid beds, or straight into it. In such cases, the amount of powder or other explosive used is excessive: as the rock is held so tightly, and hemmed in on all sides. The large amount of drilling rendered necessary is also costly, as
The tonnage of stone blasted per hole drilled is small. The author has noted the difference of cost between drilling and quarrying in a hill-side, and the same labour employed in driving straight into it on the wrong side, and found that the latter cost was as much as 30 per cent. in excess of the former, for reasons which are no doubt obvious. Fig. 1 (Plate XIV.) illustrates this feature: —If the quarry be opened at the side, E, block blasted out at the base of the pillar will practically dislodge the whole of the pillar, but if opened "straight in" at S, every shot will be solid against the bed.

Joints.—The joints in the Threlkeld quarries are irregular, and may be found at every possible angle. As a matter of observation, it is found that joints are closer together in the finer-grained granites than in the coarser-grained varieties, and it is perhaps owing to this that large blocks for engineering purposes are generally obtained from the coarser-grained granites of the Cornish quarries, which fulfil such requirements better than the finer-grained rock found at Threlkeld, where blocks of large dimensions cannot be secured. But, on the other hand, the finer qualities being very tough, and compact in structure—especially when mica is absent—are eminently adapted for road-metals, for which purpose the rougher varieties are practically useless.

Blasting.—The granite (quartz-felsite), at Threlkeld quarries, is almost invariably dislodged by means of blasting with gunpowder of coarse grain (C.B. quality), excepting in the case of wet holes, when dynamite or gelignite is used. Very little, however, of the latter explosive is allowed, as it shatters the rock too much for manufacture into square blocks. In fact, it has been demonstrated that a given weight of gunpowder in a hole, 20 feet in depth and 3 inches in diameter, will dislodge more rock than the same weight of either dynamite, gelatine, roburite or ammonite. Rules are frequently suggested for determining the quantity of powder to be used in blasting, and the position of the holes. These are excellent in theory, but almost useless in practice. As a matter of fact, before a hole is bored, a good foreman looks at the pillar or block, and if he is a practical man, he soon ascertains whether the mass has to be blown up or against the bed, and he judges also how it may be wedged between surrounding blocks. He then instructs the workmen as to the position of the hole, the necessary depth the probable quantity of explosive requisite. In the Threlkeld quarries, the average result of rock from blasting is 458 tons per 100 pounds of gunpowder used.

Rock-drills.—For heavy blasting, holes are bored 3 inches in diameter to any desired depth, up to 20 or 25 feet. Some few years ago, this work was accomplished by hand, but circumstances led to the adoption of machine-drills, which have proved an unqualified success, not only in increasing the output, but also in very materially reducing the cost.

A drill with a 2 ¼ inches cylinder is used for holes 1 inch in diameter up to 4 feet in depth and plug-holes; a drill with a 2 ¾ inches cylinder for holes 2 inches in diameter up to 10 feet in depth: a drill with a 3 ½ inches cylinder for holes 3 ½ inches in diameter up to 20 feet or more in depth; and a drill with a 5 inches cylinder, the largest made, will bore holes 6 inches
in diameter up to 50 feet in depth. A drill with a 3 ½ inches cylinder will bore holes 3 ½ inches in diameter at the rate of 4 feet per hour: a drill with a 3 ½ inches cylinder will bore holes 2 ½ inches in diameter at the rate of 8 feet per hour; a drill with a 2 ¾ inches cylinder will bore holes 2 inches in diameter at the rate of 10 feet per hour; and a drill with a 2 ¼ inches cylinder will bore holes 1 inch in diameter at the rate of 12 feet per hour. With a working-pressure of 80 pounds per square inch, the speed is 300 to 360 blows per minute. These rates fluctuate according to the number of times that the drills have to be re-set, and the quantity and depths of the holes. Much also depends upon the length of the stroke of the piston of the drill, which is almost entirely controlled by the feed or the turning of the handle. This is an important point, as, with a short stroke, the blow is too weak to be effective, and a long one is liable to stop the drill. A little experience, however, soon enables a handy man to regulate the speed of working.

Where a hole has to be started in rock, at an angle to the drill, it is advisable to prepare the point of entering with a punch (Fig. 2, Plate XIV.), as an immediate start results in a quicker speed of drilling.

The shape of the drill-bits is important. In jointy rocks, as at Threlkeld, X bits (Fig. 4, Plate XIV.) have proved the particularly for commencing holes, but sometimes a chisel-bit can be used, after entering with the X bit, providing that the block of stone is solid. The + bit (Fig. 3, Plate XIV.) produces an oval hole, but the X bit makes an almost perfectly circular one. If chisel-bits can be used at all, they are much preferred, as they are easier to sharpen than any other form: it is of the utmost importance to give them the right shape, as in harder rock, the angle of the bit should be the more obtuse.

There is scarcely any plant that will sooner repay any reasonable expenditure than air-compressors and machine-drills at large quarries and similar work. The time wasted by hand-drilling is enormous, and the output is considerably retarded, as it will take two men 1 ½ days to drill a hole 2 ½ inches in diameter to a depth of 10 feet, while it can be bored by a machine in 1 ½ hours. By the latter means, more rock can thus be dislodged in a given time in the quarry where the working-face or front is limited in extent. Hand-drilled holes also lose much in gauge or diameter: the hole will be commenced with a tool of 2 ½ inches gauge, and finish at 1 ½ inches gauge at a depth of 8 or 10 feet, whereas machine-drills start with a toed of 3 ½ inches gauge, and finish with 3 inches at a depth of 20 feet with a round hole. It will, therefore, be readily understood that the explosive is used with marked advantage in larger holes, and will dislodge considerably more rock. Generally speaking, it has been found that the saving effected by the use of machine-drills amounts to at least £18 per 1.000 tons of rock quarried.

Power.—The most suitable power for working rock-drills is compressed air: it possesses many advantages over steam, especially in conveying power to a distance without serious loss of efficiency. It can be delivered to the machines in a dry condition, and at a good working-pressure: whereas there is great loss in the transmission of steam owing to the loss of power by condensation, the drills are unduly heated, and the constant hot drizzle is disagreeable to all men working in the vicinity. It is stated that 1 cubic foot of water wasted by condensation represents 1 horsepower.
Electrically-driven percussive drills have been introduced, but the results obtained have not borne out the representations of the makers. Their construction is faulty, they are heavier than compressed-air drills of the same capacity, and their use involves the purchase of expensive plant. Electric drills may be successfully applied in metalliferous mines, but the makers hesitate to say whether they will work equally well in hard granite. It is stated that the cost of repairs and renewals of electric drills used in driving a short tunnel was about one third the cost of driving the tunnel.*

The writer is responsible for the installation of a compressed-air plant, consisting of a Schram compressor with steam-and air-cylinders 14 inches in diameter and 24 inches stroke; and it is now about to be compounded, so as to ensure ample power to drive 5 rock-drills, and 2 engines with cylinders 8 inches and 9 inches respectively in diameter. Three of the drills will be worked at a distance of 1 ¾ miles from the air-compressor and the air will be carried in Albion-joint tubes, 4 inches in diameter. The pressure at the air-receiver in the compressor-house is generally maintained at 80 pounds on the square inch, and the pressure at the supplementary air-receiver, 1 ¾ miles distant, is expected to be 75 pounds per square inch, so that the loss arising from friction, and perhaps some slight leakage in the pipes, will not exceed 5 pounds: From experiments conducted for the Italian Government at the Mont Cenis tunnel, the losses of pressure due to the friction of the air in traversing a length of 3,000 feet of pipe, 4 inches in diameter, was as follows:

<table>
<thead>
<tr>
<th>Volume of free air per minute.</th>
<th>Loss of Pressure.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cubic feet</td>
<td>Pounds.</td>
</tr>
<tr>
<td>200</td>
<td>0.14</td>
</tr>
<tr>
<td>400</td>
<td>0.54</td>
</tr>
<tr>
<td>800</td>
<td>2.12</td>
</tr>
<tr>
<td>1,000</td>
<td>3.27</td>
</tr>
</tbody>
</table>

At Coniston lead-mines, compressed air has recently been conveyed a distance of 7,800 feet over the hills—7,000 feet of pipes being 2 inches in diameter and 800 feet of pipes 3 incites in diameter. Only one rock-drill, however, is being used at the extreme end of the pipe-line, and there is no means of testing


the quantity of air passed through, as when the drill is working the safety-valve is blowing off, a little, at the air-receiver. The pressure at the compressor-end is 60 pounds, and the air-receiver at the other end of the pipe-line blows off at 50 pounds. This does not, of course, necessarily mean a loss by friction of 10 pounds per square inch; but the loss will be heavy, as pipes, 2 inches in diameter, are much too small for so long a distance.
Quarrying and Blasting.—After the holes are bored, they are cleaned out with hay and fine granite-dust to dry the sides and bottom. Then the holes are charged with gunpowder in the usual way, granite-dust from the stone-breakers is used as stemming, and it is tamped with a rod of wood or of iron tipped with copper in order to prevent the quartz from striking sparks. Tamping is, of course, a dangerous operation, and as “familiarity breeds contempt” quarrymen are liable to become very careless. It is, therefore, essential that strict rules in reference to blasting should be enforced. All persons are warned by horn or otherwise of any explosion about to take place, and they are compelled to take shelter outside of the quarry before the fuses are ignited. Should a hole miss-fire, no one is allowed to go near—according to the Special Rules of the Home Office—for 30 minutes. Miss-fires are generally caused by the use of defective fuse, or to its being damaged or cut while stemming the hole. In such cases, No. 12 of the Special Rules states that it is “illegal and dangerous to unram, bore or pick out a shot that has missed fire;” and it is recommended that a hole should be bored parallel to the charged one, with such care as not to interfere with it. This rule is difficult to enforce, as quarrymen will rather unram a shot than drill a new hole, especially if they are on piece-work, and the rock is dislodged at a price per ton. Electric firing is probably the safest, but it cannot be applied economically in all quarries. The height of a quarry-face should never exceed 60 feet, or thereabouts; and, when that height is exceeded, another level should be started. The work is then much safer, the drilling is easier, and the men are not required to hang from the long ropes employed in quarrying down the loose rock. The higher level for some time, of course, interrupts the work in the lower level until a width of 30 feet is obtained, in order that men in the bottom may work with safety from falling pieces; and when this width is attained both faces can then be worked simultaneously with very little interruption.

Setts.—After the masses of rock are detached from the face of the working, the large blocks are reduced to a workable size by plug-holes, or short holes blasted with a few ounces of powder. The stones are then transported outside of the quarries by travelling-cranes to the sheds provided for the sett-makers. These men, using large steel hammers, weighing 28 pounds each, called "bursters" or "mells," square on one end and obtusely pointed on the other (Fig. 5, Plate XIV.), break and shape the blocks into various sizes. The other hammers used are rectangular "mashes," 24 pounds and 14 pounds each in weight (Fig. 6, Plate XIV.). When the sett-maker has "blocked" his stones into suitable sizes, he sits in his shed on a wooden seat about 18 inches high, and by means of steel "tifflers" (Fig. 7, Plate XIV.) weighing 5 pounds each with a short handle, he dresses the blocks into any of the following dimensions that he can obtain: — 4 inches by 5 inches, 4 inches by 6 inches, 3 inches by 6 inches, 3 inches by 5 inches, and 6 inches by 6 inches, all up to lengths of 8 inches or 9 inches, and cubes of 4 inches. An experiment in sett-making, interesting to quarry-owners in particular, was made under the supervision of the writer, which consisted in erecting a saw-frame, capable of admitting blocks, 9 feet by 4 feet by 4 feet; and six blades, 6 inches wide by 3/16 inch thick, were used, driven by an engine of 10 horsepower, to saw the block into seven slabs of various thicknesses suitable for the usual sizes of paving setts. Chilled shot and a copious supply of water fed continuously into the slits, assisted the blades in cutting the slabs. The rate of cutting was
about 5 inches in depth per hour—good work for six blades—but, owing to the hardness of
the stone, the cost of chilled shot and the renewal of the saw-blades was high for the quantity
of setts produced and the total cost was as follows:

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<th>d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labour: wages paid</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Chilled shot</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>Saw-blades used</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Total cost at saw of setts produced</td>
<td>19</td>
<td>1</td>
</tr>
</tbody>
</table>

To this cost must be added the cost of splitting and dressing the slabs into various sizes of
setts.

The stone selected is generally that which will cut the straightest in both directions, and the
remainder is broken into rough lumps not exceeding 7 inches in thickness in any part, and
these again are broken into macadam.

Two locomotives, with 8 inches cylinders and 2 feet 4 inches gauge, transport about 500 tons
per day of lump-granite to a distance of 1 mile to 1 ¾ miles from the quarries to the crushing-
works. The heaviest gradient is 1 in 45.

Crushing-plant.—At the Threlkeld works, the crushing-plant (Fig. 8, Plate XIV.) consists of four
large Blake-Marsden stone-breakers, 20 inches by 12 inches, one of which is of the latest form
of lever-action. This type can be recommended for efficiency and capacity: it runs smoothly
and takes less power than the other machines, and it will crush 150 tons per working day of 9
hours. The safety-coupling on the fly-wheel is an admirable device, as in case of any hammer
or similar object getting into the jaw, a bolt shears in two and allows the flywheel to revolve
loose on the shaft.

After the material has passed through the jaws of the crushers, A, it is conducted between a
pair of knobbed rolls, B, 2 ½ feet in length by 2 feet in diameter, which treat the whole of the
stone passed through two of the breakers, and very effectively cube the broken granite into
macadam. All the material then falls into a revolving screen, C, 30 feet in length by 4 ½ feet
in diameter, which sorts out the various sizes as follows: — ¼ inch mesh: with proportion of
fine sand used for mortar and plastering; ½ inch mesh: with proportion of fine sand used for
concreting; ¾ inch mesh: used for topping asphalt and tar-macadam roads; ¾ inch to 1 ½
inches mesh: used for tar-macadam and railway-ballast; and 1 ¾ to 2 ¼ inches mesh: used
for general macadamizing.

All stones passing along the screen, which are too large for the holes 2 ¼ inches in diameter,
and called “rejectors” or “tailings,” are elevated by buckets, D, on to a conveyor, E, 2 feet
width, and carried back again to the cubing-rolls. By using crushing-rolls, the percentage of
tailings is very small. Some quarries adopt additional stone-breakers to deal with the
"rejectors;" but they are far from being efficient, and still leave a large amount of tailings unbroken to the required size. It may be interesting to know that the amount of dust and fine material made by plain surface-rolls is about 6 per cent. in excess of the amount made by knobbled rolls. The proportion of fine material up to $\frac{1}{2}$ inch mesh is generally about 18 per cent. of the total quantity of stone crushed. In order to secure a successful working of a crushing-plant, the speed of the stone-breakers should not be less than 250 revolutions per minute for granite and about 200 revolutions per minute for softer stone.

Manganese-steel jaws are now largely used for breakers. They cost about three times the price per cwt. of chilled-iron jaws and one serious objection to the former is that the ribs of the recessed-backs groove themselves into the cast-iron body and swing-jaw stock of the breaker, making very uneven beds. The writer found that one set of manganese-jaws crushed 21,360 tons of stone before being worn out. The working life of a set of chilled-iron jaws is about 14,000 tons, but one exceptional set actually exceeded manganese-steel by crushing 25,200 tons. The teeth of the jaws are of $2\frac{1}{4}$ inches pitch, and $11/4$ inches deep. For the side-cheeks, in the mouths of the stone-breakers, manganese-steel is, however, almost a necessity. The cast-iron cheeks, usually supplied with the machine, will in crushing granite be worn out in a few days; and, unless carefully watched, pieces are apt to chip off and pass into the cubing-rolls, thereby endangering a heavy smash. Manganese-steel cheeks have worn as long as 18 months of regular working.

The eccentric or crank-shafts of the machines should be of the highest quality of Siemens-Martin steel, capable of withstanding a tensile strain of 30 tons on the square inch, with 20 per cent. of elongation on a 6 inches length before fracture; as ordinary qualities will not stand the strain of working for many days. Delta-metal used for the bearings—on account of the dust—has proved superior to brass, as it never runs hot.

Each stone-breaker is driven by one cotton-rope, $1/4$ or $1\frac{1}{2}$ inches in diameter. Formerly as many as three ropes we used on each machine, but several years ago it was found the single rope was ample, and caused much less trouble.

It may be mentioned that the Threlkeld quarries and works have supplied nearly 250,000 tons of ballast for main-line permanent way during the past 10 years, and the total output of the works is about 110,000 tons per annum. All this material is run down inclined tramways, of 2 feet 4 inches gauge and 1 in 12 gradient, in tubs of 1 ton capacity to the sidings, where it is tipped by tumblers into railway-wagons.

The works are provided with siding- and wharf-accommodation for 200 private 10 tons wagons, which are all rebuilt or repaired on the premises.

**II.—Concrete-flags.**

Concrete-flags for footpaths are made by three methods, namely:—(1) Vibratory machine, (2) hydraulic pressing-plant, and (3) hand-labour in wooden moulds. The latter method may be dismissed as inefficient and obsolete.

The manufacture at Threlkeld is carried on in two buildings, each 300 feet in length by 33 feet in width, comprising a cement-store capable of holding 400 tons, and large mixing-platforms. The aggregate, consisting of $3/8$ inch crushed granite with a small proportion of fine material,
is run in tubs direct from the crushing-machines into these buildings, where it is elevated in buckets into a hopper, placed above the mixing-platform, to facilitate the measuring in boxes of proper dimensions. The requisite proportion of Portland cement is then added, and all is thoroughly turned over and mixed in a dry state with a 3 pronged fork. This material is then introduced into a square mixer, with tubular projections, where it receives the necessary quantity of water (about 22 gallons per cubic yard of concrete). On emerging from the mixer, the concrete is lifted by hand into moulds placed on a vibratory table, which not only consolidates the material efficiently and quickly, but thoroughly expels any air-bubbles, which rise to the top and disperse. The moulds, made of timber and lined with zinc, give a perfectly smooth face to the flags; and before being filled, the bottoms of the moulds are rubbed with an oily concoction to prevent the cement from adhering to them. After filling, the moulds are transported on bogies along the floor of the building where they are stacked in tiers, and accurately levelled and trowelled on the surface, before the concrete has had time to set. The flags are allowed to remain, at least, 4 to 5 days, before they are discharged from the moulds, and are placed in the open air to mature for at least 12 weeks. Under the conditions just described, the material retains every article of cement originally introduced into it, and owing to the wellknown property cement all superfluous moisture is thrown off after it has taken up what it requires.

When flags are made under hydraulic pressure, the aggregate consists almost entirely of very fine material, and it is a well known fact that too large a proportion of fine sand reduces the strength of the concrete. It is then more like a coarse spongy mortar and less like an artificial stone; and it is more pervious to damp and, of course, frost. The only thing in its favour is that it is much easier to obtain an apparently-better result. A certain amount of fine material is required to fill the interstices between the larger portions, or the concrete would have a honeycombed appearance. The best aggregate is that which has the largest number of angles, say, from 3/8 inch mesh graduating down to pieces not larger than coarse sand; and it enables perfect bonding to take place. If the material used is all fine, the matrix or cement has too many particles to join together, and the absence of larger portions prevents the bonding that they should impart to the mixture. The writer had experience with one of the first hydraulic presses introduced, and found that under pressure the water expelled from the flag carried with it the best and finest portion of the cement, which was consequently wasted.

In some works, the concrete-flags are immersed in a solution of silicate of soda, but it is very doubtful whether this is of the slightest benefit, as after a month’s soaking the solution only penetrates to a depth of the thickness of a thin veneer. The idea is to form calcium silicate, but granite is not sufficiently porous to absorb any of the liquid, and, in Portland cement, the calcium is mostly in the form of calcium silicate already.

The flags are generally made of 2 feet gauge, and in lengths increasing every 3 inches from 1 ½ up to 4 feet. Architecture concrete in the form of window-sills, heads, jambs, steps, etc., is made in a similar manner and to any design. The material weighs about 140 pounds per cubic foot, and the crushing-strain of a well-seasoned flag, 2 inches thick, is 389 tons on a square foot. To give an idea of its weight-carrying strength, a flag, 2 1/8 inches in thickness and 2 feet square, was placed with 1 inch
Of bearing on two sides only; and, weighted with iron blocks distributed over its surface, the flag sustained a total weight of 26 cwts. before it broke.

Granite concrete-flags have the following advantages over York and other stone, namely:—They are more durable; the material is of the same hardness throughout, thus ensuring uniformity of wear; they are of even thickness; no dressing of joints is necessary, so that there is no waste in cutting; and there are no laminations or scalings.

The plant at Threlkeld can produce over 8,000 superficial yards, 2 3/16 and 2 ½ inches thick, weekly.

III.—Coloured Granitic Tiles.

After exhaustive experiments extending over many years, coloured cement-tiles were, at first, perfected on the Continent; and the owners of the Threlkeld granite-quarries secured the right to use the special machinery and adopt means to ensure the successful manufacture and fixing of the various colours.

A ball-mill is used to incorporate the colours thoroughly with Portland cement, and a small machine will mix 1 hundredweight of tinted cement in 1 hour in a more satisfactory manner than could be done by hand in 10 hours. Unless the colour is perfectly intermixed, the surface of the tile will be tinted in light and dark patches.

The colours employed, red, blue, black, yellow, chocolate and zinc-white, are carefully sieved into steel-moulds, 8 inches square by 2 inches deep, through stencil-plates of the desired pattern—a sheet-zinc cover being required for every colour that is placed in a design. After the cement-colours are placed in position to a depth of ¼ inch, a mixture of pure granite-sand and cement is filled into the remaining depth of the steel-mould, and it is subjected to a pressure of 1 ton on the square inch in a double-gearpress, worked by a pulley from a main shaft. The thickness of the tile produced is 7/8 inch. All the materials, up to this point, are used in a semi-dry condition. On emerging from the press, the tiles are ejected by a mechanical contrivance from the mould, and placed by hand on a shelf or rack for a few hours, when the colours are treated with a solution, which prevents any efflorescence appearing in the colours after the tiles are dried. Without the use of the solution, the colours would be covered with an unsightly white powder on the surface. After this process, the tiles are moistened at intervals until the following morning, when they are totally immersed in tanks of water for some time, so as to render the material thoroughly sound, in the usual way adopted for cement-concrete.

The tiles are made with a plain surface, or with the design shewn in relief, in imitation of mosaic. All the colours are permanent, and the tiles are matured for several weeks.

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Mr. J. A. G. Ross (Newcastle-upon-Tyne), referring to the crushing of the granite at the quarries, asked whether there were any recorded experiments on the resistance to crushing and fracture, and the tensile strength of the granite-concrete.
Mr. G. H. Bragg said that the only tests which had been made was the crushing-strain of a 2 inches cube of concrete—389 tons on the square foot.

Mr. George Heeley said that Mr. Bragg had drawn attention to the trouble which he had had with the manganese-steel jaw-faces, owing to the ribs at the back wearing the front or resting part of the swing-jaw stock. This trouble had recently been overcome by an improved type of manganese-steel jaw-face, which had been cast with the same outside dimensions as the ordinary chilled-iron face, but cored through instead of being recessed, as formerly. By this means, a perfectly level resting portion on the swing-jaw stock was obtained. The cost of manganese-steel was referred to in the paper as being three times that of chilled-iron; he presumed that this meant the price per cwt.; but the weight of the jaw-faces, of course, was not the same.

Prof. Henry Louis (Newcastle-upon-Tyne) said that it was mentioned in Mr. Bragg's paper that the Blake-Marsden crusher required less driving power than other machines. Did this mean that it took less power than any other machine, or that there were worse machines than this in existence? His own predilection in the case of large quantities of materials to be crushed was for a machine of the Gates rotary type, which did not absorb an undue amount of power. The difficulty with regard to the jaws was overcome in a works with which he was connected by casting in wrought-iron chipping-strips at the back.

[Diagram: Plate XIV.--section of Crushing Plant at Threlkeld Quarries.]

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of the chilled-iron casting, and so obtaining an absolutely perfect fit.

Mr. G. H. Bragg said that the Blake-Marsden lever-type of crusher took less power than the eccentric type. If the jaw was full of stone or granite, and the belt was thrown off, or broken, the machine would finish its work until the jaw was emptied; and he found that this was not the case in crushers of the eccentric-type.

Mr. J. A. G. Ross remarked that this, of course, would depend on the weight and power of the fly-wheel.

Mr. W. Watkyn-Thomas asked whether Mr. Bragg was referring to the same conditions as to power between the different types of crushers; or was it a question of momentum, and not of efficiency? Were the conditions similar under which the different results had been obtained, or was there always the same-quantity of stone to the same steam-power?

Mr. G. H. Bragg said that four machines were working together, and two were working on a separate shaft. It was quite easy to watch the result, as the same material was being fed at the same moment into each, and the speeds of rotation and the weights of the fly-wheels were the same in each case.
It was anticipated on taking the compressed air for a distance of 1 ¾ miles in tubes 4 inches in diameter, that there would be a loss of 5 pounds in that distance arising from friction. Since writing his paper he (Mr. Bragg) had completed the work, and the loss is actually only 3 pounds on the square inch, that is, 85 pounds on the square inch at the air-receiver, in the compressor-house, and 82 pounds on the square inch at the supplementary air-receiver 1 ¾ miles distant.

The President (Sir Lindsay Wood, Bart.) moved a vote of thanks to Mr. Bragg for his interesting paper, and for the interesting excursion which the members had made, that day, to the Threlkeld quarries.

Mr. M. Walton Brown seconded the resolution, which was cordially approved.

Mr. William Leck's paper on “Ambulance-instruction at Mines” was read as follows:

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AMBULANCE-INSTRUCTION AT MINES.
By WILLIAM LECK, H.M, Inspector of Mines.

It is quite possible that the subject of ambulance-instruction at mines may, at first sight, appear to many persons as having but a remote connection with the specific business, which a body of experts like the members of the North of England Institute of Mining and Mechanical Engineers might reasonably be expected to consider. Ambulance-enthusiasts, on the other hand are more likely to claim that the promotion of this particular knowledge is of paramount and vital importance. Without attempting at the outset to differentiate between the two extremes, the writer thinks that the catholic character of the Institute is not inaptly illustrated by its readiness to consider a subject, which may be described as humanitarian rather than commercial.

Orthographically, an ambulance is, of course, simply a vehicle for the conveyance of sick or wounded persons, but ambulance-instruction, as a generic term, indicates the system of "first aid to the injured," as formulated by the St. John Ambulance Association, whose headquarters are at St. John's Gate, Clerkenwell, London. The objects of the Association include:—(a) The instruction of persons in rendering first aid in case of accidents; (b) the manufacture and distribution of ambulance-material, and (c) the formation of ambulance-depots at mines and other centres of industry.

The organization, which the Association has popularized, undertakes the formation of "centres" and "detached classes" throughout the country. The centres assume the functions of district-committees; they usually embrace large towns and are formed on application to the St. John Ambulance Association. A president, treasurer, secretary and committee are appointed, and the centre is responsible for the formation and carrying-on of classes within the sphere of its operations.

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In recent years, much good work has been done by means of detached classes, each of which is conducted by a local committee, but, instead of working under the supervision of a centre, the local committee is in direct communication with the headquarters in London. This method has been found to produce excellent results in smaller places where a centre would not be practicable.

At each class, a course of not less than five lectures is given by a qualified medical man. An examination is held at the end of the course, and successful pupils receive a certificate signed by the lecturer, examiner and local officers. Certificated pupils who pass two subsequent re-examinations with an interval of one year between each of them are entitled to receive a medallion, and are exempt from further examination.

Some idea of the magnitude of the work carried on by the St. John Ambulance Association may be obtained from the fact that since its institution 26 years ago, upwards of 500,000 certificates of proficiency, and 72,000 medallions have been distributed throughout the British Isles and the British dominions beyond the seas.

Two recent publications of the Association may be mentioned in passing:—The new official text-book, by Mr. James Cantlie, which supersedes the well-known work (Shepherd's First Aid to the Injured) familiar to all ambulance-students. The other publication, described as an Emergency Book, is an enlarged aide-memoire, containing brief but pregnant instructions on first aid, for almost every imaginable injury. It is constructed to hang on the wall, and the pages are made of strong cardboard, so that they may be readily turned. An excellent index, on the front page, forms a ready reference, and the whole of its graphic information is readily accessible. This valuable work requires only to be known to be appreciated.

The general character of ambulance-work has so far been referred to by way of preface to what, from our point of view, is its more important application to the mining-industry.

In every walk of life the acquisition of that special form of knowledge which teaches how to render first aid to the injured is of great advantage, but to the miner, employed as he perforce must be in remote places underground, it becomes a prime necessity.

The late Mr. J. L. Hedley stated in 1899, that "There is probably no class in the community to whom a knowledge of ambulance-work is of so much value as to miners. Their daily occupation is of necessity carried on in places and under conditions which obviously preclude the advantage of immediate professional attendance. It therefore becomes of the utmost importance that, in every mine, there should be, amongst the workmen themselves, men who are capable of affording skilled assistance at the critical moment."* This has long been recognized, and in the early history of the St. John Ambulance Association it is recorded that in 1878, the second year of its-existence, "a great advance was made, especially amongst the Derbyshire and Nottingham collieries." No less than ten centres have been formed at various times in direct connection with mines and quarries, but only two or three appear to be now in active existence.

The Home Office, as the Department of State responsible for the enforcement of mining enactments, nearly a decade ago, issued an important circular to H.M. inspectors of mines, in which they were explicitly desired to take every opportunity which might present itself for the purpose of promoting the formation of ambulance-classes among all persons employed in
mines in the United Kingdom, and also to encourage mine-managers and foremen to acquire a knowledge of how to render first aid to the injured. The issue of such a precise recommendation has naturally given a great impetus to ambulance-work among mining employees, and many of H.M. inspectors of mines have frequently referred to the subject in their annual reports.

In 1896, Mr. J. T. Robson (South Wales mines-inspection district), while mentioning one colliery in terms of praise as having a large proportion of trained ambulance-workmen, regretted that at some fairly large collieries in his district there was not a single person qualified to render first aid to the injured.† Mr. Robson's emphatic pronouncement has no doubt had the desired effect of stimulating interest in this important subject.

Mr. A. H. Stokes (Midland mines-inspection district), in 1900, refers at considerable length to ambulance-work in its

* Annual Report, 1899, page 63.

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special relation to accidents by electricity. He dwells on the necessity of promptly dealing on the spot with cases of electrocution, and inserts a paragraph from the Official Handbook of the St. John Ambulance Association describing, with two illustrations, Dr. Sylvester's method of artificial respiration.*

The late Mr. F. N. Wardell (Yorkshire and Lincolnshire mines-inspection district) in 1899 remarks that "classes continue to be formed throughout the district in connection with the St. John Ambulance Association, with the most useful and beneficial results. Medical men assert that when injured persons are brought to them now, the requisite first aid which has been rendered is such as hardly to require any alteration at the time."†

The testimony of doctors on similar lines to the foregoing has been one of the writer's most pleasant experiences in ambulance-work. Medical men in West Cumberland have repeatedly assured him that during the last few years the improvement in the administration of first aid in cases of accidents has been most marked and beneficial.

Mr. R. D. Bain (Durham mines-inspection district) in 1901 states that "The value of 'first aid' it is impossible to overestimate. A great amount of suffering and the loss of a limb, or even loss of life, may be prevented by skilful handling and manipulation immediately an accident has occurred, and before a surgeon can possibly be in attendance. I commend this to the consideration of all classes in the district—owners, managers, officials and workmen."‡

The late Mr. J. L. Hedley (Newcastle-upon-Tyne mines-inspection district), in his last report, wrote that "A period of six years has now elapsed since the inauguration of the Cumberland Mines and Quarries Centre of the St. John Ambulance Association, and it continues to make very satisfactory progress. As its name implies, the centre was formed for the purpose of promoting ambulance-instruction amongst the employees of mines and quarries in Cumberland, and it was the direct outcome of the Secretary of State's circular-letter on the subject of ambulance. . . . During the past six years, the centre has been the medium of conveying a complete course of instruction in

* Annual Report, 1900, pages 19 and 20.
first aid to upwards of 1,400 workmen, representing every mine and important quarry in West Cumberland. The actual amount of good accomplished can never with certainty be known, but that much needless suffering has been averted by the centre's successful operations is incontrovertible. The opinion has also been freely expressed by competent authorities that these classes are unmistakably improving the morale of the workmen attending; . . . which gives additional encouragement to all who are spending time and energy in the prosecution of this humanitarian work”* If we consider the evidence of statistics, the necessity for ambulance-knowledge amongst miners becomes even more apparent. In 1901, reports were received by H.M. inspectors of mines, of 1,229 deaths at mines and quarries and of 5,326 persons injured. It is wellknown that, under the provisions of the Mines and Quarries Acts, the immense majority of non-fatal accidents are not reported to H.M. inspectors of mines. The acts provide that, except in the case of accidents from three specific causes, only those which have occasioned serious personal injury need to be reported, and "serious personal injury" is an exceedingly vague expression, which allows of much latitude in its interpretation.

A few details of the Cumberland Mines and Quarries Centre will be of interest, as so far as the writer knows, there is no other branch of the organization working on exactly similar lines. The centre was formed in 1895 by the late Mr. J. L. Hedley, as the result of a conference with the mine-owners of Cumberland. Lord Lonsdale undertook to act as president, and on many occasions he has exhibited his warm sympathy with the movement. Mr. Hedley accepted the position of chairman, and the late Mr. Oswald and the writer were appointed respectively vice-chairman and secretary. Mr. A. D. Nicholson, as successor to Mr. Oswald, was appointed vice-chairman, and Mr. J. B. Atkinson, H.M. inspector of mines for the Newcastle-upon-Tyne district, has consented to act as chairman of committee, the position held by Mr. Hedley up to the time of his decease. There is, therefore, in Cumberland, an organization for the promotion of ambulance-instruction at mines directly officered by H.M. inspectors of mines, who, with the mine-managers, constitute the executive committee. The expenses incurred in carrying on the work are voluntarily subscribed by the mine- and quarry-owners on a pro-rata basis in accordance with the number of persons employed by each firm. The Cumberland Mines and Quarries Centre has been fortunate in securing the services of Mr. George Scolar as treasurer, and he has materially encouraged the good work by presenting a silver challenge-shield to be competed for yearly by workmen attending the ambulance-classes.

The effect of this combination of H.M. inspectors of mines and mine-managers has been to induce the workmen to attend and take an interest in ambulance-classes. In the writer's
opinion, the executive committee only needs to be strengthened by the accession of direct representatives of the workmen to make it perfect.

It has been found from experience that members who have passed through the classes, and obtained the medallion, are apt from want of practice to allow their knowledge to lapse. The inception of the organization known as the St. John Ambulance Brigade was intended to prevent or remedy this state of affairs, and the striking success which has attended its efforts is at once its justification and a proof of its necessity. The Brigade is an offshoot of the Association, and was established independently in 1880. During the last few years it has been brought prominently before the public, owing to its magnificent record during the recent war in South Africa, when upwards of 2,000 of its members volunteered for service as hospital-orderlies or as auxiliaries to the Royal Army Medical Corps. Every member of the Brigade must hold the certificate of the Association, and the Brigade is, in effect, a federation of first-aiders, (a) who meet regularly for combined ambulance-practice, and (b) who are prepared to render first aid on public occasions. The organization comprises "divisions" and "corps." A division consists of not less than 8, and a corps of not less than 72 members. A corps is frequently formed by the union of several divisions. The features which are calculated to make it specially applicable to mines are: —(a) The great attention given to methods of carrying the injured, and (b) the confidence which comes from combined practice, enabling a division or corps to work in thorough unison on occasions of exceptional disaster.

It has been decided to form a branch of the Brigade in connection with the Cumberland Mines and Quarries Centre, and the writer hopes at an early date to see it established.

Ambulance being- one of the subjects taught under Technical Instruction Act, assistance is given, more or less, by most of the County Councils to the formation and conduct of ambulance-classes. The County Councils of Durham and Northumberland make a liberal capitation-grant; Cumberland adopted this course originally, but about five years ago it materially reduced its contribution to this important work, and now merely pays the expenses of the examination. All the classes held, at mines, under the auspices of the Cumberland Mines and Quarries Centre, receive assistance from the County Council.

The writer recently came across a letter to the Newcastle Chronicle, written about half a century ago, and preserved in the Library of the Institute, describing, with illustrations, an invention for conveying injured persons from the working-place to the hospital or their home. The appliance consisted of a shallow wooden box without a lid, the injured person being placed in the box. On reaching the shaft, the box was put in an outer case, which was then slung to the pit-rope or chain and conveyed to the surface. In the light of modern experience, the appliance has a crude appearance, but it stands as the expression of a desire to lessen human suffering. In these days, the Low Moor jacket and Furley stretcher make an effective combination, which enables injured persons to be conveyed out of the mine with the minimum of pain.

The Coal-mines Regulation Act provides that "ambulances or stretchers, with splints and bandages, shall be kept at the mine ready for immediate use in case of accident." It would
certainly be advantageous, if in addition to those appliances a Low Moor jacket, and a copy
of the Emergency Book of the St. John Ambulance Association, were also provided at every
mine.

The writer hopes that he has succeeded in proving that the work of ambulance at mines is
worthy of the attention of all persons engaged in mining, comprising the workman, the
manager, the mine-owner and royalty-owner. He has always found that mine-owners and
managers are both willing and anxious to encourage in every way the formation of ambulance-
classes amongst their workmen, and he has no doubt that the

owners of mining royalties throughout the country, once they fully recognise its intrinsic
importance, will be equally ready to subscribe liberally for the furtherance of this humanitarian
work.

Mr R.- D. Lain stated in 1900 that "several collieries have been provided with wheeled
ambulance of the most modern type, thereby causing the minimum of suffering to injured
persons on the way to their homes or hospitals:"* and the writer suggests that royalty-owners
might equip the mines in which they are interested with the latest appliances for the
conveyance of injured persons.

Some managers now decline to appoint any person as an official, unless he is an ambulance-
man; this principle might be carried further, and managers might make it known that no young
man would be considered qualified for promotion to the rank of a miner, unless he is in
possession of the certificate or medallion, the qualifying badge of the St. John Ambulance
Association. This has been done with happy results in at least one of the haematite-mines of
Cumberland.

The names of qualified ambulance-men are conspicuously posted at some mines, so that
everyone may know where to find a qualified man in case of emergency. The writer cordially
approves of this commendable practice, pending the period when there will be an ambulance-
man in every working-place.

In conclusion, some striking remarks on this subject by the Secretary of State for the Colonies
may be quoted. Mr. -T. Chamberlain, at Birmingham, in presenting South African medals to
ambulance-men who had served in the war, said : "I do not think that I need dwell upon the
importance of such an Association as that to which you belong, but its value depends upon
the ubiquity of its members. They must be everywhere, at all times. It is necessary, therefore,
that you should be a very numerous body, so that if any accident befalls any member of the
community, he may not be far out of the reach of your assistance; and, if that end should be
achieved, then I am quite certain that by your instrumentality many valuable lives will be saved,
and the dangers which result from the accidents, which, after every precaution is taken, are
still inevitable in every community, will be reduced to a minimum."†

* Annual Report, 1900, page 36.
† The Times, September 1st, 1902, page 6.
Mr. John Gerrard (H.M. Inspector of Mines, Manchester), wrote that he had read Mr. Leck's paper with much pleasure. He had so many times seen where lives had been saved by first aid, by the stopping of bleeding, the careful bandaging and handling of persons with serious fractures, and even restoration after being recovered from beneath a large fall of soft coal, the person being carried out for dead, met by a qualified official and laid in the road, and after several hours' efforts, life restored that, it therefore, enabled him to testify to the value of first aid.

Dr. C. Le Neve Foster (London) wrote that his views upon ambulance work were summed up in the Report of the Departmental Committee upon Merionethshire Slate-mines, issued as Parliamentary paper [C.-7692] in 1895. He and his colleagues had reported as follows: —

II. — Care of Injured Persons. 72. — Our own personal experience, and the evidence of the medical men, fully warrant us in advising that the best methods of rendering "first aid" to injured persons should be taught to every man and boy employed in mines. We consider that the owners and agents of mines should give an impulse to such teaching by affording facilities for instruction in ambulance work, by taking a personal interest in the classes, by offering prizes, and by establishing ambulance-corps, such as already exist in connexion with some collieries. We need hardly add that we should like to see the 34th General Rule of the Coal-mines Regulation Act incorporated with any new Act for regulating the working of slate-mines. This rule compels the owner to provide stretchers, splints and bandages, ready for immediate use. We would even go further than this, and not allow any person to be a manager until he had taken the certificate of the St. John Ambulance Society, or some other society of like nature and equal standing. The certificate is so easily obtained that an owner would not be inflicting a hardship upon the working population if he required at least one-fourth of his employees to pass the necessary examination.

The old method of conveying injured men from the Festiniog mines in unwieldy litters should be abandoned, and convenient light stretchers should be provided in their place. *

In the eight years which had elapsed since the Report was issued his views had undergone no change, and he was just as much convinced of the value of systematic training in "first aid to the injured" as he was when he helped to organize some classes about 20 years ago.

On being appointed Professor at the Royal School of Mines in 1889, he at once induced the late Sir John Donnelly, who was then at the head of the Science and Art Department, to institute ambulance-classes for the students. No student can receive a diploma in Mining- or Metallurgy until he has received the certificate of the St. John Ambulance Association that he is qualified to render "first aid."

* Page xxvii.

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Mr. M. H. Habershon (Sheffield) wrote suggesting that the training of suitable men in the use of apparatus for breathing in noxious atmospheres was a branch of ambulance-work which might very well be undertaken by such an organization as the one in Cumberland referred to in this paper. With the most recent form of the Giersberg apparatus, selected men could breathe for 2 hours and do light work without discomfort, after being properly trained. This apparatus contained several important improvements which he thought made it superior to other apparatus previously tried in this country. He thought also that the success obtained with it by Mr. Meyer at the Shamrock Colliery, Westphalia, would now justify any organized centre for mining ambulance-work in taking steps towards the training of men in its use. Owing to the absolute necessity of having the apparatus always kept in perfect order, and of having men thoroughly trained and instructed (which could not be done without some expense), it seemed unlikely that progress in this matter would be attained by individual collieries; and therefore it was, he thought, particularly suitable for the joint centre or organization to which Mr. Leck had referred.

Mr. W. H. Hepplewhite (Nottingham) wrote that he had read Mr. Leck's paper on ambulance-instruction at mines with great interest, and, as he had always associated himself whenever possible with the furtherance of first aid to the injured in all its branches, he congratulated Mr. Leck in bringing the subject before the members.

The Midland mines-inspection district was probably the pioneer in introducing hand ambulance-carriages and stretchers at some of the large collieries. He well remembered their introduction, preceding the instruction department by many years, so that injuries happening underground had to await the attention of a qualified medical man either at home or at the hospital. A workman with a broken leg was put into a pit-tub without in any way receiving attention towards preventing the foot from wobbling about. He had known a case where a pit-pony's saddle was placed under the broken part to assist in keeping it rigid.

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The use of splints and bandages was unknown 25 years ago. Since that time, the development of first-aid instruction had been rapid and general throughout the Midland district.

It was worthy of record that, at nearly every colliery, classes had been formed by the managers, and continued year by year, until many of the stallmen and all officials held either certificates or medallions. At one large colliery, it was one of the conditions of the employment of a stallman that he must hold either a certificate or a medallion, and he quite agreed with this condition. There were in the Midland district many ambulance-corps established in connection with the classes, and as they all wore the regulation uniform they presented, when on parade, or under review, a smart military appearance.

As a typical example, he would describe the Babbington colliery-corps. The Tibshelf centre, which includes Birchwood, had for president Sir Charles Seeley, and Deputy Commissioner Mr. S. C. Wardell of No. 5 division as chairman. The Babbington centre had for president Mr. C. Hilton Seeley, M.P., and Mr. George Fowler as chief superintendent.

The terms usually commenced at the beginning of each year, and the examinations were generally held in the following March or April. The number of members attending the different
classes were generally about 100, which comprised persons going in for their first, second or final examinations. The number of persons that had obtained certificates since the formation of the classes in 1878, was 1,912 and the number receiving medallions 822. There was, in addition to the men's class, a women's class, many of whom studied nursing, as well as first aid.

Ambulance-stations were placed at convenient spots. Those inbye were generally near the deputy's cabin, and were provided with stretchers, splints, blankets, and the requisite material for dressing wounds. In case of an accident at the coal-face, one or two men were despatched for the ambulance-material, while others got the patient in a position to be attended to; and if the case was serious a message was sent by telephone from the site of the accident to have the roadways cleared of tubs, and In have the ambulance-van at the pit-to]] ready for removing the patient to his home or to the hospital. In mines, where the accident might happen a considerable distance inbye from the shaft, the roadways might be blocked with tubs, the use of the telephone could not be too highly estimated. Almost without exception, the patient could be taken from the workings to the hospital without a stoppage, and in severa instances the medical attendant had been summoned by telephone and was on the pit-bank awaiting the arrival of the patient.

The Babbington ambulance-corps was formed in 1889, and is now composed of 8 officers, 11 sergeants and 134 privates, making an effective force of 153 men. All wore a quiet-coloured, but neat uniform. They met regularly in the summer evenings for drill, and the members attended the ambulance-classes and assisted the new beginners. About September in each year there was a review of the corps, and an ambulance-display.

He (Mr. Hepplewhite) differed entirely from Mr. Leck in suggesting that H.M. inspectors of mines should assume the role of managing any of the centres, or should take any position as an officer; but he should in every way give his moral support and advice. He (Mr. Hepplewhite) was often called upon to distribute prizes at ambulance competitions and to give a short address on the advantage of the knowledge of being able to alleviate the suffering of a fellow-workman by rendering first aid.

There could be no doubt that ambulance-parades and the study of ambulance-work had a marked tendency to humanize the men and brought out a strong feeling of good fellowship with each other, in short, ambulance-work was a capital education for the collier.

Dr. T. Oliver (Newcastle-upon-Tyne) wrote that Mr. Leck had rendered yeoman service to all engaged in the mining industry of this country, by the clear and pleasing manner in which he had urged the claims of ambulance-instruction at mines. With most of all that he had said he (Dr. Oliver) quite agreed. There were advantages in having ambulance-centres under the wing of the St. John Ambulance Association. Not only had this society been in existence for several years, it was well organized, and had numerous centres all through the country: it undertook the formation of detached classes and its main object was the instruction of persons in rendering first aid in case of accident. It was besides, not only an examining body giving certificates and medallions to successful students, but was under Royal patronage, and this circumstance to some extent threw a glamour around
the association which it otherwise would not possess. For many reasons, therefore, it was desirable, if ambulance-instruction was to be given at mines, no matter the directing body (whether employers alone, the miners themselves or the county council) that any centre that was formed should work in union with the St. John Ambulance Association.

Mr. Leck said that a course of not less than five lectures should be given. This was fewer than in most instances would be found desirable, since the lectures proper must be prefaced by other instructions dealing in a general way with the human skeleton, the heart and lungs, circulation, the position of the main blood-vessels of the body, and a few details concerning the nervous system. At the most only a small number of lectures could be given for (1) it was not every medical man who cared to undertake the kind of teaching necessary, (2) his professional calling made too many and often very irregular demands upon his time, and (3) it was undesirable to multiply the lectures and demonstrations too much, in case of wearying the audiences.

As to the value and importance of ambulance-instruction there could be no doubt. Knowledge was power. The acquisition of that special kind of knowledge which enabled one to render first aid to the injured was of the greatest possible advantage to every man, no matter what his rank in life might be. Especially valuable was it to the miner whose vocation was a dangerous one and who perforce was often separated from his fellow-men by a considerable distance.

By a miner engaged hewing coals for a great part of the day, attendance on a winter's evening at a class for instruction in first aid should be looked upon in the light of recreation. It was an entire change to him from his ordinary work, and, besides, as already stated, he was gaining information that could be turned to good account for other people. The Home Office recognized the value of the instruction and urged the formation of classes. Ambulance-instruction was like higher education: it stimulated the miner to read and think: it gave him a larger interest in life, encouraged in him, were it needed, feelings of mutual respect for his fellow-workmen and supplied a particular kind of knowledge which would never come amiss.

Apart from arresting severe haemorrhage, one of the most important things to mite, when an accident that is not immediately

Fatal has occurred, is the manner in which an injured person is carried by his fellow-workmen. While a strong arm is necessary, this is quite in keeping with a gentle touch and delicate handling. Knowing how to place a wounded limb in the easiest position and how to lift it when required robs an accident of much of its terror, and often is the means of preventing a simple fracture from becoming compound. From experience, he (Dr. Oliver) could bear testimony to the excellent work done by men at the mines who had rendered first aid. The injured often came to the infirmary properly splinted, and with their wounds well dressed.

It is an interesting fact, of which probably many members of the Institute are aware, that miners' wounds usually heal remarkably well. After a lacerated injury to the soft parts of a limb, the wound may look black and be much discoloured, yet such a wound will in most instances heal very readily. Owing to this fact it is often contended that coal-dust is an antiseptic. Without
going quite that length he (Dr. Oliver) was in a position to state that in making bacteriological cultures of coal, microorganisms are, practically speaking, non-existent. In other words, coal at the working face is perfectly sterile, and does not contain microbes. It is to this circumstance of the coal-dust carried into a wound not being germ-laden, and not to any assumed antiseptic action which it possesses, that must be attributed the rapid healing of miners' wounds. What he had said of the healthy character of the wounds applied to those injuries received at the mine-face. In the main ways close to the foot of the shaft and near the stables, the air is not free from germs, so that wounds received at this particular part, of a pit may become septic. Owing to the proximity of the stables also, wounds may become, as he had known them, infected with a tetanus bacillus. These are details which, although small of themselves, become of importance to the wounded so far as immediate treatment and future results are concerned, and where such instruction as that gained in ambulance-lectures might be most useful.

During a course of ambulance-instruction, in addition to the application of first aid to the injured, the attention of those attending the class should be directed to the effect produced by inhalation of the various gases that may be present in coal-mines, and how to treat persons that have been overcome by them.

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Seeing too that electricity is becoming more and more employed in mines, the men should also be instructed as to how electricity kills, and how workmen apparently killed by electricity may be restored to life. Severe electrical shock causes death by immediately paralysing the heart. The muscles of respiration are thrown into a state of temporary spasm, but the heart stops beating, even though the breathing continues for some time after death. The point to remember, therefore, is that death in electric shock is from the heart, and that in order to resuscitate persons apparently killed the same methods of artificial respiration must be adopted as those employed in restoring the apparently drowned.

The illustrations that he (Dr. Oliver) had given shewed that there must be many ways in which such knowledge as that gained in ambulance-lectures might come in very helpfully. Apart from the utilitarian aspect of the question, he knew of nothing which could bring greater satisfaction or pleasure to a man, than to know that by any service that he had rendered to a fellow-workman, he had relieved pain or been the means of saving life. For these reasons, he warmly advocated "Ambulance Instruction at Mines."

Mr. W. Watkyn-Thomas (Workington) wrote that the members were very much indebted to Mr. Leek for his paper on this very important subject: and it was specially fitting for an inspector of mines to advocate this question, as it was his first duty to encourage everything which tended to the greater security of life; and "first aid" did so materially, directly and indirectly, as no one doubted who had experience of it. He wanted to emphasize what Mr. Leek had said of the results of the combination in the West Cumberland district of H.M. inspectors of mines and the mine-managers in ambulance-work: and mine-owners, officials and workmen are unitedly in earnest in trying not only to maintain the already widespread interest therein, but to extend its operations.

The fact, reported by the late Mr. J. L. Hedley, that "conveying a complete course of instruction in 'first aid' to upwards of 1,400 workmen, representing every mine and important quarry in
West Cumberland," during a period of six years, was proof of the excellence of the organization. He was convinced that this success had been attained chiefly through the active and sympathetic work of Mr. W. Leck and his colleagues: and, in his (Mr. Watkyn-Thomas') opinion, the good done through the direct influence of H. M. inspectors of mines was not limited to the cause of humanity, in lessening suffering in accidents, which were inseparable from mining work, since the whole scheme elevated and educated officials and workmen, and cultivated more kindly feeling between them, and a greater sense of discipline and method, generally. These results, and the hearty co-operation of all classes, were largely, if not chiefly, due to the fact that the organization is officered by H.M. inspectors of mines; and the memory of the late inspector of mines, Mr. Hedley, and of his ever-ready sympathy in ambulance-work, which endeared him to them, will long remain with the whole of the mining community.

It would not, however, be expedient to take it as a matter of course, from the experience in this district, that H.M. inspectors of mines should be expected to act in an official capacity in all such organizations, as he (Mr. Watkyn-Thomas) thought that each district must decide for itself, and the widest discretion should be allowed to H.M. inspectors of mines in their relations thereto.

Mr. W. Leck (H.M. Inspector of Mines, Cleator Moor), replying to the discussion, wrote that he felt exceedingly gratified at the profitable discussion which his paper had called forth. The succinct and practical remarks of Mr. John Gerrard and Dr. C. Le Neve Foster, and the specially interesting notes of Dr. Thomas Oliver, were an encouragement to all who were spending time and energy in promoting ambulance-instruction at mines. With reference to the number of lectures, the St. John Ambulance Association prescribes a minimum course of five; but, as Dr. Oliver remarks, more are usually needed. In connection with the Cumberland-mines classes an extra lecture is nearly always given, and frequently the course is extended to seven or eight separate lectures.

He cordially agreed with the admirable suggestion of Mr. M. H. Habershon that an organization like the Cumberland Mines and Quarries Centre might very well undertake to promote practical instruction in the use of apparatus for enabling persons to work in noxious atmospheres. A general suggestion of a similar kind was mentioned to him (Mr. Leck) some little time ago, but although the idea was not altogether new he obliged to Mr. Habershon for mentioning it in this connection, and he hoped that his proposal would ere long crystallize into actual realization.

Mr. W. H. Hepplewhite's opportune remarks constitute an important historical contribution to ambulance-literature, and it is clear that the Midland mines-inspection district is well to the fore in ambulance-work.*

The President (Sir Lindsay Wood, Bart.), in moving a vote of thanks to Mr. Leck for his paper, stated that no doubt many lives had been saved, both in mines and various works, since
ambulance-instruction had been given. The members could not be too high in their praise of ambulance-classes.

Mr. T. E. Forster seconded the resolution, which was warmly approved.

* An interesting incident has just occurred in connection with the annual ambulance-competition among Cumberland miners, held on June 27th, 1903. The challenge-shield was won by a team representing Whitehaven colliery, and to mark the merit of the performance, the Miners' Association have awarded a grant of £5, to which the Whitehaven Colliery Company have added another £5, for the purpose of supplying each of the four members of the winning team with a gold medal. This commendable example of co-operation between employers and workmen forms a striking illustration of one of the important side issues of the ambulance-movement in connexion with West Cumberland mines.

Mr. E. A. Newell Arber's paper on "The Use of Carboniferous Plants as Zonal Indices" was read as follows:

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THE USE OF CARBONIFEROUS PLANTS AS ZONAL INDICES.


INTRODUCTION.

When the writer had the honour to receive a communication inviting him to contribute a paper on fossil plants to the Keswick meeting of the North of England Institute of Mining and Mechanical Engineers, some doubt was felt as to the possibility of doing so with advantage to the members. Paleobotany, even when illustrated by actual specimens or by figures of fossil plants, is, in many of its aspects, too technical to appeal largely to those who have not previously taken some active interest in the subject. Yet, in regard to Carboniferous rocks, mining engineers have much in common with those who are making a special study of the distribution of the fossil plants. There exists a common desire to be able to recognize their "whereabouts," if one may so state it, in this great formation. The recognition of landmarks, in the shape of definite horizons, is a matter which the writer imagines is of vital importance to the engineer, and one which has long been the aim of the geologist and palaeontologist. It has seemed, therefore, that this opportunity might perhaps be employed with advantage in giving a brief account of the present position of the study of the distribution of Carboniferous plants, in discussing the principles and methods by which advances have been recently effected, and in describing some of the difficulties which bar the road to a more rapid progress. The Carboniferous system is the thickest of all the great divisions of the British stratigraphical series. It is also one which, in its upper portion, presents comparatively little lithological variety as traced vertically and laterally. As practically
all the workable coals of England belong to the Upper Carboniferous, lithological character is usually of little help for the purpose which we are here considering. Thus in the Somerset and Bristol coal-field, we find two sets of carbonaceous deposit resting on rocks which are termed Millstone Grit. The general character of these deposits is not, as a whole, dissimilar from the single series of measures in Yorkshire, also resting on Millstone Grit (Rough Rock).* Yet it has been shown by palaeobotanical evidence that the Coal-measures of the southern coal-field are a newer set of deposits than those in Yorkshire, belonging to what are known as the Upper and Upper Transition Coal-measures,† whereas those of the northern coal-field belong to the Middle and Lower Coal-measures.

There are three types of evidence to which we must look for help in zoning the Carboniferous. These are the fossil plants, the fossil invertebrates, and the fossil fishes.

With regard to the fossil fishes, their occurrence is hardly numerous enough to be regarded as a main line of evidence. Fish-remains do, however, occur in many different beds of the Carboniferous, and it is now possible to distinguish clearly between an Upper and a Lower Carboniferous fauna of this nature.‡ We find, therefore, in the fossil fishes, often valuable support for results obtained by other means.

At the present time, efforts are being made to zone the Carboniferous along two distinct lines of evidence. The study of Carboniferous mollusca has had for several years the advantage of a special share of the attention of a Committee appointed by the British Association for the Advancement of Science to assist in the progress of zoning the Carboniferous.§ Although perhaps the results achieved in this direction have not entirely fulfilled the hopes which have been entertained, the time has not yet come to gather how far we may depend upon this type of evidence. It must, at present, be conceded that the study of plant-remains has attained a more assured position in this respect, despite the valuable assistance which the close examination of the Carboniferous mollusca has afforded to palaeontology.

We may turn now to a short explanation of the progress which has been made in this country with regard to the use of Carboniferous plants as zonal indices. It is not proposed here

to trace out the history of this progress, in regard to either the British Carboniferous rocks or to those of the Continent.* We may rather devote such time as may be at our disposal to a consideration of the principles and methods which are adopted, and the results which have so far been attained.

Principles and Methods.
The student of Carboniferous plants has long ago realized that the kind of evidence which is drawn successfully from the distribution of marine invertebrata is inapplicable and inaccurate in the case of fossil plants. For instance, as is well known, the Jurassic rocks are divided into a number of definite zones on the occurrence of a particular species of Ammonite, confined or almost wholly confined to that zone. Apparently in regard to the Carboniferous mollusca, the same principle is being applied. Efforts are being made† to obtain a characteristic and common mollusc, which occurs in one subdivision of the Coal-measures, but which is absent or almost entirely absent from others; and to use such species as zonal indices. How far this will prove possible in the case of a fauna which is not truly marine, but largely littoral, estuarine, or even freshwater, remains to be seen. The discovery of restricted species of plants is not, however, the primary object of the palaeobotanist. Some geologists, realizing that fossil plants do not commonly afford this type of evidence, have rather hastily concluded that such remains are, therefore, useless as zonal indices. It has been shown, however, that this is not the case. It is true that, in British rocks, a number of plants, so far as our

* For the use of plants as zonal indices in the Carboniferous rocks of the Continent, the works of Geinitz, Weiss and Stur (Germany), and of Messrs. Grand'Eury and Zeiller (France) should be consulted.

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knowledge extends, are confined to one of the minor divisions of the Carboniferous, such as the Middle Coal-measures. This is the case with Zelaria delicatula, Sternb., and Sigillaria ovata, Sauveur, plants which have recently been found in the Cumberland coal-field.* The evidence of such restricted species is not, however, the foundation of any method of zoning by means of fossil plants, although it is often important as affording confirmatory support to conclusions gained on entirely different grounds.

In order to establish the position of any bed in the Carboniferous, it is necessary to collect and to study a number of different species from it, or from the associated rocks; in other words, we must know not one or two species, but a flora. The number of species need not, however, be very large. Usually twenty species or even less will suffice, if they belong to diversified types of plants; but the larger the number, the better. It is the relative abundance of certain types of plants at any one horizon, and the absence of other types, rather than the occurrence of particular species, which gives the solution to the problem of the horizon of the bed in question. By taking into account the aggregate or assemblage of plant-types, the common occurrence of certain classes, genera, subgenera or species, and the absence or rare occurrence of others, species which have a wide range in time in Carboniferous rocks can be made to yield
evidence. Such species, despite their range, are found to be much more abundant in some subdivisions of the Carboniferous than in others.

Thus the common occurrence of Lepidodendron aculeatum, Sternb., in the Cumberland coal-field points to these beds being of Middle or Lower Coal-measure age, rather than the Upper; since this species has been found to occur most abundantly on these horizons in other coal-fields, and less abundantly in the Upper Coal-measures. From a number of separate small conclusions of this nature, a general conclusion can be arrived at, for which support can often be found from other evidence, such as the occurrence of restricted species. Again, an abundance of such types of plants as Calamites and


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Sigillaria in association with Sphenopteris, and an absence of particular types of Pecopteris, Alethopteris and Cordaites, will help to distinguish a Middle from an Upper Coal-measure flora.

Occasionally, small points of disagreement with a general result are found. Thus Alethopteris Serli, Brongt., a characteristic Upper Coal-measure fern-like plant, is occasionally found in the Middle Coal-measures, as for instance in Cumberland. The disagreement of a single character does not, however, invalidate a conclusion drawn from an aggregate of characters. Such disagreements occur among recent plants, which are classified on exactly the same principles as those applied here. In the recent family Scrophulariaceae, the presence of five stamens in the flower is a single character contributing towards an aggregate of characters, which distinguishes this family or natural order from others. But many, perhaps the majority of genera belonging to this family, possess only four or two stamens, whereas their other characters, as a whole, clearly point to close affinity with those members of the Scrophulariaceae which possess five stamens. It need hardly be pointed out that if all the plants, which possess five stamens, were thrown into a group on this character alone, that group would not be a natural one, since it would include a large number of genera in no way related one to the other.

Let us now endeavour to see with what success the principles, which we have discussed, have and are being applied towards zoning the Carboniferous rocks.

It should, however, be pointed out that we owe our present knowledge of the distribution of fossil plants in British rocks almost entirely to one palaeobotanist, Mr. Robert Kidston. For several years, Mr. Kidston has devoted his attention to the examination of the Carboniferous plants of many British coalfields, and in a remarkable paper published in 1894,* he gathered together the results of years of patient and critical research, and gave us the first clear enunciation of the methods by which Carboniferous plants may be used as zonal indices. The principles explained here are those which Mr. Kidston then initiated. As a direct result of Mr. Kidston's work, it is now
possible to ascertain, within certain limits, the age of Carboniferous beds, by an examination of their plant-remains in cases where the position of such beds has been regarded as uncertain, or is in dispute.

Palaebotanical Subdivisions of the Carboniferous.
The following are the subdivisions of the English Carboniferous rocks on lithological grounds:

Upper Carboniferous: —
  Coal-measures.
  Millstone Grit.
Lower Carboniferous: —
  Yoredales and Upper Limestone Shales.
  Mountain Limestone.
  Lower Limestone Shales, etc.

In Scotland, the Lower Carboniferous rocks are, as a whole of a somewhat different type, and are subdivided as follows: —

Lower Carboniferous: —
  Carboniferous Limestone Series.
  Calciferous Sandstone Series.

(1) Lower Carboniferous.

It is an easy task for anyone who is at all familiar with Carboniferous plants, to distinguish between an Upper and a Lower Carboniferous flora. The general facies of a flora is in itself sufficient to determine the division to which the beds should be assigned. With regard to subdivisions in the Lower Carboniferous, comparatively little information has so far been published, and we are at present chiefly familiar with plant-remains from the Scottish beds. It is believed, however, that Mr. Kidston, who has devoted considerable attention to this subject, is about to greatly extend our knowledge of both the Lower Carboniferous plants of Scotland, and those of the North of England.

The Lower Carboniferous flora of Britain, as a whole, agrees closely with that of the Culm and other Lower Carboniferous floras of Germany, and elsewhere on the Continent. The whole aspect or facies of this flora differs markedly from any yet found in undoubted Upper Carboniferous rocks. The fern-like plants (Adiantites, Rhacopteris and Sphenopteris)* differ remarkably from the Pecopterids, Alethopterids and Neuropterids of the Upper Carboniferous. The well known Calamites of the English Coal-measures are

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extremely rare in the Lower Carboniferous, and their place is taken by another member of the Equisetales, Asterocalamites.† Lepidodendron, an abundant type of Lycopod in the Upper division, occurs also in the Lower, but the species are distinct in each division. Lastly, Sigillaria is much rarer in the Lower Carboniferous than in the Upper. So far as the writer is aware, with the exception of one or two doubtful cases, and of such composite species as Stigmaria ficoides, no species of Carboniferous plant is common to both the Upper and Lower divisions.

Two subdivisions of the Scottish Lower Carboniferous rocks, the Carboniferous Limestone and the Calciferous Sandstone, can be recognized by differences in their fossil flora, as well as by their general lithological character.

(2) Upper Carboniferous.

With regard to the Upper Carboniferous, progress has naturally been more rapid, on account of the relatively greater abundance of plant-remains, and of workable coal-seams in this series. At the present time, we can distinguish in it four palaeobotanical subdivisions.

Upper Carboniferous: —

Upper Coal-measures.
Upper Transition Series.
Middle Coal-measures.
Lower Coal-measures and Millstone Grit.

The Millstone Grit, which is usually regarded as the lowest division of the Upper Carboniferous, is not very prolific in plant-remains. But our comparative ignorance of its flora is probably due to the small attention which has so far been devoted this horizon, rather than to a general barrenness of the rocks, as is often supposed. A more thorough collection of the

* Sphenopteris, a very artificial form-genus, occurs both in the Upper and Lower carboniferous, but no species, so far as the writer is aware, is common to both.
† Also known as Archaocalamite.

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plant-remains from these beds is urgently needed. Such species as are known from the Millstone Grit have been found to be in every case identical with plants from the Lower Coal-measures. Thus, while we are at present unable to distinguish the flora of the Millstone Grit from that of the beds immediately succeeding it, we do, however, know that this horizon is rightly regarded as a member of the Upper Carboniferous.

In the Lower Coal-measures, fossil-plants are fairly common but not so abundant as in the higher series. Coal-bearing rocks of this age occur in many of the coal-fields of England and Scotland. Their fossil flora is distinguished chiefly on negative evidence. All the commoner Lower Coal-measure plants are found in the Middle Coal-measures, but the latter flora is characterized by the common occurrence of plants which have so-far not been found in the lower series. Certain plants are, it is true, only known from the Lower Coal-measures,* but these are unfortunately of rare occurrence, and are, therefore, not to be relied upon as zonal indices. On the whole, our knowledge of the flora of the Lower Coal-measures is fairly satisfactory, but there is still room for more research as to the distribution of plants at this horizon. It is not improbable that, in the upper beds of the Lower Coal-measures, a transition-
flora will eventually be detected. Such a transition-flora is already known to exist in the beds immediately above the Middle Coal-measures, which yield a mixture of typical Upper and Middle Coal-measure-plants.

The Middle Coal-measures are the most abundant coal-bearing rocks in England, and, in beds associated with the coal, fossil plants are, as a rule, extremely common. This flora is distinguished, as we have seen, from the subordinate series by the common occurrence of species restricted to this division. It marks a period during which several plant-types, such as Sigillaria among Lycopsids, and Neuropteris and Sphenopteris among fern-like plants, attained their maximum development.

Intermediate between the Middle and Upper Coal-measures, there is an horizon known as the Upper Transition series. The

* For a list of these, and for an enumeration of the characteristic plants of the different subdivisions of the Carboniferous system, see "On the Various Divisions of British Carboniferous Rocks as determined by their Fossil Flora, by Mr. Robert Kidston, Proceedings of the Royal Physical Society of Edinburgh, 1893, pages 223-232.

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general character of the flora of these beds has been already indicated. These rocks are present, and have been recognized by their fossil flora, in many coal-fields, including the South Wales* (Lower Pennant rocks), Somerset† (New Rock and Vobster Series), Potteries,‡ South Lancashire (Ardwick series), and possibly also in the Cumberland coal-field; though in the last mentioned, few fossil plants have yet been found in the Upper division of the Sandstone Series of Whitehaven.§

The flora of the Upper Coal-measures, an horizon which only occurs (so far as our present knowledge extends) in the three southern coal-fields of South Wales, Somerset and the Forest of Dean, is, as a whole, very distinct from that of the Middle Coal-measures. It is especially characterised by an abundance of certain types of Pecopteris and Alethopteris (A. Serli, Brongniart), and by a comparative rarity of Lepidodendra and some other genera, which are abundant in the lower series. The Upper Coal-measures are the highest series of Carboniferous deposits which occur in this country, though still higher subdivisions are found in the Carboniferous beds of the Continent.

Such is an account, necessarily brief, of the use to which British fossil plants of Carboniferous age have been put as tests of succession, and of the progress which has attended the study of the distribution of such remains. There is not time here to mention the invaluable services that such plants have rendered to botany in the elucidation of the phylogeny of plants, and in extending our knowledge of the habit and structure of members of the vegetable kingdom in past times.

The writer would wish to point out in conclusion the great need for, and importance of, still further work among Carboniferous plants to both the botanist and geologist; and, he might add also, to those engineers who are directly connected with the working of our carbonaceous deposits. Several of our coal-fields are as yet unexplored botanically, and in most of them

* Mr. R. Kidston, Ibid., 1894, pages 228 and 229.
more detailed work than has yet been possible is necessary on many horizons, if we are to increase the number of landmarks in the Carboniferous system. The workers in this particular field of research are at present few, and thus the task of detailed collection of plant-remains over such wide areas is beyond their powers. Such work can, in most cases, be only carried out successfully by local geologists. The writer would, therefore, make a special appeal to members for help in the collection of specimens, and for records of the occurrence of plant-remains in the rocks with which they may be familiar. If only a few members, who are engaged in mining operations in rocks of Carboniferous age, would take an active interest in the subject by "keeping a look-out" for plant-remains, and by collecting and forwarding them as they may be found to those who are specially working on the distribution of Carboniferous plants, it would soon be possible to extend considerably the use of such plants as zonal indices beyond the limits which are here described.

Mr. J. T. H. Teall (Director of the Geological Survey, London) wrote that the work of determining the distribution of fossil Carboniferous plants in space and time is undoubtedly one of great importance, both from a scientific and from an economic point of view. It is, moreover, a work which can only be effectively performed by the co-operation of those who are actively engaged in raising coal and in sinking shafts, with palaeobotanists like Mr. Newell Arber and Mr. R. Kidston. The results already obtained by these gentlemen are most important, and constitute a guarantee that any assistance which members of the Institute can render will not be thrown away.

Whenever borings are made for coal in undeveloped fields, as for example in the concealed part of the great Yorkshire and Nottinghamshire coal-field, every trace of a plant or other fossil should be most carefully preserved and submitted to competent specialists for determination. But the full value of the evidence furnished by fossils found under such circumstances can only

* Specimens may be forwarded either to Mr. R. Kidston, F.R.S., 12, Clarendon Place, Stirling, N.B., or to the writer at the Sedgwick Museum, Cambridge. It is of the utmost importance that each specimen should be labelled with a record of the exact bed, pit, and locality from which it was obtained. Such inform often much more valuable than the specimen to which it applies.
be obtained when the distribution of fossils has been accurately determined in areas where the relations of the strata are well known. Every effort should therefore be made to increase our knowledge in this respect.

As Mr. Arber pointed out, there is no probability that the Carboniferous rocks will ever be zoned by fossil plants as minutely as the Jurassic rocks have been zoned by ammonites and the Lower Palaezoic rocks by graptolites, but it has already been proved that, by taking into account assemblages of plants and noting the relative abundance of particular forms, it is possible to establish a chronological classification of great value; to correlate, within certain limits, the strata of different coal-basins in this country; and to bring our measures into relation with their equivalents in other parts of the world.

Mr. R. Kidston had kindly undertaken to prepare a memoir on the horizons of the British coal-measures, as determined by fossil plants for the Geological Survey, and as Director of that survey, he (Mr. Teall) desired most strongly to support Mr. Newell Arber's appeal for assistance from members of this Institute for the work which he and Mr. R. Kidston were doing.

Mr. E. Leonard Gill (Newcastle-upon-Tyne) wrote that Mr. Newell Arber had given a clear and interesting account of the broad results attained through a study of the fossil-remains of the Coal-measure floras. His paper showed that the labours of the naturalist may have a practical value, even for the mining engineer; and on the other hand it made it evident that only such thorough and patient work as that in which Mr. Robert Kidston and the author were engaged could really have any such value. But anyone having access to collieries and shale-heaps was in a position to help with this work, in the way pointed out by Mr. Arber; and now that the practical and systematic nature of the investigation had been demonstrated before this Institute, it was much to be hoped that the members would contribute to the attainment of a better knowledge of the fossil flora of the Northumberland and Durham coal-field. He (Mr. Gill) might add that the Natural History Museum at Barras Bridge contains a collection which will be found useful for reference by any who may become interested in the subject, and could be used as a temporary deposit for specimens. It also contains

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the Hutton collection of coal-plants (presented by this Institute) which is a classic example of what may be done towards forwarding this particular branch of knowledge by anyone who makes that use of his opportunities which the author and Mr. Kidston so strongly urge.

Mr. Audrey Strahan (Geological Survey, London) fully concurred with the author in attaching great importance to the search for definite recognizable horizons in the Carboniferous rocks. In the exploration of unproved coal-fields, and especially of those concealed under newer rocks, the need for such landmarks was now being felt daily, and would be felt more in the near future. Lithological character was an untrustworthy basis for correlation in such rocks as the Coal-measures. Sandstones and shales replace one another rapidly even in the same basin, and can only be matched in a most general way in adjoining basins. In correlating the measures of coal-fields so far apart as those of the south-west and those of the Midlands or the North of England, reliance would have to be placed on the fossils.

It was unfortunate that neither of the two lines of investigation referred to by the author had yet yielded results so precise as were desirable for practical purposes. Among a large number
of molluscan species, scarcely any could be trusted as indices of horizon, and in the case of
the plants the enormous proportions attained by "transition-series" shewed the difficulty of
classifying strata by fossils with so indefinite a vertical range. There were other fossils,
however, not only in the Lower Carboniferous rocks, but at several horizons in the Coal-
measures, which probably would be a surer guide to the zoning, if they were not unfortunately
extremely rare. The fossils referred to were of purely marine types, and belonged to genera
which ranged through a large part of the Carboniferous system. Among them Cephalopoda
were generally represented, and would probably furnish a better paleontological time-table
than either the Lamellibranchs or plants. But though attention was being directed to them,
with the result of shewing that they were more frequent than was supposed, the fossiliferous
bands were still too rarely recognized to be of much practical use.
Notwithstanding the difficulties referred to, the study of the Coal-measure plants had yielded,
and would yield valuable results.

The importance of being able to determine whether a boring carried down through Secondary
rocks into Carboniferous strata had struck those strata below or above the productive
measures could hardly be overestimated, and the researches referred to in this paper had
gone far towards rendering such determinations possible. Their progress in the future must
depend largely on the amount of material available: for the relative abundance of certain types
of plants at any one horizon, on which the author rightly placed much reliance, could be
ascertained only by the collection of many specimens. In this work the cooperation of mining-
engineers was urgently needed.

Dr. Wheelton Hind (Stoke-upon-Trent) wrote that there was of course nothing like leather, but
while leather was a very useful article in its place, its usefulness was distinctly limited. It had
always seemed to him that palaeobotanists had not done enough field-work, and, therefore,
were too much inclined to magnify the value of plant-remains as a factor in determining
horizons in the Carboniferous series. At the outset, it must be remembered that a very large
portion of the great thickness of Carboniferous rocks was deposited under marine conditions
and, therefore, if plants were found in them, they were there only casually. Again, in the
Lower Carboniferous rocks, plants were absent through many hundred feet of strata in certain
districts, and, therefore, afforded no help whatever to the identification of horizon.
Carboniferous plants were undoubtedly land-organisms, and could rarely, if ever, be in the
exact spot where they grew, but had drifted to a greater or less extent. The mainland of the
Carboniferous period was not far away, probably occupying the North of Scotland, while part
of the Lake country was also land. Plants would be laid down only in strata near to land, and
hence were not distributed over wide areas.
He (Dr. Wheelton Hind) quite agreed that in attempting to zone the Carboniferous rocks, it was
the fauna or the flora as a whole which was important, and not so much the presence of one
or two species. This was certainly true of the mollusca, and he gladly learnt that the flora also
bore out this fact. As a matter of fact, in the Upper Carboniferous, where plants were fairly
common, the mollusca gave a much more exact and definite index to the actual bed than
the plants, which he understood
only as a whole, illustrated artificial subdivisions rather than beds. The table of subdivisions of the Carboniferous sequence was to his mind somewhat unsatisfactory, because no definition of the Yoredale series was given, and many writers confused two distinct series under this name. He was not aware that plants had been found to any extent in this series; but, as the true Yoredale series was only the equivalent of the upper part of the thick limestone of the Midland counties and contained the same fauna, and the series was probably marine from top to base the question of plant-remains was quite subordinate to the mollusca as an index of horizons.

If the Yoredale series was intended to include the shales and black limestones of the Midland counties, then he emphatically joined issue, for these beds were characterized by a rich fauna, which unmistakably indicated a different condition of deposit from that which obtained in the true Yoredale country. In this series, the Pendleside series, plants occurred at a few horizons, but they were very rare, and too unfrequent for much to be based on them. At present, therefore, plants were only plentiful enough in the Calciferous Sandstone series (a series of detrital material, laid down not far from the shore), and in the productive Coal-measures, to give any help, and it behoved all those who came across specimens to have them identified and properly labelled for reference. He might say, in conclusion, that his own researches did not lead him to accept the subdivisions of the Coal-measures proposed by the palaeobotanists, but he was open to conviction. At present he was of opinion that the plants and the fauna of the Carboniferous series told the same great tale, as nearly similar, as organisms with such different habits could do; and the only scientific attitude was not to neglect the evidence of either, or to belittle the results obtained from the study of a single group. It was most improbable that fossil plants and mollusca would give absolutely the same results.

Prof. G. A. Lebour (Durham College of Science) congratulated Mr. Arber on his valuable paper, on the possible zoning of the Carboniferous rocks by means of plants. Such attempts were the more to be encouraged, because of their extreme difficulty and of the almost hopeless nature of the enquiry. He (Prof. Lebour) had no desire to throw cold water on work of this kind, but he could not shut his eyes to the many obstacles which must be met with in carrying it on. Zoning in the Carboniferous series by means of animal-remains was only now beginning to enter the sphere of practical geology, and that chiefly in the Midland counties, owing to the excellent detailed investigations of Dr. Wheelton Hind, Mr. Walcot Gibson and Mr. J. T. Stobbs. Animal-zones were, however, far more easily determined than plant-zones. They were also more useful, because the life of a genus or of a species was, in general, shorter in the animal kingdom, and, therefore, restricted to a smaller range of strata than in the vegetable kingdom. Thus a single plant-zone might be and often was, represented by several animal-zones. Again, those portions of the organism which enabled one to name a genus or a species with certainty were much more often preserved in animal-remains than in those of plants. The literature of fossil botany showed, by the terrible bulk of its synonymy, the want of agreement as to nomenclature that existing among experts, and this was especially true as regards Carboniferous plants. This evil, though it existed also with respect
to animals, was, in this case, far less rampant and more easily remedied. As against these objections to plant-zoning, it must be admitted that whereas in the non-calcareous divisions of the Carboniferous series animal-remains were comparatively scarce and represented by a small number of forms, plant-remains were abundant both individually and specifically. It was probable that when some standard of nomenclature—say Mr. Kidston's—came to be adopted more generally than at present, and when (if such a degree of knowledge ever be possible) the associated plants of each district at each moment of time during the Carboniferous period came to be known, so that the flora of the Lower Coal-measures (for example) of South Wales could be intelligently compared with that of the synchronous period in the Newcastle coal-field—it was probable that then, but not till then, plant-zoning in these rocks might become of practical value. It was as a valiant attempt to take part in this forlorn hope that he, as a member of the slow-moving British Association Committee to which the writer of the paper referred welcomed Mr. Arber's very interesting communication.

Mr. J. T. Stobbs (Stoke-upon-Trent) wrote, cordially welcoming Mr. Arber's contribution to the Transactions. He perused the paper with mixed feelings: on the one hand, it was another indication of the growing interest of the geologist and the specialist in the Coal-measures and it would probably result in an increase of the number of workers in the subject; but the other hand, it made an unfair estimate of the work that had been done along other lines. Whilst he would like to consider himself just as anxious for the greater use of fossil plants as of fossil mollusca or fishes, yet many years' devotion to Coal-measure geology had compelled the acceptance of views which did not harmonize with those expressed in the paper.

Dealing more particularly with Coal-measures, in addition to the three types of zoning enumerated by the author, namely:—Plants, fishes and invertebrates, there was a fourth method which he (Mr. Stobbs) believed capable of more exact and far-reaching results, namely:—The discovery and the tracing of marine beds known to exist in most of our coal-fields. The latter method enlisted the knowledge of specialists of the above-named three types of organic life, and it might be seen at a glance that a combination of these forces must be more powerful than their isolation and, should it be said, their mutual negation and neutralization?

As to the nomenclature of the Carboniferous system, adopted by Mr. Arber, it was unwieldy and was a compromise with a system that had now fallen out of use. In seeking to initiate a scheme of classification based on palaeontological data, why cling to one based on lithological characters? The artificial divisions advocated by Mr. Arber were objectionable for the following reasons:—(1) There was no actual break in the succession or sequence of the Carboniferous rocks: and (2) no palaeobotanical line of demarcation capable of being mapped had been pointed out in any of our coal-fields.

With regard to the actual zoning by fossil plants indicated by Mr. Arber, the limits were somewhat nebulous, and it seemed to him (Mr. Stobbs) to be almost as easy by other criteria to recognize single beds, as the scientific compartments devised by palaeobotanists. Further, it was necessary that the zones should be numerous enough to ensure the identification of coal-seams in more than one district; for, it must be remembered that palaeontology dealing
with other organisms than paleobotany had already achieved this. It was more than doubtful if fossil plants

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could ever be relied upon for work of such exactness, although it might well be that certain broad divisions might be taken, which, as a whole, might materially promote more exhaustive zoning by other life-forms.

The inferiority of plant-remains for the object in consideration seemed to arise from: —(1) The difficulty in determining the species with accuracy. Sir R. I. Murchison related how Mr. Robert Brown, the botanist, would never name the "genus," much less the "species," of a fossil plant. (2) The fact of their presence in a stratum being no evidence of the condition under which the bed was deposited. He (Mr. Stobbs) had carefully worked ten different marine beds in the North Staffordshire coal-field and had found plant-remains in every one of them, and obviously the plants would not indicate marine conditions. In his opinion, the time was not ripe for zoning by fossil plants (as evidenced by the breadth of those zones specified by Mr. Arber) nor would it be, till one typical coal-field had been exhaustively worked. In the interests of the science of the Coal-measures, it was to be hoped that specialists would desist from framing classifications which had no regard to the evidence afforded by branches of knowledge other than their own.

The Rev. J. F. Blake (London) wrote that he recognized the great interest and truth of Mr. Arber's paper, and believed that on the principles laid down certain zones could be indicated. In comparison with the indications by animal-remains it had been claimed that plants are superior as zonal indices. Thus, Mr. R. Kidston* had stated that at the Hamstead colliery, Great Barr, near Birmingham, some strata which had been classed as Permian, were found to contain animal fossils which would refer them to Lower Coal-measures, but the plant-remains shewed them to be Upper Coal-measures, which was much nearer the mark. Plants, however, are much more dependent on climate, and this might be the main cause of any difference between them. We learnt that Lower Coal-measures, as determined by the plants characterized Scotland, transition-zones the North of England, Middle Coal-measures the Midlands, Upper Coal-measures the South of England, and still higher measures the coal-fields of France. This zoning by latitude seemed significant. All these


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floras might be coexistent, and they were not entirely distinct; thus only the hardiest reached the northern coal-fields while the tenderer for climate (but more prolific), flourished in the south, and as the climate became warmer the latter gradually reached a little farther northward, so as to characterize the upper part of the Coal-measures there, and so we got the sequence. But it was not like the zones of the Chalk or the Lias—where the occurrence of any one zone led one to expect all the lower zones beneath it. If the flora of the Upper Coal-measures was found in any sinking we could not, speaking generally, assume that the Middle and Lower Coal-measure floras and their corresponding coals would follow at a lower
level, but only if such coals were known to occur in the district. The recognition of the zonal character of a flora might assist in the extension of a known coal-held, but it would not determine the value of a new one.

Prof. E. Zeiller (Paris, France) wrote that he heartily congratulated Mr. Newell Arber on having so clearly summarized the characters of the flora of the different stages of the Coal-measures. He hoped that those, to whose lot it fell to work mines, would increasingly appreciate the interest of palaeobotanical investigations and the practical advantages to be derived from these in determining the relative ages of the workable coal-groups. Already well nigh half a century had passed since the late Prof. H. B. Geinitz had shown the variations in the flora of the Saxon Coal-measures on passing from one horizon to the next: but the distinctions pointed out by the learned professor were hardly susceptible of generalization, as the Saxon measures comprised only a limited portion of the Carboniferous series. It was not until 1877 that Mr. Grand'Eury indicated with precision the successive modifications undergone by the flora during the Carboniferous period, and the characteristics exhibited by it at each successive stage. The conclusions at which he arrived were, moreover, confirmed by the researches carried on at about the same time by other geologists, such as Messrs. Weiss, Stur and Lesquereux, and the present writer. If the Carboniferous formation be regarded as a whole, three great divisions may be distinguished therein, each so sharply characterized by its flora, that it is sufficient

To identify a few species from one or the other in order to assign to it the particular deposit which one may be investigating.

The first of these divisions, starting from the base, is the Lower Carboniferous or Lower Coal-measures, or Culm stage, with which may be correlated the Lower Carboniferous of Great Britain, especially characterized (as Mr. Arber observes) by a Group of species of the genera Adiantites, Rhaeopteris, Cardiopteris, Rhodea, Diplodema, Archaeocalamites, and by certain particular forms of Lepidodendron. Above this come the Middle Coal-measures, or Westphalian, to which belong the greater portion of the deposits included in the great coal-bearing belt that stretches across Europe from England to Russia, comprizing the Upper Carboniferous of Great Britain, the Franco-Belgian coal-fields, and the Westphalian and Silesian coal-fields. The flora of these is characterized by species of the genera Sphenopteris, Mariopteris, Alethopteris, Lonchopteris, Neuropteris, Sphenophyllum, and by the abundance of ribbed Sigillaria. The topmost division, Upper Coal-measures, or Stephanian, (unrepresented, as it would seem, in England) more especially includes the coal-fields of Central and Southern France, the highest zone of the Saar coal-field, the uppermost horizons of Saxony, etc. The predominant forms are ferns or Cycadofilicinaceae of the genera Pecopteris, Callipteridium, and Odontopteris, ribless Sigillariae, and Cordaites. Thence we pass, without observing any notable variations of flora, up to the Permian, which is characterized, however, by certain special generic or specific types, such as Callipteris, Taeniopteris and Walchia. If we enter into details, and endeavour in each of these great divisions to distinguish subsidiary divisions by means of their respective floras, it becomes necessary to compare a greater number of specimens, and to determine with precision the specific forms represented among
them. Mr. Newell Arber has indicated, in a few words, the characteristics which differentiate the several stages, from the Lower Coal-measures up to the Upper Coal-measures, in which latter the species of the Stephanian flora begin to appear in fairly large number, though still associated with a considerable proportion of Westphalian forms. Variations of much the same order allow us (as Mr. Grand'Eury had shown) to distinguish a series of groups in the

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Stephanian formation, the lowermost beds of which still contain a few species of the Westphalian flora, the Cordaitaeae dominating towards the middle, while the uppermost beds characterized by the abundance and variety of ferns, and by the incoming of some forms which are destined to prevail in the Permian.

It may not be altogether uninteresting to remind the members that on more than one occasion have palaeobotanical investigations led to practical results of real importance, from the point of view of the working of mines. Thus, for instance at La Grand'Combe, in the Gard, Mr. Grand'Eury and the present writer were enabled to recognize as being of manifestly distinct ages two groups of measures separated by a fault: these were originally thought to belong to the same horizon, but, after palaeobotanical studies had revealed the unconformity of their age, a boring was put down below the younger group and struck at a depth of about 2,460 feet the seams of the older group.* Conversely, the present writer was enabled to determine as contemporary, and as belonging to one and the same group, the seams worked in different districts of the Graissessac collieries, and originally thought to be of different ages. In the Allier coal-field, moreover, the investigation of the flora had enabled Mr. Grand'Eury to assert that it was needful to look, at a greater depth than had been hitherto attempted so far, for the main seam of St. Eloi, thrown out by a fault: and the exploration-work carried out in accordance with his predictions revealed this seam at a depth of 951 feet, with a thickness of 45 feet of coal.

There is little doubt that in many cases the study of vegetable remains, if these be collected with the precautions recommended by Mr. Arber, will continue to render similarly useful service to the mining industry.

What lends particular importance to the characteristics which we have been considering is their remarkable constancy from one locality to another on the globe. The flora, which appears to have been then uniform all over the earth, at least up to about the end of the Westphalian age, underwent everywhere the same modifications in the same order of succession. Thus, in the United States and in Canada on the one hand,


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Asia Minor on the other, the same groups are found as in Europe, containing the same specific forms associated in a similar manner, with the sole exception of an extremely small number of types which appear to have been restricted to certain limited areas.

Without entering into minute detail, it may be permissible to remind the members that the palaeobotanical characteristics described by the present writer in 1888 as distinguishing the several stages of the North-of-France coal-field were subsequently observed by Mr. R. Kidston
in Great Britain and by Mr. Cremer in Westphalia, exactly as the present writer had noted them. It has thus been possible to correlate horizon by horizon the successive strata of these different coal-fields.* The lower and the middle zones of the Valenciennes coal-field correspond almost exactly to the Lower and Middle Coal-measures of England, while the upper zone may be assimilated to the Upper Transition series as defined by Mr. R. Kidston. On the other hand, the Upper Coal-measures of England are not represented in the North of France, but their equivalents occur in various other parts of Europe, as, for example, in the Saar coal-field, in the United States, and in the Heraclea coalfield in Asia Minor, forming there, as in England, the summit of the Westphalian formation.

So complete an agreement between the results obtained by different observers must induce confidence in the characteristics noted by them, as admitting of the precise determination of the particular horizon of the beds which form the subject of their investigations.

Prof. C. Grand'Eury (St. Etienne, France) wrote that he had read with extreme interest Mr. Newell Arber's paper on the results to which he had been led by the application of fossil-plants to the classification of the British Coal-measures; the determinations appeared to be absolutely accurate. The Edinburgh coal-field does indeed belong to the Culm; and the great English coal-fields correspond exactly to the Westphalian; while the


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Millstone Grit, which he (Prof. Grand'Eury) had seen near Manchester, is undoubtedly associated with the Middle Coal-measures. But in England the Stephanian is incomplete and between the Upper Coal-measures and the Permian there is a great gap, represented by the coal-fields of Central France.

A more detailed study of the species will most certainly lead to the subdivision of British groups into zones. He (Prof. Grand'Eury) doubted, for instance, whether Alethopteris Serlii ranges up into the Upper Coal-measures. In France it is replaced by Alethopteris Grandini, which is near to Serlii, and if Mr. Newell Arber desired, he would most willingly send him an example of the French species, in order that he might compare it with the British species.

Mr. E. A. Newell Arber, replying to the discussion, wrote that some of the points raised were of great interest, but that he could only attempt to reply briefly to a few of the objections which were urged in regard to the value of fossil-plants as zonal indices. In the first place, he wished to gratefully acknowledge the sympathy with the aims and objects of the paper expressed by several writers, and more especially by the Director of the Geological Survey of the United Kingdom.

In reply to Dr. Wheelton Hind's interesting remarks, he (Mr. Newell Arber) was glad to learn that, in zoning by means of mollusca, the aggregate of the fauna was regarded as important. Judging by the most recently published list of molluscan zones, to which a reference was given in the paper, this did not appear to be always the case. In more than one instance, the
occurrence of a single species, such as Anthracomya Phillipsii, seemed to be solely relied upon as marking a particular zone. With regard to field-work, there was no doubt that a great deal remained to be done, more perhaps than was in the power of those engaged in the subject at the present time: hence the appeal for local help which he had ventured to make in this paper. At the same time, a considerable number of British coal-fields had been most carefully examined and collected from by paleobotanists, who were constantly engaged in field-work of this nature. The results, which had been attained, had not all been placed on record as yet.

He (Mr. Newell Arber) was glad to see that Prof. Lebour had called attention to some of the difficulties of the subject, but he was far from agreeing; with the conclusion that the task was he was of an "almost hopeless nature. On the contrary, the application of the knowledge acquired in areas where the age of the beds was clear on stratigraphical grounds to other areas where their age was in dispute had given results which bore a distinct promise of successful application of the principles explained here. It was true that, in the past, paleobotany had suffered severely at the hands of those who had insisted on the identification of remains, often too fragmentary or too ill preserved for such a purpose. It was to this that the confusion in the synonymy to which Prof. Lebour referred was largely due.

The far higher standard of preservation and completeness of detail, which was nowadays demanded before identification is attempted, had tended to eliminate much of this confusion. The dictum of Robert Brown, quoted by Mr. J. T. Stobbs, was a wise one at the time, for the study of fossil-plants was then in a chaotic state. Within the last forty years, paleobotany had been raised to the dignity of a science, and the detailed knowledge which we possess of several Carboniferous types would no doubt astonish some who may not be familiar with the present position to which this branch of palaeontology had now attained. These facts alone had tended to remove many sources of error in identification.

He (Mr. Newell Arber) was inclined to agree with Mr. J. T. Stobbs that it might some day be necessary to put forward a scheme of zonal classification in terms of palaeobotanical evidence. As, however, the work was still in progress, and it was hoped that many further additions to our knowledge would be forthcoming, there seemed to be no immediate necessity for such a scheme at present. He (Mr. Newell Arber) was, however, unable to agree with Mr. Stobbs that the zones proposed here were invalid because an exact line could not in some cases be drawn between them. Just as there was usually no actual break in the sequence of Carboniferous rocks, so, in regard to the Coal-measures, there was no break in the flora, but merely a gradual change. This was one of the most interesting facts which had been revealed by the study of Carboniferous plants. In the neighbourhood of the hypothetical line between two Coal-measure zones, a mixture of types typical of the rocks above and

below occurred, which at least afforded some evidence as position of the bed, while there was a marked contrast h + the two floras on either side of the line at some little distance from it. Breaks in the flora did, however, occur for, (as has been shown here) there was a marked break between the flora of the Upper and Lower Carboniferous rocks. It might be also pointed
out that the number of zones proposed here was quite as numerous as those put forward on the evidence of the mollusca in the paper already referred to.

The question of the influence of climate which Mr. Blake raised was an interesting one, and one on which the evidence of fossil plants was not a little puzzling. Such evidence as was available rather pointed to the fact that local variations did not appreciably affect the flora. This was shown by the close identity of the flora in Upper Carboniferous times in Europe, North America, and in certain portions of Asia. Among Mesozoic plants, this uniformity was even more marked in several cases, many, if not the majority, of the species possessing an almost world-wide distribution.

He (Mr. Newell Arber) gladly welcomed the remarks of Prof. Grand'Eury, whose magnificent work on the palaeobotanical subdivisions of the French Carboniferous rocks was well known in this country. With regard to the occurrence of Alethopteris Serli in the English Upper Coal-measures, the author believed that all those who had worked at the flora of these beds were agreed that this species was very abundant in them, and far more so than at any other horizon in the British coal-fields. Possibly what was known as Upper Coal-measures in this country might not exactly correspond to the zone in which Alethopteris Grandini was common in France.

He (Mr. Newell Arber) also desired to express his thanks to Prof. Zeiller for his valuable and interesting remarks, which, coming from so high an authority on this subject, would have great influence in establishing confidence in the value of fossil-plants as zonal indices in this country.

The President (Sir Lindsay Wood, Bart.) moved a vote of thanks to Mr. Arber for his valuable paper.

Mr. M. Walton Brown seconded the resolution, which was cordially approved.

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DISCUSSION OF DR. F. SCHNIEWSIND'S PAPER ON "THE PRODUCTION OF ILLUMINATING-GAS FROM COKE-OVENS."

Dr. P. P.- Bedson (Newcastle-upon-Tyne) wrote that Dr. Schniewind's account of his experiments with Otto-Hoffmann bye-product coke-ovens should prove of great interest at the present juncture, when there is evidently a revived interest in the manufacturing of coke in retort-ovens. This paper contained, so far as he was aware, the most complete and exhaustive account of the different phases of the process of coking yet published. It dealt not alone with the quantity and composition of the coke produced, but gave also data as to the hourly variation in the composition and volume of the gas formed during the process of distillation; data not alone of interest from the insight afforded into the nature of the chemical changes involved, but of considerable practical importance as demonstrating at what period of coking the gas produced could with advantage be separated into a richer portion and a poorer portion, the latter to be used to supply heat for the distillation of the coal and the former to be employed as an illuminating-gas. This "surplus gas" might also be utilized in other ways: for example, as a power-gas.

The perusal of the paper and the study of the numerous experimental data were most assuredly convincing of the complete utilization of coal, which the carbonization in the bye-product oven made possible, and substantiated many of the advantages claimed for this mode
of treatment. Regarded simply from the point of view of coke-production, there was a distinct increase in the yield of coke, and that, as shown by the analysis, in the form of dry coke.

Most instructive was the examination into the heat-distribution in the products of distillation of the coal and the comparison which Dr. Schniewind instituted between the working of the bye-product coke-oven and the results of the practice in the distillation of coal in gas-retorts, which placed the efficiency of the bye-product oven in a most favourable light. Again it was shown that the proportion of the nitrogen of the coal obtained in the form of ammonium sulphate was higher than usual.


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As one who had always taken keen interest in the utilization of coal, he had read Dr. Schniewind's paper with very great profit, and he felt that the facts cited in it put the question of the bye-product oven outside the domain of mere theoretical advocacy, leaving a burden of considerable responsibility upon the practice of coking with an expenditure of some 30 to 35 per cent. of the heat-value of the coal. But then the use of raw coal in our domestic fires under boilers, etc., was responsible for a great waste of the heat-value of coal, and further for the production of the dust and smoke-laden pall which hovered over our large towns; a condition of affairs which would be greatly improved were smokeless fuels, such as coke and gas, more extensively employed.

DISCUSSION OF MR. T. ADAMSONS PAPER ON "WORKING A THICK COAL-SEAM IN BENGAL, INDIA."

Mr. Thomas Adamson (Giridih, India) wrote that the value of a system of working should be judged by the death-rate which it entailed; and for the last 12 years, there had not been a single death arising from the system described. The collieries land 600,000 tons of coal per annum, and the death-rate per 1,000 persons employed underground and aboveground was 0.38 and 0.23 for the years 1901 and 1902 respectively. The British record under the Coal-mines Regulation Act did not compare favourably with these figures, for in 1900 the death-rate was 1.30 per 1,000 persons employed. The overmen had all had experience of mining in Great Britain, and all labour was performed by natives. At least 90 per cent. of the coal in the seam was wrought, and this compared somewhat favourably with the instance given by Mr. J. B. Atkinson, of the Fifeshire seam, of which only 60 per cent. was worked.

The seam occurs in the Lower Coal-series of the Gondwana system of Permian age.

In the Joktiabad mine of the East Indian Railway Company, visited by Mr. R. R. Simpson, the seam is 17 feet thick, including a band of stone 2 feet. The lower portion of the seam (8 feet thick) up to the stone-band, is taken out in the


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first working over an area of 50 feet by 50 feet, about one-fourth of the area of a pillar, 100 feet square. The band of stone the and hupper and remaining 7 feet of coal are then dropped in the same way as the 13 feet of top-coal at the Komaljore mine.

Four chowdkars, or tell-tales, are left in an area of 100 feet square at the Joktiabad mine, while four are left in an area of 80 feet square at the Komaljore mine. Consequently, as stated. Mr Simpson, less coal was lost at the Joktiabad mine than as stated in his (Mr. Adamson's) paper at the Komaljore mine. The thickness of strata over the seam at the Joktiabad mine is 450 feet. There is a goaf standing now, measuring 400 feet by 250 feet, with nothing but chowkidars (tell-tales) left standing; these tell-tales are 10 feet square, and are spaced from 40 to 50 feet apart. The system of working, as stated by Mr. Kirkup, was introduced by Dr. Saise about 16 years ago, and, under Dr. Saise's superintendence, the working under varying conditions had perfected the system.

Mr. F. L. G. Simpson (Mohpani Mines, Central Provinces, India) wrote that the system of preparing the top-coal for dropping seems as perfect as it well could be, but the possibility of entering the goaf at all to cut up and fill the fallen pillar of coal evidently depends upon having a very exceptionally good roof such as that described by Mr. Adamson; and a description with sketches shewing the mode of attacking this block of fallen coal, and the method of timbering would be highly interesting, as this part of the operation does not seem to be so easily carried out as the preliminary drivings. With most roofs, and even with a good post-roof after a time, a heavy fall of top-stone seems pretty sure to follow the dropping of such an area of top-coal as that described, and this fallen stuff would probably fill up the spaces on the two sides farthest from the goaf, and from which the coal has to be again approached. The time required for getting at the dropped coal, in addition to the 24 hours during which the place is fenced off, would seem to give time for the main roof in many cases to fall, especially when, as mentioned by Mr. Kirkup, a goaf of any considerable size had been formed and the condition of the roof impaired. With the roof unsettled or partly fallen or damaged, as it appears likely in many cases to be in practice, it would seem highly impracticable to re-timber the goaf, especially where logs 21 feet high are to be built and trees 21 feet long set up, for as the filling and timbering advance into the goaf, the weighting of the roof is becoming more imminent. The very strong character of the roof, which is so great an advantage in allowing the dropped coal to be reached, has its disadvantages in not allowing it to fall when desired, and thus throwing extra weight on the pillars next to the goaf, and this would seem likely to destroy the chowkidars or tell-tales, if only 8 or 10 feet square and 21 feet high, almost as soon as they were formed, and would also prevent the nine small knobs or stooks from being reduced as much as required. One can hardly suppose that such conditions as the above could always be avoided, even with the splendid roof described at Komaljore colliery, and it would be useful to learn how they are met when encountered. It would be interesting to know the cost of timber, the cost of labour for setting and withdrawing same, and how many cutters and fillers can usually be engaged in clearing away the 40 feet square of dropped coal at one time: whether they go at it on the two entire sides of the block farthest from the goaf, or in what manner, and how long it takes to remove the 850 tons of coal which it contains. It would also be most useful to know whether trouble has been experienced with surface-water during the monsoons, as the great settlement experienced in wholly
removing thick seams will lead to the formation of lakes in the rainy season, which might be suddenly emptied into the workings by such a fall as that described by Mr. Adamson. An area of depression, about 600 feet square or over 8 acres, if 1 foot deep, would contain about 3,500,000 gallons of water, and with a rainfall amounting to say 6 inches in as many hours, such a lake would be collecting feeders at the rate of 5,000 gallons per minute. As to fires in the coal, it would be useful to know what happens when from any cause it has been found impossible to remove all the fallen coal.

At the Mohpani mines, the writer had worked out some 10 acres of coal in a seam 25 feet thick lying under a river-bed, with a cover of 60 to 100 feet of strong posts and shales, but not always a post-roof, next to the seam. This seam was worked on the bord-and-pillar system to the boundary, with the bords and headways first driven next the roof, 6 feet wide, and then cut right down to the thill at that width, leaving pillars 40 feet square with no idea of entirely removing them. Afterwards, however, finding it possible to remove them, the "brokens" were taken clean out by a system of modified longwall, taking three to four lifts one above the other, the first being next the thill and packing and following up. This packing was sent down from the surface, and hauled to the coal-face by a self-acting incline. All the lifts were packed, except the top one, and that only partly. This system formed three to four sets of faces in steps, with hewers about 10 feet apart along each face, and packing following within 10 or 15 feet; and the only limitation to the output was the rate at which the packing could be kept up. This system was profitable under the special circumstances of the case, as it gave perfect control of the settlement of the roof, and the coal could not have been removed below the river by any other method, but the cost of packing would in ordinary circumstances prohibit its adoption. The seam was inclined about 1 in 3, rising both eastward and westward from the bottom of the basin. The cost of packing, including working at the surface-quarry, filling into trams, sending down, tipping and filling into goaf underground, with supervision, etc., was 6 annas per ton; the cost of pit-timber, 3 annas per ton; the cost of timbering and drawing timber, 1 anna per ton; and the total cost amounted to 10 annas (10d.) per ton. The system of driving next the roof and then cutting down is not desirable, and in new seams at Mohpani mines of about the same thickness, the first workings are all driven in the bottom-coal next the thill.

The Komaljore system appears to be adapted only to special circumstances; and, to render the principle applicable to ordinary cases, the top coal would probably have to be dropped in smaller lifts, or really in vertical slices across the end of the pillar. The chatnies might be cut in such a position that the slice would drop close to the fast side, thus rendering it easier to get at, and enabling the coal to be filled without having to enter very far into the goaf for that purpose.

Mr. James Grundy (H.M. Inspector of Mines in India) wrote that members freely criticized the system of working before they had been able to fully understand it, and even went so far as state that it seemed very dangerous "and one which would
not be allowed by H.M. inspectors of mines in this district** and one of H. M. inspectors of mines endorsed this opinion. It was quite natural, when such opinions were expressed that he, who had been the only inspector of mines in India for several years, during which time he was cognizant of the working of this system, should ask himself whether he, and the colliery managers who were most closely concerned in this case were less careful of workmen’s lives and general safety than they were in some parts of Great Britain.

Let them now at once turn from surmise to facts, and these should settle the question. He (Mr. Grundy) was told by the officials that for a period of 12 years this system had been responsible for 70 per cent. of the total coal raised, and about 90 per cent. of the present output at this large colliery was worked by this system, yet there had not been a single death in this time that could in any way be attributed to this particular system of working. He (Mr. Grundy) did not mean to infer that they had such a remarkable colliery, etc., that no accidents had happened at it, because there had been 15 deaths during the past five years: still the brilliant record remained that there had been none attributable to the system of working under discussion.

To avoid wrong impressions, he would detail the causes of the 15 deaths above mentioned:—

On surface tram-line, 3; by runaway tubs, underground, 3; by falling from cage in shaft, 2; in a sinking shaft, 1; by a piece of coal falling down shaft, 1; by falls of roof: (a) Went into a goaf, immediately after the timber had been drawn, and a piece of roof-stone fell on him: this mine was worked on the old system; (b) a piece of coal fell from the side of a pillar worked on the old system; (c, d and e) a piece of roof-stone fell in a place worked on the old system of pillar working, 5; a total of 15 deaths.

Reference had also been made to the system of “leaving the little knobs to come down at random.”† He (Mr. Grundy) might state that the above degree of safety had not been brought about, and maintained for so long a time, by allowing anything to happen at random. It would not be easy to find anything that was allowed so to happen: and, on the other hand, the excellent results obtained might rather be attributed to the management having very earnestly endeavoured to understand

† Ibid., page 14.

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The nature and behaviour of the excellent sandstone-roof, and to deal with it as they believed to be best: and the same might be said of the coal.

Much was due to very careful supervision and inspection, both of which he (Mr. Grundy) believed to be fully equal to the best at any colliery in any district in Great Britain; also to to careful selection and training of the European overmen, the work and supervision that these men must carry out themselves, and the kinds of work that a native was not allowed to do; and finally the innumerable precautions to avoid accidents that were based on experience and forethought.

The description of the heavy fall of roof was very graphic: it did not, however, represent what usually took place, but rather an extraordinary occurrence. As to this matter, he (Mr. Grundy) was only speaking of the past, and would not surmise as to the future, any more than to hint
that as time went on the size of a standing area before a fall might be such as to give quite a new experience when it did happen to fall. In this respect he might also state that great reliance was placed on the chowdkars, "policemen," or "tell-tales." No one expected these comparatively small pillars to keep up the roof, but it was really wonderful how much of the tale they did tell to an observant official when the roof began to move and he wanted all the information that anything and everything could give him. The chowhikars were of value because:—They gave valuable and timely warning; the workpeople were then removed: when the chowkidar had done most of its duty the roof fell; but the value of the chowkidar did not cease until the fall was complete, and it did much to modify the suddenness and force of the fall.

Again, one or two systems of longwall were recommended. The section showed that the seam was 21 feet thick, with a strong sandstone-roof and floor. To work the seam safely, by any ordinary system of longwall, would require very thorough packing. Where was the packing-material to come from, and what company would go to the trouble and expense of packing when the coal could be worked so well and safely without it?

It would indeed be very interesting to have some particulars any colliery where so large a proportion of the total coal was extracted, the coal sent out of the mines in such good condition, with so few accidents, and at so small a cost.

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**DISCUSSION OF MR. S. J. POLLITZER'S PAPER ON “THE UNDERLAY TABLE”**

Mr. H. D. Hoskold (Buenos Aires) wrote that Mr. Pollitzer had produced a very ingenious and curious original invention, and, in his (Mr. Hoskold's) opinion, when speed was not a question and it was immaterial how much time was expended upon an underground survey, then no objection should be raised against the use of the underlay-table as an additional means for connecting an underground survey to the surface.

However, further investigations might enable Mr. Pollitzer to devise a second instrument, or apparatus, which could be used on, or parallel, to the underlay-table, and so command a much greater distance at each setting up of the instrument. If this could be done, the length measured (or hypothenusal line) would be a constant quantity, and, with a suitable clinometer, the vertical angle for each length could be measured and the perpendicular and base determined. This, however, was only a suggestion for the consideration of Mr. Pollitzer, and not intended to convey an adverse opinion against the underlay-table for the use for which its inventor intended it. It was to be hoped that he would be equally successful in his further efforts. This was an age of electric speed, as also of rigid competition in doing things; and, for these reasons, generally speaking, mine-surveyors would, naturally, select, such an instrument or instruments for their use as would not only ensure the greatest possible accuracy and speed, but offer the greatest facility in saving time and labour.

Mr. A. Lupton had correctly estimated the capabilities of the Hedley improved mine-surveying dial. We had, also, the Thornton dial-circumferentor, and more recently, the newly introduced Grubb-Davis miners' dial-circumferentor, each being constructed with a vertical semicircle capable of reading vertical angles to 90 degrees. These instruments were very useful and handy for surveying narrow inclined tortuous roads in mines. Undoubtedly the best and most speedy practice would be to use three low tripod-stands with these instruments, as indeed with all other classes.
The common, or plain Y theodolite, in its improved form, with


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divided circles of from 4 to 4 ½ inches in diameter, with a vertical semicircle reading 1 to 80 or 85 degrees and mounted upon a low stand, might be employed for such surveys as they were discussing with great advantage. The triangular levelling-frame, screwed to the tripod-head, and into which the three levelling-screws of the theodolite are locked, carries a small and convenient traversing or centreing apparatus, enabling the surveyor to move the theodolite in all directions for a certain distance, or until the vertical axis and plumb-line are in the same vertical plane as the station-point. There was nothing new in this traversing apparatus, as it was supplied with all the best instruments. If, however, the greatest possible accuracy were to be sought, then, for general mine-surveying, a small specially constructed and light transit-theodolite, with from 4 to 4 ½ inches circles, reading to either 30 or 20 seconds of arc would give satisfactory results. To render such an instrument capable of being employed for observing vertical angles from the nadir or perpendicular line to the zenith, he (Mr. Hoskold) had devised an improved form of adjustable prism-reflector attachment.

The experience of the writer (Mr. Hoskold) was that the connection of a surface line with an underground survey and made through an underlay-shaft, was one of the commonest and most facile operations to be found in the whole art of mine-surveying: and, further, it was beyond all doubt that the greatest accuracy and speed could be obtained by the proper use of a handy theodolite of moderate weight, although the roads to be surveyed might be tortuous and have a great dip such as those described by Mr. Pollitzer. More than 50 years ago, when he (Mr. Hoskold) occupied himself largely with mine-surveying operations under all conditions, and without possessing such facile appliances as now exist, he encountered no insuperable difficulty in completing such surveys satisfactorily. Some 25 years ago, when he made valuations of various calamine- and blende-mines situated in Picos de Europa, Spain, it became necessary to make an instrumental survey. The under lay-roads had all manner of zig-zag directions, and, in various places, dipped at high angles up to 80 degrees. The underlay-rock consisted of limestone and was very smooth in places; still, with great caution and a proper selection of places as stations of observation, the survey was closed in a satisfactory manner. At that time he possessed his angleometer mine-surveying instrument, represented in Figs. 15 and 16, illustrating his "Notes upon Ancient and Modern Surveying and Surveying-Instruments" and as the vertical circle attached to that instrument read vertical angles to 90 degrees, it was a matter of indifference what amount of dip underlay-roads in mines had.

The silver- and copper-mines of this country exist under conditions similar to those above mentioned, and it would be difficult to find mines with less facility for surveying operations; still when he (Mr. Hoskold) had occasion to commission the engineers of his official staff to make surface and underground surveys, and to connect the same through underlay-shafts all
obstacles were overcome. It was true that more labour, care and time were expended than in more ordinary cases.

If any survey, such as that described by Mr. Pollitzer, were to be made for the object of setting out and conducting the execution of some long and expensive drift or tunnel through solid rock from one or two points at the same time, no moderate amount of trouble and cost should be spared in order to ensure accurate results, and in order to guarantee this, it might sometimes be necessary to repeat the survey. If, therefore, wooden platforms were really required for the surveyor's use and to be fixed at various points in the underlay-road, the small comparative cost connected therewith certainly ought not to be considered. It was out of all reason to urge that such platforms could not be easily and properly fixed by the use of short blocks of wood and wedges, by means of which the platform could be secured to the sides of the roads or to the upright timbers, if any, as the case might be. Apart from the question of platforms, he (Mr. Hoskold) believed that no more difficulty would be experienced in setting up a theodolite tripod-stand upon a given inclined road, than would be attached to the tripod-stand used by Mr. Pollitzer with his underlay-table. No doubt it would be preferable to use a theodolite in such surveys, and in adopt wooden platforms to facilitate the work, and then it would be an easier matter to fix the tripod-stand in such a convenient position that the line of sight to a forward station would not be impeded by either of the legs of the stand.


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Mr Hoskold felt great pleasure in being able to endorse the sentiments expressed in the statement of Mr. Henry Jepson in reference to the connection of an underground survey with a surface survey,* and upon this question, Mr. Pollitzer had shown no good and sufficient reasons for preferring the uncertain plumb-line plan for such a connection as indicated, to the more precise, scientific and highly practical system associated with a properly-constructed optical instrument.

Upon this same point, Mr. Bennett H. Brough, had also fallen into a great mistake in his statement, "as the optical methods present serious difficulties." The theoretical opinion conveyed in that expression was certainly contrary to the evidence, as the successful practice of Messrs. Bourns, Beanlands, Liveing, Richards, Jepson, the writer and various other British and North American engineers proved.

However, it was true that, at the expenditure of much time, labour and inconvenience, and under certain particular conditions in comparatively shallow pits, the plumb-line mode had given fairly good results. But there was always much uncertainty and great risk attending it, when employed to give the direction of long tunnels to be driven from two points; and, for these reasons, the plan had been abandoned by men of great experience in favour of the surer system by such optical instruments as offered every advantage for this process.

The information offered to us in reference to the exploits of "Hero, of Alexandria, 2,000 years ago," would have been more acceptable and interesting if a footnote had been added giving a reliable authority in its support.

Referring to mistakes sometimes made in the use of surveying instruments, he (Mr. Hoskold) had frequently indicated that the accuracy of a horizontal angle might always be known before leaving a station by observing the supplementary angle, which, together with the angle itself
first observed should, theoretically speaking, make up an entire circle. But, as small imperceptible errors arose from incorrect setting up of the instrument, sighting, coarse divisions of the instrument, personal defects and booking, the sum of the two angles would, sometimes, be in excess or defect or 360 degrees. However, with a good instrument and proper manipulation, the differential error due to such defects should


never exceed the amount indicated by the smallest subdivision obtainable from the verniers. This method of observing was much to be recommended, because it proved the amount of accuracy obtained at each station, and also gave the surveyor the opportunity of making a correction for any error which might have occurred. There would, however, always exist a very small angle amount, which could not be read, no matter how finely the instrument and verniers might be divided, and this common error became an accumulated amount at the end of the survey; but it could not be known unless the survey finished at the point of commencement. In such a case it became a question of balancing the survey, or distributing the total error between the whole of the angles. It had, however, been stated that the errors likely to arise, in the manner indicated, were counterbalanced; but this could not happen, unless the length of the lines between the stations were equal, and the errors could, by some unknown influence or law, equalize themselves in plus and minus quantities.

In order to provide for observing short lengths of lines not commanded by the telescope, to which Mr. Pollitzer seemed to refer, he (Mr. Hoskold) placed two plain sights on the top of the telescope more than 40 years ago, and he always found it a great convenience for the object intended. The error mentioned by Mr. Pollitzer as having occurred in his survey, and derived from the use of his theodolite, must have been due to some inherent defects in the instrument itself: otherwise, with good manipulation, such errors ought not to have existed.

He (Mr. Hoskold) would like to know how Mr. Pollitzer obtained the horizontal and vertical angles by the use of his underlay-table in the tortuous underground-roads that he had described. If such necessary elements could not be so obtained, then it was to be inferred that it would be necessary to employ some other class of angle-measuring instrument.

Referring to a remark made in a former discussion upon Mr. Pollitzer's paper, it might be stated that various North American instruments, with a second or interchangeable auxiliary telescope, had been introduced from time to time. When the second telescope was required for use it was placed on the top of the permanent telescope, or attached to the side of the horizontal axis of a transit-theodolite, and in either position it was believed that sights could be taken down a perpendicular or inclined shaft. All these instruments might be considered to be of the same type, and in a recent American scientific publication discussing the Shattuck double-reflecting solar attachment, those transitis with auxiliary telescopes were referred to in the following terms:—"Every engineer knows of the extreme difficulty in carrying an accurate traverse-line up or down a shaft whose dip is greater than 50 to 60 degrees. Beyond this point, small instrumental
errors such as collimation, inequality in height of standards, errors in plate-levels, etc., become very exaggerated. By the use of the top or side telescope attached to an ordinary transit, some one or all of these errors—according to the method used—affect the work and cannot be eliminated or easily allowed for, throwing uncertainties about the results, not mentioning the great care required to avoid disturbing the adjustment of the attached telescope between stations, especially in narrow or crooked shafts."

Such was the dictum of a well-informed North American writer, from which we were led to infer that something better and more certain than a transit-theodolite with auxiliary telescope was really needed, or was already in existence, for sighting down perpendicular and inclined shafts and making a connection between underground and surface-surveys.

DISCUSSION OF PROF. A. RATEAU’S PAPER ON "THE UTILIZATION OF EXHAUST-STEAM BY THE COMBINED APPLICATION OF STEAM-ACCUMULATORS AND CONDENSING-TURBINES."

Mr. B. Woodworth (Baxterley) wrote that the system of utilization of exhaust-steam devised by Prof. A. Rateau was an extremely interesting development of the regeneration-principle applied to exhaust-steam: and if the variations necessary for free absorption and re-evaporation of intermittent exhaust-steam could be kept within the limits of 15 to 19 pounds of absolute pressure there was every prospect of a successful future for the system, if the actual costs of the apparatus and its working did not absorb all the profits of the working. It became specially applicable in the case of central condensing-plants for


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groups of engines (where the original motive power could deal with its own work without the aid of a vacuum) as it avoided the trouble from excessive cooling of the engine-cylinders etc. when not at work, and leakages of air at the joints to injure the vacuum, except for the few parts connecting the accumulator and turbines. All the other appliances were subject to pressure slightly above the atmosphere, and consequently shewed up any defects by leakage of steam; but if the vacuum power was required to help the original motors to do their work the system would not be applicable in such cases.

He (Mr. Woodworth) was not enough of a scientist to determine exactly the amount of material necessary to form an accumulator for absorbing and giving out the amount of heat that should be dealt with during intermittent working in the very short spaces of time allowed for these actions to take place; but if it was necessary to allow much surplus steam to escape, so as to avoid abnormal back pressure on the prime movers, or to use much live steam to assist the accumulator in working the turbine, he would doubt very much that the results would be profitable, and for continuously working engines he would hardly consider the system a profitable substitute for the ordinary low-pressure cylinder of the prime mover.

Prof. A. Rateau (Paris, France) wrote that the diagrams which were attached to his paper showed conclusively that the variations of pressure necessary for the absorption and regeneration of the steam could be restricted to 15 or 19 pounds per square inch, and to less
even than that, if the weight of the substances accumulating the heat were sufficiently increased.

The cost of installation of the accumulator-apparatus could not be regarded as high. Moreover he (Prof. Rateau) had recently found a means of dispensing with the cast-iron basins by using water alone for accumulating the steam. On an average, 3 or 4 tons of water would suffice to keep going an engine of 100 electric horsepower. The apparatus became then very inexpensive and very practical.

As Mr. B. Woodworth had very justly remarked, the most obvious application of the system was to the case of central condensation-plants, and it was precisely in a case of that kind that the first plant was erected, at the Bruay collieries. But

they should not run away with the idea that it was needful to allow the steam of the primary motors to escape at atmospheric pressure, in order to ensure the success of the system. The desired advantage was gained, even if the low-pressure turbine worked at a pressure inferior to that of the atmosphere. Thus, for instance, in a case where the steam would enter at an absolute pressure of half an atmosphere, and the condenser would yield a vacuum of 27 inches (an easily attainable vacuum), the turbine would still produce one electric horsepower at the poles of the dynamo for a steam-consumption of only 40 pounds per hour. For cases where the turbine would receive the exhaust-steam during a part only of its working time, and where consequently it must needs be supplied with live steam during a comparatively long interval, he (Prof. Rateau) had indicated in his paper a solution that would satisfy the most exacting conditions. This consisted in providing a turbine to work at high pressure and at low pressure simultaneously, in such wise that it could be supplied at one and the same time both with steam at high pressure (unrelieved by preliminary expansion) and with steam at low pressure. In this fashion, a plant was got together that could be erected no more expensively than an ordinary group of high-pressure piston-engines, and yet capable of utilizing under the most favourable conditions imaginable either high-pressure or low-pressure steam. Engines of this kind, of 300 electric horsepower, were now being built for a mining company, and several others were being designed for steel-works.

Mr. David Burns' paper on “The Gypsum of the Eden Valley” was read as follows: —

THE GYPSUM OF THE EDEN VALLEY.

By DAVID BURNS.

On the line of the Midland railway, for some miles south of Carlisle, there is a considerable industry in the manufacture of plaster-of-paris and allied cements, which has been steadily on the increase for a couple of generations. Turning to “Mines and Quarries: General Report and Statistics for 1901,” we find that the total output of gypsum in the United Kingdom in 1873 was 66,124 tons, while in 1901 it was 200,700 tons.* There is probably no better index of the wealth, comfort and refinement of a nation than the amount of gypsum that it consumes, seeing that it enters so largely into ornament and improved house-property. Of the above output in 1901, the Eden valley produced 20,055 tons, or over 13 per cent. of the whole. This
report adds the following note: “The principal gypsum-deposits worked in the United Kingdom are those of Cumberland, Nottinghamshire and Staffordshire, where the mineral occurs in irregular seams and in spheroidal and lenticular masses in the Keuper division of the Trias. The gypsum of Derbyshire and Westmorland occurs in rocks of the same age, whilst the seam worked in Sussex is considered to belong to the Purbeck Beds.”†

Gypsum is at present worked at five different points in the Eden valley, three of which are in Cumberland and two in Westmorland‡ (Fig. 1, Plate XV.). The northernmost is situated at Cocklakes, near Cumwhinton station, and is owned by Messrs. John Howe & Company. There are here extensive works for the manufacture of plaster-of-paris,

* Page 203.
† Page 202.
‡ The writer desires to express his thanks to the proprietors and managers of these works, for granting him every information and facility in their power. Especially is he indebted to the late Mr. Ch. J. Howe, who took the greatest interest in the investigation, and but for whose sudden death while this paper was in preparation it might have been more conclusive on some points still unsettled.

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parian and other cements. There are several abandoned quarries near the works, but now all the rock is raised from shafts.

The next mine, at Knothill, is nearly 2 miles south of Cocklakes, and is about due west of Cotehill station. It is owned by Messrs. Joseph Robinson & Company, Limited. There are here also extensive works, and, besides manufacturing plaster-of-paris, they make a fire-proof cement known as "Robinson cement." Here again the outcrop-rock had all gone, and mining had begun, but a steam-navvy has been introduced and removes the 50 feet of soft sandstone and marls, which overlie the bed of gypsum. In this way it is possible to obtain the whole of the rock, and this would not have been practicable in underground workings, owing to the very bad roof which covers the gypsum.

Each of these works is connected to the Midland railway by branch-lines. They are the largest works and the pioneer gypsum-mines of the Eden valley. Before the Midland railway was prolonged from Settle to Carlisle, the gypsum was carted into Carlisle, a distance of 5 to 7 miles, and manufactured there into plaster-of-paris. The first person to use gypsum from this district was an old woman who dug out pieces, baked it and sold it to her sister-cottagers to make geometrical patterns on their hearths and doorsteps.

The third mine is that of the Long Meg Plaster Company (named after a celebrated prehistoric circle close by), situated between the Lazonby and Little Salkeld stations. It is smaller and of more recent origin than the two works already mentioned. It is connected by a branch-line, worked by water-power, with the Midland railway, and is well equipped for the manufacture of
plaster-of-paris. Originally it was worked as a quarry, but as the rock dips slightly into the steep south-eastern bank of the Eden, it has had to be mined for many years.

The fourth mine is situated between Culgaith station on the Midland railway, and Temple Sowerby station on the Eden valley branch of the North-Eastern railway. It is owned by Mr. H. Boazman of Acorn Bank. There are no works here, the rock being sold as such, and carted to the station. This, like the others, was first worked as a quarry, but has boon for a long time worked as a mine.

The fifth mine* is near Kirkby Thore station on the Eden valley railway, and belongs to Messrs. Joseph Robinson & Company, Limited. There are no works here, and the stone is carted to the station. This deposit, like the others, has been followed from the outcrop, and is still worked as an open quarry. The overburden, of soft marls and clay, is in places as thick as 30 feet. It is removed with pick and shovel, with an occasional shot hauled in bogies by a steam-engine, and tipped on the spoil-bank.

There is only one other gypsum-mine worked in the North of England, and though it does not come within the scope of this paper, its position may be pointed out with respect to the others. It is situated close by the sea-shore, just under St. Bees Head, near Whitehaven.

When we remember that gypsum is a very soluble rock in ordinary rain-water, and that probably nearly every drop of water that comes down our rivers to the ocean carries its minute burden of gypsum and there leaves it, we can see that its distribution must be wide and its forms of deposit various and perplexing. We accordingly find gypsum in the old crystalline rocks and in the newest formations, in veins, in beds, in nodules and in crystals. In proportion to this perplexity do we find its treatment by recognized authorities unsatisfactory. Having hit on an explanation that accords with the features of one locality, they have generalized it, and it has been copied and repeated unthinkingly by book-makers all the world over.

The Eden-valley gypsum, however, has had special and original treatment. Mr. J. G. Goodchild, of H. M. Geological Survey, in the course of his survey-work was led into the Eden valley, and took a special interest in the gypsum-beds there. Among other writings on the subject he contributed a long and able paper to the Geologists' Association.† He there points out with truth that current theories are unsatisfactory, and then,

* A quarry.
along with much valuable information, proceeds to elaborate a theory of his own. Mr. Goodchild had noticed that the surface of the gypsum-bed had a very irregular hummocky form, and he explained the presence of the bed and its outline in the following manner: —

When the marls, in which the bed of gypsum lies, were deposited in shallow, inland seas, they carried a considerable proportion of gypsum which got deposited as crystals of selenite throughout the body of these marls, sometimes in greater quantity and sometimes lesser. At the horizon of the bottom of the present bed was a particularly strong layer of selenite. When surface-waters began to circulate they dissolved these crystals of selenite, and carried them down to the bottom-bed where the gypsum was deposited. In this way, the bed grew upwards, and vertically under the part where the marls were most loaded with crystals, the solid bed grew fastest and thickest. In short, the present thickness of the bed of gypsum at any point is the measure of the extent to which the marls over it were filled with selenite before the accumulation of that bed. Just as the hump of the growing dromedary rises against the pressure of the superincumbent atmosphere by the animal inhaling and appropriating part of it, so Mr. Goodchild supposes that the molecule of gypsum thrust up in some semi-vital way, the superincumbent rock to find room for itself upon its fellows. But it may be better to state Mr. Goodchild's views on this point in his own words:

From this phase of development it is often easy to trace further gradations, up to the point where nodular masses of various dimensions consist entirely of mixtures in variable proportions of selenite, satin-spar and granular gypsum – the clay at that point having been, it would seem, entirely extruded by the growth of the nodule. I have seen many such cases, especially in Staffordshire, and in both Westmorland and Cumberland, where large nodular masses of gypsum have steadily grown in situ, and have clearly extruded the clay whose position they now occupy. In such cases the original bedding of the marls can be distinctly traced through the nodules themselves, just as in the case of the nodular masses of ironstone, or of calcareous matter, concreted in many of our Carboniferous sandstones, or as the bedding of the Chalk can be traced through flint, or of the Carboniferous Limestone through chert, or, again, of the same limestone through pockets of haematite occurring in it in Cumberland and elsewhere. In each and all of these cases, gypsum, flint, haematite, it is clearly a case of replacement, only in that the case of the gypsum molecular change has played a less important part, mechanical forces have been at work equally with the chemical.*


The writer has no hesitation in saying that no feature of the marls is traceable into the gypsum of the main beds of the Eden valley, but such may possibly have been observed in tain gypsum-beds occurring over the principal bed, and presently to be noticed. Again:

In association with the nodular gypsum just described, one occasionally meets with deposits of a much more persistent character. These differ from the nodular deposits only in regard to their horizontal extension . . . . These have long been worked in open
quarries in the lower parts of the basin of the Eden between Appleby and Carlisle. A careful examination of these in the field teaches us that much the same mode of occurrence as that just described characterizes these deposits also. But, on the other hand, their stratiform features are often strongly marked, and it is difficult to believe that in these cases we are not dealing with a veritable stratum contemporaneous with the beds amongst which it now occurs. Still, there is present the same evidence of passage into nodular gypsum, which can be traced into fibrous gypsum, or into selenitic marls; and it is quite certain in many cases that the lamination seen in the gypsum can be traced into the marls, as in the other cases noted. And there is, again, abundant evidence of irregular upgrowth of the surface, as if the same kind of action that has been at work concreting the nodules had in this case simply united, or added on, gypsum that had been drained out of the clays above, to a pre-existing sheet or bed occurring below . . . This view will enable us to account satisfactorily for such of the marked irregularities of the upper surface of the gypsum as are not referable to the dissolving action of surface-waters . . . It will also serve to explain the strange contortions so commonly seen in clays overlying gypsum in deposits of all ages all the world over.*

It is scarcely necessary to add that on dynamical grounds this theory is quite untenable, and protracted study of these formations has quite satisfied the writer that it is not necessary. There has been no addition to the Eden-valley gypsum since it ceased to be a land-surface and became covered by the shales and marls, except the bed presently to be referred to, and it occurs in the marls, and there has been little loss, except along certain joints, and between the mass and the enclosing clay at the sides, and except, of course, where these beds have been swept away by denudation in common with the other beds of the district.

Nor is there any call for a special theory so far as the origin of this bed is concerned. It has been formed as the limestones of the Carboniferous period were formed, by the accumulation of calcareous organisms. Whether these lived in salt or fresh water there is probably no means of telling, as, so far as writer has been able to learn, every trace of organic structure is


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gone The white gypsum is in striking contrast to the red beds both above and below, and the gypsum must have been formed in some sea or lake from which the red water then prevailing was all but completely shut out. This would serve the double purpose of allowing the shells to thrive, and of keeping the gypsum pure. Near Whitehaven, there is a bed of pink gypsum, showing that molluscan life was possible with a certain small amount of iron in the water. A bed of calcareous matter having accumulated, as had so often happened before in the previous period, sulphuric acid was washed into it and converted it into a sulphate. Whether shells, lying at the bottom of a deep sea acidulated with sulphuric acid, would gradually become converted into a solid crystalline mass of gypsum without any other covering, the writer could not pretend to say, and possibly experiment may be necessary to settle that point, and certainly the evidence tends to this effect: but, under the one circumstance or the other, the bed became a great crystalline mass of sulphate of lime.

There is nothing new in this theory. Prof. James D. Dana says: —"There is a noted 'acid-spring' in Byron, Genesee County, New York . . . besides others in the town of Alabama. This
sulphuric acid acting on limestone (carbonate of lime) drives off its carbonic acid and makes sulphate of lime, or gypsum; and this is the true theory of its formation in New York.”

Sir Archibald Geikie states that gypsum may be formed “(2) through the decomposition of sulphides and the action of the resultant sulphuric acid upon limestone; (3) through the mutual decomposition of carbonate of lime and sulphates of iron, copper, magnesia, etc.; . . . (5) through the action of the sulphureous vapours and solutions of volcanic orifices upon limestone and calcareous rocks.”

Sir Charles Lyell says:

The crater of Taschem, at the eastern extremity of Java, contains a lake strongly impregnated with sulphuric acid, ¼ mile long, from which a river of acid-water issues, which supports no living creature, nor can fish live in the sea near its confluence. Near the volcano of Talaga Bodas, . . . sulphureous exhalations have killed tigers, birds, and innumerable insects.


The Pusanibio, or Vinegar river of Colombia, which rises at the foot of Purace . . . is strongly impregnated with sulphuric and muriatic acids, and with oxide of iron.*

It is probably more interesting than profitable to speculate on the source of the sulphuric acid that formed the gypsum of the Eden valley. It may have accompanied the Whin Sill when it spread among the limestones of the North-east of England if indeed that intrusion was not of later date; or if may have come from the overflow of the mineral veins of Alston Moor, which were still later, abounding as they do in sulphides-or it may have come from volcanic vents in the South of Scotland or elsewhere.

After the bed had become a compact crystalline mass, it became exposed to subaerial denudation, at any rate at its northern end, its present surface having been unequivocally a land, or at the lowest a littoral surface. At one time Messrs. John Howe & Company had ¼ acre of it exposed, and unwrought in their quarry at Coklakes, where this feature was seen beyond all dispute. Lines of little runnels were clearly visible across it, and its appearance was rather suggestive of the weathered surface of a fine-grained crystalline limestone in the bed of a river. Along one or two lines there had been some decay of gypsum since the overlying marls had been deposited, and the bottom-beds were there slightly broken; but, over most of the area, the surface of gypsum, exposed by the workmen, was the identical surface that had sunk below water-level, and had been covered up by dark mud followed by red shales and sandstones.

If this be the second time that the gypsum has been covered by strata since its accumulation as calcareous matter, it seems rather strange that the whole of the first covering has been swept away and a perishable rock like gypsum left to stand the brunt of the denuding forces. But, a solid bed of gypsum would be able to withstand force such as that of running water, or the waves of the sea or lake for a limited time, much better than loose marls such as overlie it now. Gypsum perishes more readily by chemical action than by mechanical abrasion. As it is,
the areas known and those remaining to be discovered are probably only isolated patches of what was a continuous bed that may have extended over a large area. Still, though


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the writer has made persistent inquiry, he has never seen nor has he had reliable verbal evidence from managers or foremen-quarrymen of gypsum having been worked up against a face of stratified marl. In every case that has come under his observation, he has found the rock cut off by Boulder-clay or valley-gravel. Were he to dogmatize on his limited field of observation, he would say that the bed had been continuous till Glacial times, but this is extremely unlikely. Undoubtedly, however, there has been a great sacrifice of gypsum by Glacial action. Mr. Howe thought, from the many borings that he had put down at Cocklakes, that he could trace a line of denudation, as if it had been the course of a river.

The gypsum-rock shows posts as limestone does, but the joint between the posts is sometimes so close that it takes the practised eye of the miner to detect it. The writer once saw on a beautiful face of rock in the Knothill quarry a faint contortion highly suggestive of lateral pressure, but such is not a common feature, although the contorted junction of posts in the Long Meg mine would sometimes bear such a construction.

Gypsum is a hydrated sulphate of lime, and consists of, in round numbers:—Calcium, 33 per cent.; sulphuric acid, 46 per cent.; and water of crystallization, 21 per cent. The rock is ground to a fine powder between millstones, and then placed in circular pans under which is a fire. In this way the water is "boiled" off the powdered rock, which is being continually agitated by stirrers. The water comes off in little puffs of steam, and has much of the appearance of a fluid boiling. The dehydrated powder is commercial plaster-of-paris.

A varying proportion of the rock is anhydrite,* and has the same chemical composition as commercial plaster-of-paris, but none of its other qualities. Anhydrite is much harder than gypsum, is harsher to the feel, and is at present of no commercial value. It usually occupies in some proportion the centre of the deposit, The prevailing idea is that the whole bed was at one time anhydrous and has gradually, through geological ages, been converted into gypsum, a process which is still going

* Called "cobble" by the miners, while gypsum is styled "rock."

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on. This conclusion is founded on the following observations: (1) Near the outcrop of the bed, where the circulation of water has been freer, the anhydrite entirely disappears, as it also does at the edges of the bed where it comes up against the clay; (2) following a deposit into the hill, in the centre of its breadth, as the cover increases so usually does the proportion of anhydrite; and (3) wherever a feeder of water has been found to traverse the bed, the rock has been found hydrated in that neighbourhood.

Were anhydrite a more perishable rock than gypsum, the above observations would be very convincing, but the opposite is to some extent the case, and one might with some consistency reason as follows:--
Before the bed was broken up by denudation, the parts that were pure gypsum got filled with swallow-holes, and this weakened those areas and all the beds that were over them, and hence they fell more readily than the anhydrite-areas to the ravages of denudation. The pure gypsum round the areas left is on the edges of the pure areas that have been removed. The reason why a feeder of water is in a particular position is because the absence of anhydrite allowed the water to cut its way through at this spot. We might even go further, and say that the whole mass was originally gypsum, but where it has had most cover and been kept driest and warmest the water of crystallization has been slowly passing off, as it does in the pan of the manufacturer.

Seeing that the bulk of the rock when gypsum, is about 33 per cent. more than when anhydrite, it is difficult to see how a ball of anhydrite, in the midst of gypsum, could be converted into gypsum without bursting the surrounding rock. The very different texture of the two rocks is another difficulty, but possibly both could be overcome by supposing that the balance of the anhydrite for which there was no room was carried away by the circulating water.

It is a pity that the anhydrite, of which there is a considerable quantity in the Eden-valley mines, cannot be turned to commercial account, containing, as it does, nearly 59 per cent. of sulphuric acid. Any sulphur or acid derived from this source would probably be chemically pure, and seeing that sulphur free from arsenic is a desideratum, there is here a problem worth the attention of inventive members.

Mr Goodchild states that "sulphate of lime precipitated from solution under a pressure of ten atmospheres falls as anhydrite." He does not state his authority, but if this be the case, it may have an important bearing on the presence of anhydrite in these beds. Almost universally in the Cocklakes district and to some extent in the others, in the top-post, the rock consists largely of crystals of gypsum, that seem to have crystallized out of a magma of the same substance, for these crystals lie among crystalline gypsum of nearly equal purity. Mr. Howe informed the writer that these crystals were about equally prevalent in the bottom-post, which also bore pieces of selenite as clear as glass. These imbedded crystals are occasionally met with in both the top and bottom posts of the quarry at Kirkby Thore. Now, clearly these external posts were newer anhydrite, and it might be that the top and bottom posts were first attacked by the sulphuric acid and converted into gypsum. Then the acid, eating its way in, either from pressure or heat, left anhydrite in the central posts instead of gypsum.

It is entirely a subject for the experimental chemist, and further speculation without experiment may not be of much value. The writer would say, in leaving the subject of anhydrite, that in his opinion the balance of evidence is to the following effect: (1) The top-post has always been gypsum, and the bottom-post has nearly always been the same; (2) the central posts, where now anhydrite, have always been anhydrite: and where now gypsum they have generally been gypsum: and (3) in exceptional cases, and to a moderate degree: by the free access of water and air, anhydrite has been converted into gypsum.

These deposits of gypsum are often spoken of as "lenticular." They certainly sometimes become a little thinner at the edges, owing to the greater decay there; but they are no more lenticular than any bed of pure and perishable limestone is that has decayed somewhat near its outcrop.

Fig. 2 (Plate XV.) shows how a bed of anhydrite was cut off sharply as it approached a feeder of water running from the top to the bottom of the gypsum-bed at Cocklakes. Fig. 3

(Plate XV.) shows that about 1 foot of the gypsum has washed away over an area of several square feet and red sandstone deposited in its place. Exactly over the point, where this wash dies out the overlying anhydrite thickens, about 2 feet on its lower margin.

The bed is usually over 20 feet thick, and it has been quarried at Cocklakes as much as 28 ½ feet thick, and probably the undenuded thickness in that district may be about 29 feet. It is dangerous drawing conclusions from isolated instances, and the total areas mined form but a very small proportion of the original deposit. But, judging from what the writer has been able to ascertain, the bed thins steadily from north to south, and scarcely attains 20 feet, when complete, at Kirkby Thore.

Some 3 feet over the top of the gypsum at Cocklakes comes a thin greenish bed some 2 inches thick. It is so constant throughout the Eden valley, where gypsum is known to exist below, as to challenge attention. The writer examined it under a microscope, and found that it consisted, seemingly, of the ordinary shale, mixed with a large number of minute crystals. He is indebted to his colleague at the time, Mr. McCreath, of Aspatria Agricultural College, for the following analysis: —

<table>
<thead>
<tr>
<th></th>
<th>Per cent.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water and other volatile ingredients</td>
<td>8.30</td>
</tr>
<tr>
<td>Oxide of iron</td>
<td>6.00</td>
</tr>
<tr>
<td>Alumina</td>
<td>32.50</td>
</tr>
<tr>
<td>Carbonate of lime</td>
<td>3.18</td>
</tr>
<tr>
<td>Sulphate of lime</td>
<td>7.88</td>
</tr>
<tr>
<td>Magnesia</td>
<td>3.06</td>
</tr>
<tr>
<td>Potash and soda</td>
<td>0.10</td>
</tr>
<tr>
<td>Insoluble silicate and sand</td>
<td>38.98</td>
</tr>
</tbody>
</table>

This analysis and the appearance under the microscope show that when the shale had been deposited up to this point, sufficient mineral waters invaded the area to cause a slight deposition of crystals of sulphate and carbonate of lime. The thinness and general uniformity of this bed throughout the area mined show a corresponding uniformity in the conditions when the shales were being deposited.

At one point in Knothill quarry, the section between the top of the ordinary gypsum-bed and the green bed is largely made up of impure gypsum, alternating with thin bands of shales, clearly the result of deposition. As far as can be seen, this

gypsum thins rapidly and only covers a small area of a few hundred square feet, and has not been considered of any commercial value.

In the Acorn Bank mine, however, this top bed has been recently found in a remarkable state of development. Along the face of the old quarry, the green bed can be seen at one or two places with its usual development. From the quarry face, the bottom rock was followed into the hill by an adit-level and worked for many years, but to the north it was found to pass largely into anhydrite. A new adit-level was, therefore, driven in such a position as to explore this
higher bed, which showed in places balls of gypsum. It was found to be about 10 feet above
the lower bed and to be about 6 feet thick. About 3 feet of the top of this bed is mixed with
impurities, and has been left and forms an excellent roof. This leaves from 3 to 5 feet of good
gypsum, which has been proved north and south, for a length of 600 feet. Part of this rock is
not distinguishable from the best of the rock in the main bed below, but much of it has a banded
appearance, shewing different shades of colour, which betrays its sedimentary origin. The
bottom post, about 1 foot thick, is in places an anhydrite, so that possibly the determining
conditions that have made gypsum here and anhydrite there have yet to be discovered.
The writer was confidently informed by Mr. Boazman and his mine-foreman that plant
impressions, described as "ferns," had been seen in the top layers of this bed: this is the first
intimation of fossil evidence of which the writer has heard.
There can be little doubt that the source of the gypsum of the upper bed was the decay of the
lower bed. The following table shows a comparison of the gypseous deposits at Cocklakes
and in parts of the workings at Knothill and Acorn Bank: —

<table>
<thead>
<tr>
<th>Cocklakes</th>
<th>Thickness, Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description of Strata</td>
<td></td>
</tr>
<tr>
<td>Green bed.</td>
<td></td>
</tr>
<tr>
<td>Dark brown shale</td>
<td>3</td>
</tr>
<tr>
<td>Extreme limit of good gypsum</td>
<td>29</td>
</tr>
<tr>
<td>Total</td>
<td>32</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Knothill</th>
<th>Thickness, Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description of Strata</td>
<td></td>
</tr>
<tr>
<td>Green bed.</td>
<td></td>
</tr>
<tr>
<td>Impure gypsum</td>
<td>2</td>
</tr>
<tr>
<td>Marls predominating</td>
<td>2</td>
</tr>
<tr>
<td>Gypsum predominating in thin layers</td>
<td>6</td>
</tr>
<tr>
<td>Probable amount of good gypsum</td>
<td>22</td>
</tr>
<tr>
<td>Total</td>
<td>32</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Acorn Bank</th>
<th>Thickness, Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description of Strata</td>
<td></td>
</tr>
<tr>
<td>Green bed.</td>
<td></td>
</tr>
<tr>
<td>Impure gypsum</td>
<td>2</td>
</tr>
<tr>
<td>Pure gypsum</td>
<td>4</td>
</tr>
<tr>
<td>Marls</td>
<td>10</td>
</tr>
<tr>
<td>Probable thickness of main bed under the good upper bed</td>
<td>16</td>
</tr>
<tr>
<td>Total</td>
<td>32</td>
</tr>
</tbody>
</table>

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Not only does the main bed thicken towards the north but it has been more exposed as a land-
surface and more wasted, and quite sufficient material has been taken from it to form all the
supplementary beds yet discovered. The distance from the bottom of the main bed to the
green bed is about constant. To explain the higher beds it would be necessary to suppose,
after the close of the formation of the main bed, that the gypseous area was divided into three groups:—

1. Areas that were raised above the water-level, and in which denudation was going on;
2. Areas into which the gypseous waters from the first areas drained and were evaporated, sometimes with an admixture of mud, as at Knothill, and sometimes without it as at Acorn Bank;
3. Areas into which muddy water from a distance flowed forming only shales and marls.

The boundaries of these areas have frequently changed so that an area that was marl-forming at one time became gypsum-forming later, and the reverse. But, for a brief period, when the green bed was being formed practically the same conditions obtained throughout the whole area, and water carrying sulphate of lime, carbonate of lime, magnesia and mud spread uniformly over most of the area, leaving a mail filled with crystals; and then the gypseous period came to an end for the time being. Further developments may reveal further local variations, but this in the main was the succession of events in the Eden valley.

Probably the impure gypsum that forms the roof in the present Acorn Bank mine is the result of the deposition of mud on the yet soft gypsum below, and the top of the main bed at Kirkby Thore seems to show the same conditions. This is quite different to the gypsum of extra purity found in the form of imbedded crystals at Cocklakes. The evidence seems to prove that in the Cocklakes district the waters of the acid sea were cut off and it gradually dried up: the uppermost 6 inches or so of the deposit being the result of the gypsum crystallising out of the in mother-liquor. When this liquor completely evaporated and the surface became dry land the surface of the gypsum assumed the weathered form now found.

This still leaves the crystals in the bottom bed at Cocklakes to be explained. These are similar to those in the top bed, but are generally smaller and lie more in horizontal bands. The very bottom is a mixture of gypsum and marl, very similar to the mixture in the roof of the mine at Acorn Bank. The ribs of satin-spar running into the red beds below, both at Cocklakes and Long Meg, have suggested to the writer a dried and sun-cracked surface invaded by gypseous waters. It may be as well, however, to suspend judgment on this point, but the following is conceivable:

1. The introduction of calcareous covered life into the area was at first very fragmentary.
2. When it had made moderate accumulations of calcareous matter, it was attacked and all but exterminated by an inrush of acid water, accompanied no doubt by some readjustment of levels, and this washed the dissolved sulphate of lime into areas hitherto dry and which now show masses of crystals.
3. The supply of acid water was then stopped and the invaded areas dried up, the cracks were filled with sulphate of lime and mixed the top layers of marl with it. Then after a time, when the final drying up was approaching, gypsum crystallized out of the mother-liquor as it did later when the top bed was forming.
4. Water again invaded the whole area, this time without acid, and shell life flourished uninterruptedly until the calcium of the whole bed had accumulated.

But what makes this thin line of discoloration more interesting is the fact that it rises and falls with the rise and fall of the solid gypsum below. This gives quite the appearance of the beds just above the gypsum having been thrust up by the prominences of the latter, and no doubt suggested to Mr. Goodchild his theory of their origin. But a careful study of the excellent freshly-cut section, some 40 feet high, which bounded the bared surface at Cocklakes, already referred to, made quite (dear the meaning of this peculiar phenomenon (Fig. 4, Plate XV.).
The first bed to be deposited on the billowy surface of the weathered gypsum was a rather dark shale. This filled up the hollows, first to the level of the prominences, and then spread evenly all across, and this went on till the green bed was formed. Then, either owing to the lapse of time, or by pressure, or by the area having become dry land or nearly so for a short time, which is quite consistent with the previous supposition as to the cause of the green bed, the black mud shrank. Where it was deepest it shrank most, namely, over the hollows; and where it was shallowest, over the prominences, it shrank least. In this way, the rises and falls in the surface of the gypsum were reproduced in a somewhat modified degree in the overlying green bed. By the time a thickness in the covers of less than 6 feet is reached all trace of the undulations is lost, and the strata run undisturbed, except at one or two points where there has been further decay of the gypsum along certain joints by circulating water since it was covered up, and the marls have fallen down a little.

The gypsum-bed is situated a short distance above the Penrith Sandstone, a red rock largely developed in the Eden valley Mr. Goodchild claims to have discovered signs of unconformity between the gypsum and the Penrith Sandstone, but the writer has never been able to detect any evidence of this. Indeed, into some of the cavities in the gypsum near the bottom of the bed at Cocklakes, sand had washed and had been formed into a sandstone identical in texture and colour with the Penrith Sandstone, showing as far as such evidence can be trusted, that after the gypsum had been accumulated and consolidated into crystalline rock, the Penrith Sandstone had not yet become strong enough to resist the attack of underground circulating waters, which carried it, particle by particle, into the vacant space in the gypsum. There is other evidence that sandstone is slower in consolidating than limestones. No sandstone of the texture of Penrith Sandstone is known to occur above the gypsum-bed. The quotation at the beginning of this paper places this gypsum-deposit in the Keuper division of the Trias and Mr. Goodchild appears to take the same view.* Without entering on that prolific source of discussion, the classification of strata, the writer would point out that in the Eden valley the continuity of the beds from the Penrith Sandstone (so-called Permian) to the top of the marls with the gypsum (so-called Trias) is most distinct and unbroken, and at the deposition of the gypsum-bed, which no doubt marked the greatest change in the physical condition of the district in the period embraced, there is not the slightest indication of an unconformity. It seems rather remarkable to the mere stratigraphical geologist to be told that in the middle of red and similar strata, without any break in

formed by the addition of sulphuric acid, and that the same bed may be dolomite in one area
and gypsum in another according to the chemical nature of the volcanic products that have
reached it. The 3.06 per cent. of magnesia, in the analysis* of the green bed, equal to the
carbonate of lime present, and to half of the sulphate of lime may be significant and would
represent the magnesia of about 14 per cent. of dolomite.

The following are analyses of Eden-valley gypsum, in each case from the main bed:—

<table>
<thead>
<tr>
<th></th>
<th>Acorn Bank I</th>
<th>Acorn Bank II</th>
<th>Cocklakes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphate of lime</td>
<td>79.09</td>
<td>78.57</td>
<td>78.88</td>
</tr>
<tr>
<td>Water of crystallization</td>
<td>20.85</td>
<td>21.032</td>
<td>20.77</td>
</tr>
<tr>
<td>Oxide of iron (Fe₂O₃)</td>
<td>--</td>
<td>0.11</td>
<td>--</td>
</tr>
<tr>
<td>Silica</td>
<td>0.06</td>
<td>--</td>
<td>0.35</td>
</tr>
</tbody>
</table>

Sulphate of lime
Water of crystallization
Oxide of iron (Fe₂O₃)
Silica

An analysis of the water from Cocklakes mine is as follows:—

<table>
<thead>
<tr>
<th></th>
<th>Grains per gallon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloride of potash (KCl)</td>
<td>3.13</td>
</tr>
<tr>
<td>Chloride of soda (NaCl)</td>
<td>1.79</td>
</tr>
<tr>
<td>Sulphate of lime (CaSO₄ 2 H₂O)</td>
<td>149.76</td>
</tr>
<tr>
<td>Carbonate of lime (CaCO₃)</td>
<td>7.96</td>
</tr>
<tr>
<td>Carbonate of magnesia (MgCO₃)</td>
<td>7.76</td>
</tr>
<tr>
<td>Silica (SiO₂)</td>
<td>0.18</td>
</tr>
</tbody>
</table>

It is desirable that the features of the Eden-valley deposit be briefly considered as compared
with those of Nottinghamshire and Derbyshire as set forth in the Transactions in an instructive
paper by Mr. A. T. Metcalfe.† Wash-holes are mentioned as being frequent in that district.
The writer has seen one in the

† Ibid., 1890, vol. xii., page 107.

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Cocklakes mine: it consisted of a round symmetrical chamber about 5 feet in diameter and
about 10 feet high to the top of a gothic roof. The roof and upper parts of the sides above
the level of the stagnant water were smooth and ribbed; the lower
parts of the wall were also smooth and covered with very fine mud that had been washed in:
and the middle part of the walls towards the surface of the water was covered with crystals of
selenite. The surface water getting in had dissolved the gypsum of the roof, and some of it
had been deposited as crystals against the walls possibly during periods of drought. There is
much satin-spar about the bottom part of the bed, and in the red beds just below, at the
Cocklakes and Long Meg mines, but that described by Mr. Metcalfe must be harder and finer grained. It does not occur above the main mass that the writer has seen.

Mr. Metcalfe says "The innumerable inosculations of minute veins of gypsum frequently bind beds of marl into extremely hard rock:" this is similar to what occurs at Acorn Bank on the upper bed of gypsum. He further refers to the "saddle back" formation over the balls in the marls and like Mr. Good-child ascribes it to the "increase in bulk of the concretionary mass below:" also that it has been suggested as due to the swelling of the mass by the passage of anhydrite into gypsum. He further notices that around these balls the marls are destitute of gypsum, while it mixes with the marls in the hollows. The late Mr. Howe pointed out to the writer that at Cocklakes on the top of the bed in the hollows there was a scale of gypseous marls, whereas the prominences were smooth and polished and made a clean contact with the shale. The conditions in Nottinghamshire seem, therefore, to be very similar to what they are at Cocklakes. The writer's view is that in each case probably, and certainly at Cocklakes, the prominences have still been exposed and weathering, while muddy and gypseous water invaded at intervals the depressions and then formed by evaporation the hard scale. The ordinary alternation of rain and dry weather would be sufficient to accomplish this.

The writer is not aware that any of the gypsum of the north has ever been sold as "alabaster" for statuary purposes, but sometimes the workmen in their leisure time make very pretty little objects such as letter weights and the like. Mr. Metcalfe


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adds:--"apparently there are no grounds for believing that the gypsum deposit of Nottinghamshire and Derbyshire are in any way whatever connected with volcanic agencies."* He adopts the evaporation and precipitation theory.

The writer is indebted to Prof. Lebour for the following abstract of Prof. Ochsenius's views brought forward in 1885, and since, owing to the high reputation of that chemist, held in great esteem by geologists. According to Prof. Ochsenius, the conditions essential to the formation of a natural salt pan, like those of the Caspian Sea, are:— (1) The presence of a shallowing or "barrage" which impedes without completely interrupting the communication between the sea and the concentration basin; then (2) a climate dry enough for active evaporation, whilst the basin can receive but a feeble proportion of fresh water. In these circumstances the water which flows into the basin is heated and evaporates in part. What is left becomes more dense, falls to the bottom, and determines little by little the death of organisms or the departure of such of them as can pass the bar. Deposition of gypsum begins when the percentage of salt is quintupled and salt itself is precipitated when its proportion, multiplied eleven times, has raised the density of the water to 1.22. Above the deposit of salt floats a mother-liquor in which are present, in ascending order, sulphate of magnesia, chloride of potassium, chloride of magnesium, borates, bromides, salts of lithium and compounds of iodine. When the density of this liquor permits it to surmount the force of the current flowing into the basin, the dissolved salts overflow into the sea over the bar, just touching its crest, whilst above them the sea-water continues to arrive in the contrary direction. But the latter on mixing with the saline liquor, abandons its sulphate of lime, which, in traversing the salts of the liquor in the act of precipitation, becomes anhydrous and tends to form a cap of anhydrite above the sea-salt already precipitated.
If at this moment communication with the sea becomes interrupted by a rise of the bar, the mother-liquor evaporates in place, attacks the anhydrite while forming palyhalite and may afterwards give rise to an entire series of deliquescent salts, such as are observed in Germany in the Stassfurt deposit. Moreover,


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the destruction of all organic life in the basin and on it renders much easier the carriage of the solid materials from the sides. Thus are explained the layers of mud which alternate with the salt and which will, later on, thanks to their imperviousness, assure its conservation. This explains very well certain alternations of gypsum, common salt and other complex chemicals, discovered in other districts, but it is no explanation of the simple deposit in the Eden valley. If Prof. Ochsenius could show why in New Red Sandstone times the whole ocean was rilled with "barrages" and divided up into bays with nicely adjusted bars, without wind or tide, thus allowing the double current to play for long ages, the theory would be worthy of being seriously entertained, and there may be beds here and there which have been actually formed in the way described; but it really affords no satisfactory explanation of the carbonate of limestone of the Carboniferous period almost entirely disappearing, while in its place came sulphate of lime and magnesian limestone.

In conclusion, the writer is of opinion that there was a great influx from the volcanic districts of Permian age into certain basins in which had flourished the lime-accumulating life of the Carboniferous period. This nearly killed off these species and converted their carbonate-of-calcium stores into sulphate of lime; and the principal gypsum-bed of the Eden valley represents this product. This bed being perishable in itself and poorly protected by weak marls was to a great extent swept away. Gypsum is easily attacked, but it is not easily removed. Hard granites may be transformed into sandstones, arenaceous shales and kaolin, but gypsum remains gypsum and sooner or later forms a bed elsewhere. Much of this waste was carried into small basins to form the higher beds of gypsum in the red rocks, sometimes purer than the original bed; and other portions of it were carried into the ocean and deposited by evaporation as alternations with common salt and it may be other chemical precipitates.

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Mr. W. Watkyn Thomas said that he did not attempt to have a grasp of the paper, which was on a very complicated and difficult subject, but there were one or two points which (it occurred to him) might be cleared up by the writer of the paper, or by some other speaker. With regard to crystallization, in some measure it seemed to him possible to look upon that as confirmatory of Mr. Goodchild's position, in which the writer of the paper did not concur. Mr. Goodchild treated the deposition of gypsum as due to the wasting away of the upper marls. Mr. Burns had not, he thought, said anything which clearly proved that the marls might not have lost the crystals which went to form the gypsum below. With a great deposit of gypsum, a. great [431]

[Plate XV.:-- Maps and sections to illustrate Mr. Burns' Paper on "The Gypsum of the Eden Valley." ]
feeding stratum above would be required, and he did not know whether Mr. Goodchild's theory dealt with that point.

As to the difference of origin between gypsum and anhydrite, and the supposed flow of water through the anhydrite to bring about the hydration of the gypsum, might not that be due to the anhydrite lying more or less along the middle horizon of the gypsum-deposit? Might not the occurrence of anhydrite (the absence of water of crystallization making it so) be due to the fact that the greatest crystallizing-activity took place along the central line of the deposit, and so eliminated the water? It seemed to him difficult to conceive that a flow of water through the central bed of gypsum or anhydrite should cause the rest of it to become hydrated. It appeared to him that the anhydrite had been more probably gypsum to start with, and that the water of crystallization had been driven towards the top and bottom of the gypsum-deposit.

Mr. D. A. Louis (London) said that it was not necessary to attribute a volcanic origin to the sulphur in deposits of gypsum. The immense deposits in the neighbourhood of Paris were obviously deposited from sea-water and a similar occurrence was taking place at the present day in Karabugaz bay on the eastern side of the Caspian Sea. This bay was connected to the Caspian Sea by a very narrow channel, so that in the dry season the loss of water by evaporation greatly exceeded the supply of water; consequently, concentration ensued, and a considerable deposition of the salts from solution took place.

Prof. Henry Louis (Newcastle-upon-Tyne) said that it was only fair to the writer of the paper to point out that it was well ascertained that there were two very different ways in which gypsum could be formed. A typical deposit of the one kind was found at Stassfurt, which had certainly been formed by evaporation. He had, on the other hand, seen several gypsum deposits, which, had as certainly been formed by the action of sulphuric acid. He pointed this out in 1878, when he examined some extensive deposits in Nova Scotia, and he based his argument on the fact that the gypsum, in certain places, enclosed small crystals of sulphur. Another important point was that a number of rare borates occurred; and he thought that the occurrence of boric acid was a crucial test as to this method of formation. In Almeria, in the south of Spain, also, there was a similar occurrence covering many square miles, and these two were typical instances which showed that Mr. Burns' theory was, at any rate, possible. The possible hydration or dehydration was not a matter of difficulty.

Mr. D. A. Louis (London) said that the chemical method of formation, volcanic or otherwise, was well-known, but he had not seen any very large deposits of chemically-formed gypsum. In volcanic districts, it was plain that the gypsum formed there was due to chemical action, but then it occurred only in local bunches. The Paris beds were very extensive, and undoubtedly they were formed by evaporation.

Mr. D. Burns said that in his paper he spoke only of the formation of gypsum in the Eden valley. There are two principal ways in which gypsum could have been formed in any position in which it was now found, and most theories were refinements or modifications of one of these. The first was the deposition from sea-water of gypsum that had been leached out of the land by rain-water, or had been dissolved off some pre-existing beds of gypsum. The other was the formation of gypsum out of other material, and the only substances out of which it
could be formed were carbonate of lime and sulphuric acid. The former was the method by which it was renewed and redistributed, but the latter was the means by which its amount had been added to. No one surely would doubt that there was a great addition to the stock of gypsum all the world over in New Red Sandstone times, and to suppose that the shell life that had been so abundant, and had built up such thick limestones in Carboniferous times still lived on, and formed the calcareous basis of the beds of Magnesian Limestone and

[gypsum of the earlier Red Beds, and that magnesian salts and sulphuric acid were in a peculiar degree products of that particular phase of volcanic activity which characterised Permian times, is the most natural and direct way of accounting for what we now find. The onus of proof lies with those who would base the theory of the origin of a world-wide deposit on subtle laboratory experiments or the discovery of crystals of selenite or isomorphs of salt in the marls. It is easy to reason from anhydration to hydration or the reverse, and in his view the special conditions that gave rise to gypsum and anhydrite respectively formed the principal difficulty that remained and on which further discussion would lie valuable.

Prof. Gr. A. Lebour (Durham College of Science) wrote that Mr. Burns had brought forward, as he always did, a theory of great ingenuity. This theory depended, however, upon an assumption which few geologists would be willing to accept without much stronger evidence of its probable truth than Mr. Burns had offered in his paper. It was obvious that gypsum might result from the occurrence of sulphuric acid in the presence of limestone. It was quite another thing to say that great deposits of gypsum such as those of the Eden valley had been formed in this manner, especially since there were several other modes of gypsum-production known, some of which would seem, in the absence of proof to the contrary, to be more applicable to the cases in question than the one selected by Mr. Burns. There was, as he quoted from Prof. Dana, "a noted 'acid spring' in Byron, Genesee County, New York," but there was no such spring in the region under consideration, nor was there anything to show that anything of the kind ever existed there. In fact Mr. Burns had still to show that "the sulphuric acid that," he says, "formed the gypsum of the Eden valley" was at the proper time available in that part of England. He suggested that this acid "may have accompanied the Whin Sill," but beyond the fact that it must be later than a portion of the Lower Carboniferous series, the age of the Whin Sill was, and must in all likelihood remain, unknown. It might be of much earlier date than the gypsum-bearing beds of Cumberland and Westmorland. The sulphides of the Alston Moor veins and volcanic vents in

the South of Scotland "or elsewhere" were mentioned by him as possible sources of the acid necessary for his theory. The first of these possible sources could only be seriously considered after the age of the infilling of the Alston veins had been proved. There were certainly Permian volcanoes in Ayrshire, Nithsdale and Annandale, and their aid might possibly be invoked in accounting for gypsum-deposits in or near their immediate neighbourhood, if there were any. To look to them for explanations of the Vale of Eden beds of gypsum could scarcely be seriously proposed. If the Whin Sill injection was accompanied by the occurrence of sulphuric acid, and if the action of this acid on limestone were such as Mr. Burns supposed, where were the huge gypsum-masses which there must have been such ample opportunities of producing
from the Carboniferous Limestone strata traversed by the Whin Sill? Also, where were the similarly easily-formed masses in the vicinity of the Alston metalliferous veins? It came to this, that where there was some slight evidence (though no proof) of possible acid-emanations of adequate magnitude, gypsum in large masses was unaccountably absent. It was, however, as Mr. Burns well showed in that valuable portion of his paper which dealt with actual observed facts, present in considerable quantities among those red sandstones and marls (the natural home of gypsum, anhydrite and salt all over the world) which, in the North-west of England, yield no tittle of evidence of such conditions as might favour the production of sulphuric-acid springs and the like.

Mr. Philip Allan (Carlisle) wrote that there were many features connected with the deposits of the Eden valley requiring further study and investigation. Among these might perhaps be mentioned the beds of anhydrite (or "cobble" as it was locally called) found associated with the gypsum. It was not an uncommon occurrence for two separate and distinct beds or anhydrite to extend throughout the greater area of the deposit. On the underside of these beds of anhydrite, there was generally a distinct parting between the gypsum, while on the top side the gypsum and anhydrite was somewhat grown together. Between the two bottom beds of gypsum, there was also a very distinct division. Fig. 5 (Plate XV.) might perhaps more fully explain the occurrence. It would appear, therefore, that the gypsum had been deposited in Layers, and that alternate changes had taken place in the calcareous matter as (lie gypsum was being formed. On the other hand, the anhydrite was sometimes found in rolls or balls, enveloped entirely in gypsum, with no distinguishing division whatever.

Mr. David Burns (Carlisle), replying to the discussion, wrote that it was possibly an indiscretion, indulged in with evident hesitation, to refer to the Whin Sill and Alston veins as the source of the sulphuric acid, which formed the gypsum of the Eden valley. If they were such, it was merely because they were local phases of a world-wide outburst in late Permian times. But, taking the metalliferous veins, no one could deny that they had been filled with mineral matter that was largely a compound of sulphur and various metals. What was now left were the truncated remnants of the original veins as formed and filled; and the measure of the action of these sulphides on the limestone was the width of the veins in limestone as compared to what they were in other rocks, which was considerable. The limestones were probably not turned into gypsum, because a hot and dry sulphide had not the ability to perform this change. But when the upwelling stream overflowed at the surface, and came into contact with water and the air, free sulphuric acid would be formed, and this would change carbonate of lime into sulphate of lime, wherever it was washed, if it were a hundred miles away. Prof. Lebour was rather unreasonable in asking the writer to point out the exact "acid spring" from which any particular bed of gypsum had been formed. A geologist could seldom point out with any certainty the position of the land-area from which a particular bed of shale had been washed, or even the position of a volcano from which a bed of ash had, for a certainty, been scattered. Then how could it be expected that any one could point out, among perishable beds, the particular solfatara from which came some special supply of sulphuric acid? We are dealing, as had been pointed out, with the "natural home of gypsum all over the world," and it is sufficient that we can point to an equally wide-spread contemporaneous volcanic activity, which was competent to supply the necessary sulphur. Prof. Lebour knew of other modes of gypsum-production, but the writer did not know of any. As
pointed out, elsewhere, the evidence of re-distribution brought forward by several observers was no explanation whatever of how the "natural home of gypsum . . all over the world" was filled with that remarkable mineral.

He (Mr. Burns) agreed with Mr. P. Allan that there is much that is unsatisfactory in our knowledge of what has determined the relative distribution of gypsum and anhydrite; and his paper will have served a good purpose if it induced the managers of gypsum-mines to record accurately observed facts in this connection. Mr. Allan's sketch (Fig. 5, Plate XV.) shewed that there are distinct posts (usually about four) in the gypsum just as there is in a bed of limestone, and that the division between the anhydrite and the gypsum often follows the joints. But it does not always do so; and in one case, at least, in Cocklakes mine, observed by the late Mr. Howe and the writer, the junction-line between the gypsum and the anhydrite was as shewn in Fig. 6 (Plate XV.). As indicated by Mr. Allan, the rounded appearance of the masses of anhydrite is often suggestive of something of the nature of concretionary action.

The President (Sir Lindsay Wood, Bart.) moved a vote of thanks to Mr. Burns for his interesting paper.

Mr. T. E. Forster seconded the resolution, which was cordially approved.

Mr. J. Malcolm Maclaren's paper on "The Occurrence of Gold in Great Britain and Ireland" was read as follows:--*

* This paper was read at a General Meeting held on October 11th, 1902.
Strabo, writing about 19 A.D., and dealing with Britain's trade and relations with Rome, mentions gold and silver as occurring among its products.* Tacitus, in his biography of, his father-in-law, Agricola, relates that the latter in his oration to his soldiers before the battle at the foot of the Grampians, in 84 A.D., where Galgacus was defeated with great slaughter, heartened them in this wise: "Fert Britannia aurum et argenturn, et alia metalla, pretium victoriae."† On the other hand, Galgacus is reported to have indicated the inevitable issue of defeat, as servitude in the mines "Ibi tributa, et metalla, et cetera servientum poena." And as is shown by Diodorus Siculus (8 B.C) the Romans were indeed hard taskmasters. Again Glaucus in his speech (with indirect reference to Britain) says, "Neque sunti nobis arva, aut metalla, aut portus, quibus exercendis reservemur"‡ thereby inferring that all these were to be found in Britain. The elder Pliny (77 A.D.), states that gold (auraris metallis) was found in the stream-works (elutia), the stream of water washing out (eluens) black pebbles, a little varied with white, and of the same weight as the gold.† Caesar also, in his Commentaries, accuses the Britons of having assisted the Gauls with their treasures.

Of the early Roman gold-workings, there are no authentic remains; but it has generally been supposed that the old workings of Ogofau, near the village of Pumpsant, some 12 miles west of Llandovery, are evidences of Roman occupation and of their search for gold. The name Ogofau or Grogoafau is probably Ogofawr, which means a large cave or large disused workings. Ogo being a generic term for such old excavations.§ At this spot, the remains of Roman pottery, ornaments and baths have been found. Some of the ornaments are of gold, and are of considerable artistic merit. The workings are extensive, and have evidently been opened first along the cap of the lodes. When these open cuts became too deep, levels 170 feet long, 6 feet high, and 5 feet to 6 feet wide were driven through the country-rock to cut the lode. The upper level communicated with the opencast workings by a rise, and the lower and upper levels are similarly connected as shewn in plan and section (Figs. 2 and 3, Plate XVI.).ǁ The workings are in Lower Silurian rocks, which here dip slightly to the northward. The lodes are of quartz, and vary both in dip and strike. The quartz is massive and somewhat opaque, showing in places a tendency to form interpenetrating growths of crystals. The accompanying minerals are iron-pyrites, in cubes and pyritohedra, and a little galena. A while sericitic mica and inclusions of slate are not uncommon. The slates, when fine-grained,

* Book iv., cap. 279.
† Vita Agricola.
‡ Pliny, Historia Naturalis (Natural History, book xxxiv., cap. 47 to 49.
§ British Mining, by Mr. Robert Hunt, page 40.
are very dark and very fissile, and through them run occasional thin veins of greenish-blue serpentinous mineral.

Some idea of the primitive method of crushing employed is furnished by an interesting relic. Between the old workings and the entrance to Dolau Cothi is a rudely prismatic block of very coarse sandstone, the grains of which are not by any means well rounded. The block is now set up vertically on a small mound, and in the course of time local traditions have gathered round it furnishing miraculous explanations of its present shape. On each of the four longer sides is a depression, from 2 to 3 feet long and about 8 to 10 inches wide, caused by the successive formation of elliptical grooves, the minor axis of the ellipses being successively moved to a parallel position along the line of the major axis. The latter axis was probably about 15 inches, and the former about 9 inches, in length, and the grooves vary from 4 to 6 inches in depth. It is quite clear that the stone was used as an anvil or mortar on which the quartz from the adjacent workings was crushed. From the gradual shallowing of the depression to its edge, it would appear that the groovings were made by a suspended pestle or block of stone to which a compounded horizontal and vertical reciprocating motion had been given—something indeed akin to the old Australian dolly, where the heavy pestle is raised for the next blow by the spring of a bent pole. In this case, instead of the simple vertical motion given to the Australian machine, the motion was in all probability horizontal, the point of suspension being over the minor axis of the ellipse. The result certainly could not have been produced without the suspension of the pestle, for a single workman operating a heavy pestle by mere attrition would form a depression crescent-shaped in plan as he moved the stone to and fro. The crushing might indeed have been performed after the manner practised, even at the present time, in remote parts of the world, where two natives facing each other and seated astride a large stone alternately draw a large stone over a groove in the lower stone in which the material to be crushed is placed.

Pliny, though he gives the sequence of operations in gold-mining in Roman times, unfortunately supplies no details of the actual processes (quod efoesium est, tunditur, lavatur, uritur, molitur in farinam, ac pilis cuditur, which is mined, crushed, washed, burned, ground to powder and pounded with pestles).* It

* Pliny, Historia Naturalis.

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may be here noted that Pliny omits the final washing, which is necessary to separate the gold from the products of the oxidation of the pyrites and other concentrates produced by the initial washing process.

Gold was first noted at Ogofau in modern times by Sir W. Warington Smyth* and Dr. Percy, though Sir Roderick Murchison had some years previously, submitted the quartz to assay without result.†

The Gogofau veins were worked for a short time (during 1889 to 1891) by the South Wales Gold-mining Company, but the results were extremely discouraging, the total yield being 4 ozs. 19 dwts. The whole of the milling machinery has now been removed, leaving only a large heap of tailings to mark the scene of this company's operations.

England.

Cornwall. ---Of the production of gold in Cornwall and Devon in early times there are no records, but that from time to time the gold-mines of these counties were considered sufficiently remunerative to be worked is evidenced by the numerous writs and grants from
Henry III., and from his successors down to Elizabeth, to various grantees. With all these, however, not a single ounce of gold is recorded as having been obtained. In 1564, a patent or monopoly was granted to William Humphreys, Cornelius Devos, Daniel Hochstetter and Thomas Thurland, to seek for gold, silver and quicksilver in certain counties in England, Wales and Ireland within the Pale. This patent was confirmed and amplified by James I., and became the charter of the Mines Royal Company, which existed and claimed the right to all royal metals until after the middle of the nineteenth century. It does not appear, however, that their operations at any time met with any degree of success.

Notwithstanding the fact that gold in quantity has not been recorded from Cornwall, there is no doubt that the tin-streamers from time to time in the course of their work obtained small quantities. Indeed, Carew‡: says "Tynners doe, also, find little hoppes of gold among their owre. which they keep in quils, and

Sell to the goldsmithes oftentimes with little better gaine then Glaucus exchange."

In the early part of the last century, gold was obtained in small quantities at Ladock by Sir Christopher Hawkins. A specimen presented by him to the Royal Geological Society of Cornwall was enclosed in its quartz-matrix,* indicating, therefore, a local origin.

Native gold has been found in most of the Cornish tin-streams flowing to the south. Of these the Caron stream, at the head of Restronget creek in the Falmouth estuary, has perhaps yielded most abundantly. Small nuggets are not uncommon here. One specimen, found at Caron, is reported to have weighed more than 10 guineas, and was probably about 2 ounces in weight.

In 1753, certain tin-streamers in the parish of Creed, near Grampound, met with some grains of gold, and "in one stone, a vein of gold, as thick as a goose-quill was found." Shortly after, gold was discovered at Luny, in the parish of St. Ewe, in blue sandy slate. "Some of it," to use the miners' phrase, "was kerned about spar." Gold-ore is reported to have been worked in 1846, at Wheal Samson, in St. Teath, but little was obtained.† In 1852, gold was discovered in quartz-veins at Davidstowe, North Cornwall.‡

Borlase mentions that he had seen a nugget from the parish of Creed, near Grampound, weighing 15 dwts. 3 grains, which was then in the possession of Mr. Lemon, of Carclev. Gold was also found in the Crow Hill stream-works, at Trewada, at Kenwyn, and at Llanlivery, near Lostwithiel. In the Natural History Museum at South Kensington there is exhibited a small water-worn nugget from Wendron, near Helston. Gold is also reported from Cornwall in the matrix from a cross-course in Huel Sparnon, and in the gossan of the Nargiles mine.§ Mr. D. Forbesǁ records the presence of gold in the argentiferous tetrahedrite, chalcopyrite and galena of a lode at Bound's Cliff, near St. Teath.

The alluvial gold is generally found associated with stream-tin, and such gold as has been recovered has been obtained during the

† Siluria, page 450.
‡ Carew's Surrey of Cornwall, 1602, book i., page 7.

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course of streaming operations. Analysis of several grains of gold from St. Austell Moor, the largest of which was only 2.1 grains in weight, gave Mr. D. Forbes* the following result: -Gold, 90.12; silver, 9.05; and silica and iron, 0.83 per cent. The specific gravity of the gold was 15.62. Gold from Ladock was analysed by Mr. A. H. Church, showing it to be slightly finer in quality than the above:- Gold, 92.34; silver, 6.06; and silica, 1.6 per cent. The former specimen was worth about £3 16s. 6d. and the latter about £3 18s. 6d. per ounce.

Devon.— In this county the existence of gold has been known, or assumed, for many centuries. In the beginning of the nineteenth century, a miner named Wellington is reported to have found gold at Sheepstor, on South Dartmoor. At different times he brought to a silversmith at Plymouth quantities which in the aggregate were valued at about £40.†

The principal auriferous locality in Devon, is, however, at North Molton (Fig. 4, Plate XVI.). Here in 1852, the gossan-ores of the Britannia, and Poltimore mines were discovered to be payably auriferous. This discovery, coming immediately after the world-wide excitement and unrest caused by the discovery of the Californian diggings, attracted an extraordinary amount of interest. The first trial of the gossan yielded 26 ½ ounces from 20 tons of ore, and the average yield of further trials of 50 and 75 tons was 10 dwts. per ton. The gold was of very good quality, and was worth nearly £4 4s. per ounce. The total value of the gold produced from the Poltimore mines up to November 2nd, 1853, was £581 5s. 1d.‡

The North Molton copper-mines are situated in an area of Devonian rocks, some distance away from their contact at the surface with the overlying Carboniferous sandstones (Fig. 4, Plate XVI.). Both the Devonian and Carboniferous strata are very highly inclined, in many cases approximating to verticality, and the lodes appear to dip with the country-rock. The auriferous gossan-lode is from 4 to 10 feet wide, and dips to the north. There is considerable evidence of this mine having been worked, probably for copper, in very remote times. The auriferous gossan

† Transactions of the Royal Geological Society of Cornwall, vol. v., page 141.
‡ Mining Journal, 1853, page 690.

Is a friable ironstone highly mineralized, and containing copper. It is brown on the western side of the Mole and reddish on the eastern bank. The latter is reputed to be twice as valuable in auriferous content as the former (assaying 17 dwts. and 8 dwts. respectively).

The Britannia mine is ¾ mile north of the Poltimore. Gold was found there, in grains and small plates, by Mr. Flexman of South Molton, prior to 1822. It is also a gossan-ore, but more siliceous than the Poltimore.
These gossans arise from the decomposition of slightly auriferous metallic sulphides, mainly iron-pyrites. In a specimen from North Molton, in the Natural History Museum at South Kensington, small particles of gold are clearly visible in the brown and somewhat siliceous ironstone.

Cumberland.—In the tenth year of the reign of Elizabeth, after a famous lawsuit with the Earl of Northumberland, resumption was made by the Crown of the rich copper-mines at Goldscope, Newlands, Keswick, Cumberland (where gold was reported to have been first found in the reign of Henry III.). The mines were claimed in respect of the gold and silver which the copper-ore contained. For as set forth in that trial: —"Where the Oar, which is digged from any Mine doth not yield, according to the Rules of Art, so much Gold or Silver, as that the value thereof doth exceed the charge of Refining, and the loss of the baser Metal in which it is contained and from whence it is extracted, it is called a Poor Mine, but when the Oar doth yield such Gold or Silver as exceedeth the charge of Refining and loss of the Baser Metal, it is called a rich Oar, or a Mine Royal, this appertaining to the King by his Prerogative."**

Though these mines were resumed by the Crown, it would appear that it was rather on account of the argentiferous content than for any gold that they may have contained, for a writer of 1709† remarks "The ore got by the gin under level was so rich in silver that Queen Elizabeth sued for it, and recovered it from the Earl of Percy for a royal vein." The name Goldscope was formerly Gowd-scalp and would suggest the occurrence of gold at

* Plowden’s Reports, page 301.
† An Essay towards a Natural History of Westmorland and Cumberland, by — Robinson, London, 1709.

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that place. These mines were worked extensively by Germans introduced into this country, for their mining knowledge, by Elizabeth, who, according to Sir John Pettus* was moved to do so "from Her observation of the inartificialness of former Ages in this concern, which may be collected from Her sending for and employing so many Germans and other Foreiners (where Mines were plentiful and the Arts belonging to them) who might put us into the tract of managing ours, in finding and digging and in smelting and refining Metals."

Somerset.—Gold has been recorded from the Carboniferous Limestone near Bristol.† Messrs. W. W. Stoddart and Pass found appreciable quantities of both metals in the limestone at Wharton, near Clevedon. Analyses of the dried limestone gave:

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alumina (Al₂O₃)</td>
<td>0.8777</td>
</tr>
<tr>
<td>Ferric oxide (Fe₂O₃)</td>
<td>4.8000</td>
</tr>
<tr>
<td>Calcium carbonate (CaCO₃)</td>
<td>94.3000</td>
</tr>
<tr>
<td>Silica (SiO₂)</td>
<td>0.0200</td>
</tr>
<tr>
<td>Silver (Ag)</td>
<td>0.0023</td>
</tr>
<tr>
<td>Gold (Au)</td>
<td>traces</td>
</tr>
</tbody>
</table>

Mr. J. P. Merry, of Swansea, found in one sample 94 grains of silver and in another nearly 1 ounce of silver; while both contained 3 to 5 grains of gold per ton. In the absence of proof of
the absolute purity of the fluxes used (and especially of the litharge), these results must be received with some degree of caution.

Wales.

The auriferous veins of Merionethshire appear to have been discovered in 1843. There are three claimants for the honour of the discovery—Mr. Arthur Dean, who read a paper, reporting the existence of gold at Dol-y-frwynog, before the 1844 meeting of the British Association for the Advancement of Science;‡ Mr. James Harvey, owner of the Cwm Eisen mine: and Mr. Robert Roberts of Dolgelly, who claimed to have been cognizant of the existence of gold in 1836, and to have several years later pointed out the locality to Mr. Dean.§ The locality of the discovery, according to Mr. Roberts was Cwm Eisen. Mr. Roberts says:—"In the year

* Fodinae Regale*.
‡ Report of the British Association, etc., 1844, page 56.
§ Mining Journal, 1814, page 383; 1845, pages 6, 37 and 38.

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1836, I had samples of ore assayed which proved to be very rich in gold and silver, but not being aware that the working of such would be allowable in North Wales, I left off further search until 1843. . . I certainly informed him (Mr. Dean) 12 months ago (October, 1843) of the existence of precious metals in this country."" Mr. Dean appears to have been called in by Mr. Harvey, the proprietor of the Cwm Eisen mine, to furnish an expert report on the mine, in order to form a company to work the gold-ores. To which claimant belongs the honour it is now impossible to say, but it is at least certain that Mr. Dean's paper, read before the British Association in 1844, contained the first published notice of the discovery.

In 1846, an attempt was made to raise capital to work the gold-mines, but, owing to the ridicule cast on the project, the attempt resulted in failure. Early in 1847, however, the North Wales Silver, Lead, Copper and Gold-mining Company was floated with a capital of £125,000 in 12,500 shares of £10 each to work the veins at Vigra, Clogau, Tyddyn-gwladys and Dol-y-frwynog. Vigra and Clogau were then being worked for copper alone. The Cwm Eisen lode during this year was worked vigorously, but only for copper-ore and for argentiferous galena. Dol-y-frwynog lode yielded a little gold during 1847; but, being in places 12 feet wide with good copper-ore, it was worked almost entirely for the latter metal.t

Before January, 1849, the first extensive trials of Welsh auriferous veins had been made at Cwm Eisen, and 7 pounds of gold of the approximate value of £350 had been obtained from 10 ¾ tons of concentrates, the produce of 300 tons of ore.‡ Gold-mining operations were at this time much hindered by the claims of the Mines Royal Corporation, to which, as we have already seen, the Crown had granted, by patents of Elizabeth, its royal prerogative in Wales. The matter was finally settled by the Crown requiring a royalty of 5 per cent. on private property and of 10 per cent. on Crown land.

In 1853, an impetus was given to gold-mining in Wales by the introduction of the Berdan machine for gold-recovery, and coming as it did at the height of the excitement caused by the gold-discoversies in California it created a mild boom, of which the

* Mining Journal, 1845, pages 37 and 38.
† Ibid., 1847, page 23.
usual advantage was taken by unscrupulous persons. At that time, gold was reported from all parts of England and Wales, nearly all the alleged discoveries being, of course, fictitious. The gold-mines worked during this boom were all about the upper waters of the Afon Mawddach, in the vicinity of the Rhaiddr Mawddach.

On August 16th, 1853, gold was discovered at the Prince of Wales mine (now the Voel mine, Merioneth) about ½ mile w of the junction of the Mawddach with the Afon Wen, and in the same week a similar discovery in an old dump was made at Vigra (Clogau?) by Messrs. Goodman and Parry of Dolgelly.* In 1854, a single piece of stone worth £25 was crushed from Clogau and 2 years later, 100 pounds of quartz from the same mine yielded 14 ½ ounces of gold.†

It was not, however, until 1860, that the St. David's lode of the Clogau mine gave any indication of its exceedingly rich bonanzas. On May 21st, 1860, a mass of 15 cwts. of gold-quartz of the estimated value of £500 to £600 was broken down. During the first 6 months of 1861, 98-3 ounces of the value of £3,664 were obtained. This rich discovery naturally stimulated enterprise in the vicinity: and, in 1863, the Clogau, Cefn Coch, Dol-y-frwynog and Cwm Eisen mines were being vigorously worked, and visible gold was discovered at Garth-gell, Cambrian, Cae Mawr, Prince of Wales, Moel Offryn, Glasdir, Tyddyn-gwladys and Ganllwyd mines. In April, 1862, gold was met with in situ in the Berthllwyd mine, near Tyn-y-groes, and a crushing of 333 ½ tons from the adjacent Welsh Gold-mining Company's mines gave a yield of 282 ½ ounces of gold.‡ The gold of the Gwyn-fynydd lode, which yielded so handsomely a quarter of a century later, was discovered early in 1864 by Capt. Griffith Williams, but the discovery was kept secret until February 23rd, 1864.

During 1865, many thousands of pounds were expended on useless metallurgical machinery: Berdan pans, Mitchel pans and Mosheimer machines being erected and condemned in rapid succession. Considering, however, the world-wide ignorance of the principles of gold-recovery at that period, this result is not surprising. In 1865, the Clogau mine paid £22,575 in dividends and had, in little more than three years, produced gold to the value of £43,783.* Table I. contains an estimate of the total produce gold, of an average value of £3 4s. per ounce, obtained from the Mawddach district from 1844 to 1866.

<table>
<thead>
<tr>
<th>Table I. — Gold-production of the Mawddach District from 1844 to 1866.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ounces.</strong></td>
</tr>
<tr>
<td>Berthllwyd, Welsh Gold-mining Company*</td>
</tr>
<tr>
<td>Castell Cain Dochan, Llanuwchlllyn†</td>
</tr>
<tr>
<td>Cefn Coch</td>
</tr>
</tbody>
</table>

* Mining Journal, 1865, page 134.
‡ Mining, Journal, 1864, page 674.
Cwm Eisen 176
Grwynfrwynog (Gwyn-fynydd ?) 6
Prince of Wales, Voel Mines 63
Vigra and Clogau 11,788
Total 13,897

* Mining Journal, 1866, page 168.
† Ibid., 1861. page 674.

Table I. is certainly incomplete; and Table II. contains another and probably more accurate return to the end of 1865,‡ compiled from official records (1865).

Table II.—Gold-production of the Mawddach District to 1865.

<table>
<thead>
<tr>
<th>Ore.</th>
<th>Gold.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alluvium</td>
<td>100 0 0</td>
</tr>
<tr>
<td>Cambrian</td>
<td>50 0 0</td>
</tr>
<tr>
<td>Castell Carn Dochan, to June 30th</td>
<td>3,500 0 0</td>
</tr>
<tr>
<td>Cefn Coch. Welsh Gold-mining Company</td>
<td>1,982 8 1</td>
</tr>
<tr>
<td>Cefn Dewddwr</td>
<td>5 0 0</td>
</tr>
<tr>
<td>Clogau, prior to 1860</td>
<td>50 0 0</td>
</tr>
<tr>
<td>Do., from 1860</td>
<td>5,140 0 0</td>
</tr>
<tr>
<td>Cwm Eisen</td>
<td>487 0 0</td>
</tr>
<tr>
<td>Dol-y-frwynog</td>
<td>312 1 2</td>
</tr>
<tr>
<td>Gwyn-fynydd</td>
<td>5 1 3</td>
</tr>
<tr>
<td>Mawddach River</td>
<td>1 4 0</td>
</tr>
<tr>
<td>Prince of Wales</td>
<td>20 0 0</td>
</tr>
<tr>
<td>Totals</td>
<td>11,652 15 2</td>
</tr>
</tbody>
</table>

After 1866, gold-mining languished for nearly 20 years, and there is little of importance to note in that period. The Vigra and Clogau mines had worked out their bonanzas, and in 1868, produced only 490 ounces of gold.§ In 1870, the total yield

* Mining Journal, 1865, page 518.
† Treatise on Ore-deposits, by Mr. J. Arthur Phillips, page 204; second edition, by Prof. H. Louis, 1896, page 294.
§ Mining Journal, 1869, page 137.

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from Wales was only 191 ounces of which Gwyn-fynydd contributed 165 ounces. During the following year, not a single ounce of gold was produced.
In 1881, a low-level tunnel was driven to intersect the St. David's lode (Clogau mine); and, shortly after it was intersected, a small patch of 225 ounces was obtained. Nothing of importance was recorded from the district until 1888, when a rich shoot was discovered in the Gwyn-fynydd lode. The Morgan Company was floated to work this mine, which in 2 years produced over £35,000 worth of gold. After the exhaustion of the shoot, the company suspended operations; but a new company was formed, and carried on operations for many years, with varying success. The two most important mines, the Clogau and the Gwyn-fynydd, are now united as the St. David's Gold and Copper-mines, Limited.

Table III., compiled from official records, shows with some degree of accuracy the total produce of the Merionethshire gold-field since its discovery. The column "estimated value" of Table III., requires some explanation. It is the "estimated value of the ore at the mine" as furnished to the Mines Department of the Home Office, presumably by the mine officials, and means merely the estimated profit that should accrue from the treatment of the ore, the estimated expenses for the year having been deducted. These figures are, therefore, almost valueless, and yet it is these that are added in the official returns to obtain the total value of the gold-ore raised since 1873. This total value is now, however, accurately shown for the first time in the last column of Table III.

It will be seen that the returns, at times, have been so large as to admit of a handsome profit. The net profits of the St. David's Gold and Copper-mines, Limited, for the year 1900, were £39,729, which admitted of the payment of dividends at the rate of 60 per cent. on the capital. While the gross receipts for that year were £51,344 4s. 10d., the total expenses were only £8,423 9s. 7d., or 8s. 7¾ d. per ton. The royalties paid to the Crown were £2,038 7s. 7d., or, at the rate of 2s. 1d. per ton of ore crushed. During 1901, 15,500 tons of ore were treated for a yield of 5,537 ounces of bullion, worth together with the concentrates £19,710. The total expenses for the year were £6,730, or about 8s. 8d. per ton, thus leaving a net profit sufficient to pay a very handsome dividend.

Geology.— The rocks (Fig. 5, Plate XVII.) of the auriferous area of North Wales may be grouped as shewn in Table IV. The

Harlech grits, the oldest members of the sequence occupy the most westerly position in the area under discussion. They extend from Barmouth to Harlech, and for a considerable distance eastward. They are composed in the main of greenish-grey grits, with, towards their upper horizon, interstratified bands of green and purple slates. Their dip is to the east at fairly low angles and their estimated thickness is 6,000 feet. Their junction with the overlying Menevian beds is best seen about ½ mile east of Barmouth.
Upper Cambrian or Ordovician  
Bala Series  
Bala Age  
Arenig Age  
Castell Carn Dochan Slates.  
Felstone-porphyries and felspathic ashes.  
Igneous intrusive rocks.  
Diabases (greenstone).

Middle Cambrian  
Lingula-flag Series  
Dolgelly Beds.  
Ffestiniog Beds.  
Maentwrog Beds.

Lower Cambrian  
Menevian Series  
Harlech Series  
Harlech Grits.

Menevian series overlies conformably the Harlech grits, and is composed of dark sandstones and flags. These are as a rule felspathic, and at times are somewhat coarse-grained. In weathering, these Lower Cambrian rocks fail to furnish any soil, and the outlook northward from Y-Garn across their exposure is barren in the extreme, offering a wide expanse of succeeding ridge and scree. Neither in the Harlech grits nor in the Menevian beds are metalliferous veins developed.

The horizon of the auriferous veins of Wales is that of the Lingula-flats. These are divided into three groups. The lowest, the Maentwrog, rests in this area directly and without unconformity on the Menevian beds, and like them, dips south-east and east at angles varying from 45 degrees near Barmouth to 10 degrees near Gwyn-fynydd. They are fossiliferous at Tyddyn-gwladys and Cwm Eisen. At Tyddyn-gwladys, the following fossils have been found on this horizon*: —Anopolenus Henrici, A. Salteri, Paradoxides Hicksii, Microdiscus punctatus, Agnostus Davidis, A. princeps, A. nodosus, Paradoxides Davidii, Theca corrugata, and others. From Cwm Eisen, Olenus cataractes, O. gibbosus, Agnostus princeps and A. trisectus are recorded. From


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Penrhos, Olenus micrurus, one of the most characteristic fossils of this horizon, has been obtained. The most richly auriferous lodes are in these beds, and include Gwyn-fynydd, Cwm Eisen, Cefn-dewddwr, Granllwyd, Berthllwyd, Cefn Coch, Voel mines and Clogau. The junction between the Maentwrog and the underlying Menevian beds is, especially in the Llechau and Mynach valleys, clearly traceable on the surface, the slates of the Maent-wrog beds yielding a fair soil which supports an abundant vegetation. This junction-line runs northward from the estuary of the Mawddach to near Llyn-bodlyn, and passing round the head of the valley, turns south-eastward to near Clogau, whence it crosses

[Photograph:—Fig. 10.—Pontdu and Cwm Llechau Valley.

the Cwm-llechau and Cwm-mynach valleys in an easterly direction, gradually turning, however, to the north-east. At Cefn Coch it coincides with the large quartz-lode, and, continuing in a northeasterly direction, crosses the Eden opposite the high bluff at Cefn-
dewddwr, and thence pursues a northern course passing within a short distance of Gwynfynydd. The rocks of the Maentwrog beds are, on the whole, grey and dark-coloured slates, sometimes highly ferruginous, together with occasional bands of sandstone. The Ffestiniog beds, which overlie conformably, the Maentwrog beds are developed from Moel-Hafod-Owen through Glasdir to Penmaenpool. The auriferous veins on this horizon are

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those at Dol-y-frwynog and at Glasdir. The slates are highly fossiliferous near Moel-Hafod-Owen, yielding Lingulella Davisi, Hymenocaris vermicauda, Bellerophon cambrensis and others. The Ffestiniog beds, in this neighbourhood, have been very considerably altered by dynamic stress, occasioned possibly by the extrusion of the great neighbouring igneous mass of Rhobell Fawr. The ordinary slaty rocks of the Lingula flags give place to hard massive rock, indistinguishable in many cases from the intrusive felspathic igneous rocks of the area. In places, it contains a large quantity of talc, becoming a talcose schist, weathering along fissure-planes to a somewhat kaolinic clay.

The Dolgelly beds are exposed near the town of that name and also north of Rhobell Fawr, and are, as a rule, soft black slates. No auriferous veins have been discovered on this horizon. Igneous rocks are well developed in the area under discussion, the intrusions, especially north of the Mawddach river, between the Barmouth estuary and Llanelltyd, running parallel with the strike of the lower beds of the Lingula-flag series. They occasionally occupy fault-lines, a remarkable instance of which is seen between Tyn-y-groes and the Clogau. Here, the large Cefn Coch quartz-lode occupies the plane of contact between the Menevian and Maentwrog beds. Farther south-west, the fissure, which runs into the head of the Mynach valley, is occupied by an intrusive diabase, at times again giving place to quartz. No less than 150 of these intrusions, varying from a few feet to nearly a mile in length, have been mapped by the officers of the Geological Survey. Many of the dyke-rocks are light in colour, exhibiting imperfect crystallization due to rapid cooling. Some are calcareous, showing effervescence on treatment with acid. They are, as far as may be seen from hand-specimens, dolerites and diabases.

The Welsh gold-mines are, with the exception of Castell Carn Dochan, disposed along the northern and western slopes of the watershed of the Afon Mawddach, a stream flowing into St. George's Channel, at Barmouth. The auriferous belt extends from near Pontddu, midway between Barmouth and Dolgelly, in an easterly direction to 1 mile beyond the falls at Rhaiddr Mawddach, beyond which no discoveries of importance have been made. The two most productive lodes are located one at each end of

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the already proved auriferous belt the Clogau on the south-west and the Gwyn-fynydd on the north-east. They are now both under the control of the St. David's Gold and Copper-mines, Limited. The Clogau mine is situated some distance from Pontddu up the Cwm-Ilechau valley. Midway between Pontddu and the mine is the crushing-mill, the ore being conveyed by an aerial tramway from the mouth of the main level. The mountainous nature of the country permits of the lode being worked level-free, and at the same time furnishes abundant fall for the use of the water of the Ilechau as a source of motive-power. The St. David's lode lies in the Middle Cambrian slaty rocks (Lingula-flags) a short distance south of their line of surface-contact with the coarse greenish-grey underlying Lower Cambrian or Menevian grits and
sandstones. The vein, which has a nearly east-and-west strike, or parallel with the line of contact mentioned, is almost perpendicular, any dip being towards the north. It varies in width from 2 to 9 feet, but it is much split in places, forming occasionally large horses. The matrix of the vein is quartz, somewhat white and chalcedonic in appearance, especially near and at the surface, to which the lode has been sloped. Calcite is not uncommon, and occasionally contains gold. In general character, the auriferous matrix is a fairly clean opaque white quartz, occasionally stained with iron-oxides, but in depth it contains undecomposed sulphides. Of the sulphide-ores, blende is by far the most abundant, but iron-pyrites and chalcopyrite also occur in quantity. An uncommon associate of gold is met with at Clogau, namely, the silvery white telluride of bismuth, tetradymite. The gold itself is occasionally in the clean white quartz, where it is shotty, but is more often associated with blende or with a darker veinstone, probably rendered so by the contemporaneous deposition of sulphides in a state of extremely fine division.

The Gwyn-fynydd (White Mountain) mine lies a short distance above Rhaiddr Mawddach, and like the Clogau has the advantage of an ample supply of water under a good head, and also is worked level-free. This mine was originally worked as a lead-mine, but in 1870 a small rich pocket of gold-ore was discovered a few feet below the surface, portions of which yielded at the rate of 7 to 10 ounces to the ton. The auriferous character of the lode was first discovered in 1864. The Gwyn-fynydd lode, like the St. David's, from which it is distant about 8 miles, is close to the contact between the Maentwrog slates and the Menevian sandstones. The former, in this area, dip to the east at angles varying from 10 to 60 degrees. The latter also dip in the same direction, but much lower angles.

The Gwyn-fynydd lode strikes east-and-west, dipping to the north at about 80 degrees. It branches in several places forming numerous small horses of slate. As a natural consequence, its width varies considerably, 2 feet to 20 feet being the extreme limits. The matrix of the gold is a white and opaque quartz. In places, it is much mineralized, the most abundant sulphide being blende: but pyrite, mispickel, galena and chalcopyrite are also present. The gold here is, as a rule, much finer than that from Clogau; indeed, in some cases, it is so finely divided that it imparts a yellow stain to the stone, with which it is obviously of contemporaneous origin. In other cases, the gold is of subsequent deposition, occurring in vughs in blende, and infiltrating the somewhat cavernous quartz. In the latter case, the gold is often leaf like and wiry.

Since the discovery, in 1888, of the rich shoot, which has been traced for more than 800 feet, this lode has yielded consistently,

and with vigorous prospecting for new shoots, should yield equally well in the future. For many years it has furnished the greater proportion of the Welsh gold-yield.
In the vicinity of Gwyn-fynydd, the mines which have yielded good specimens but have never been sufficiently rich in gold to pay for working expenses, are the Cwm Eisen (Cwm-heisian), Dol-y-frwynog, Cefn-dewddwr, and Tyddyn-gwladys.

Of these, as we have already seen, Cwm Eisen and Dol-y-frwynog were among the earliest worked, and though never remunerative, the gold produced from them has been of considerable quantity. Cwm Eisen, in the early days of gold-mining, yielded two large returns, of 170 ounces from 300 tons and 148 ounces from 157 ½ tons respectively. There are several specimens (wrongly labelled Cwm-y-swm) from this mine in the Jermyne Street museum. The quartz is on the whole rather clear, and the invariable associate of the gold is zinc-blende, the latter being sometimes contemporaneous and sometimes prior in point of deposition. Galena and pyrites also occur, and indeed the veins were originally worked as a silver-lead mine.

The Dolfrwynog (or Dol-y-frwynog) mine, about 1 mile east of Cwm Eisen, has produced some very rich specimens. The gold here is somewhat fine, at times staining the quartz. It is also associated with blende and with pyrites. The main lode averages about 5 feet in width, strikes west-north-west and east-south-east, and dips towards the north at about 40 degrees. At a depth of 200 feet, very rich ore was met with in this mine.

The Tyddyn-gwladys silver-lead-mine has yielded a small quantity of gold, as also has the Cefn-dewddwr. Both are situated almost at the junction of the Menevian and the Maentwrog beds.

On the west of the river Mawddach, below its junction with the river Eden, gold has been obtained in small quantities from Ganllwyd, Coed-cy-fair, Berthllwyd, Goitref, Caegwernog, Cefn Coch and Cae-mawr. These are all in the Maentwrog beds or, as in the case of Cefn Coch, are at the junction with the underlying Menevian beds. East of the Mawddach, and opposite the above are Penrhos, Tyn-y-Penrhos, and Glasdir. The last is situated opposite the Tyn-y-Groes Hotel, a short distance up the Afon Pabi. The country-rock here is of bedded slate (Ffestinoig beds) striking about north-east and south-west,

and dipping south-eastward. The ore-body is not a defined vein, but appears to be an impregnation of the country-rock along a line of faulting, and is contained between two fairly well-defined walls, which are usually slickensided. The auriferous pyrites (pyrite and chalcopyrite) is distributed in irregular patches throughout the ore-body. The general tenour of the ore-body is about 1.1 per cent. of copper, with a very small proportion of gold—less than 1 ounce per ton of concentrates.

The only other lodes-to be noted in this area are those included in the Voel mines near Llanelltyd. So far as can be seen, there are here two main lodes, both striking north-northeast and south-southwest, and dipping-east-southeastward with the country-rock. Throughout this section are numerous intrusive sheets of diabase, generally conforming to the strike and dip of the slates. The

lodes in places occupy the plane of contact between the diabases and the slates, the igneous rock, in one case, forming the hanging-wall and the slates the foot-wall of the vein. The
auriferous quartz is generally stained with green chloritic matter, and is associated with the usual indicator for gold, namely, zinc-blende. The gold is sometimes contained in the quartz, but is more often deposited on the accompanying blende.

The only important auriferous occurrence outside the watershed of the river Mawddach is that of Castell-carn-dochan, about 5 miles from Bala and 2 miles from the small village of Llanuwch-lllyn. The main auriferous vein strikes north-east and southwest, dips southward, and is composed of extremely clean quartz, completely free as a rule, from sulphide-ores. The gold occurs in specks disseminated throughout the quartz. The lodes are in soft black shaly rocks, dipping eastward at about 45 degrees, very near their junction with the felspathic ash-beds and lavas which form the summit of Castell-carn-dochan.

Complete reduction-works were erected in 1864, and up to the end of 1865, about 3,500 tons had been treated for a yield of 1,606 ounces. The lode has since been worked spasmodically, yielding 12 ½ ounces from 50 tons, in 1889: and, during the years 1895 to 1898 inclusive, 393 ounces of gold from 2,638 tons crushed.

The gold or electrum of the Welsh auriferous region, when met with in situ, is scattered throughout a quartz-matrix, or occurs deposited on blende or pyrites in vughs and cavities. It rarely shows any approach to crystallization. The following are average percentage analyses of vein-gold from Clogau:

<table>
<thead>
<tr>
<th>No. of Sample</th>
<th>Gold</th>
<th>Silver</th>
<th>Quartz</th>
<th>Loss</th>
<th>Specific Gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>90.16</td>
<td>9.26</td>
<td>0.32</td>
<td>0.26</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>29.83</td>
<td>9.24</td>
<td>0.74</td>
<td>0.19</td>
<td></td>
</tr>
</tbody>
</table>

These samples represent a value of £3 16s. to £3 16s. 6d. per ounce.

The alluvial gold of the river Mawddach is found mainly in the bed of the stream, but a fair prospect may be washed in many places from the soil on the slopes of the valley. It occurs in small flattened grains, often coated with a haematitic film, and is associated with galena, blende, titanic iron-ore, marcasite and pyrite. Its specific gravity is low, namely, 15.79, due, however, not so much to impurities as to the presence of numerous small air-cavities. As a general rule, the Mawddach alluvial gold is worth about 5s. per ounce more than vein-gold. It is also lighter in colour than the Clogau gold, owing to the admixture in the latter, of copper with the ordinarily prevailing silver.

The earliest recorded attempt to obtain gold from the sands the river Mawddach was that of Mr. Frederick Walpole and Sir Augustus Webster, who obtained an appreciable quantity in the summer of 1852. In 1870, owing to the unprecedented lowness of the river Mawddach, several Australians and Californians worked its bed with good results. One sample of about 1 ounce weight was taken to Liverpool and there assayed at the rate of 23 ¾ carats (nearly 990 fine).*

Above Gwyn-fynydd, no nuggets have been found, but they occur along the whole course of the river Mawddach from Rhaiddr Mawddach to Cymmer Abbey, the gold gradually becoming finer as the latter place is approached.

An analysis of the alluvial gold of the river Mawddach made by Mr. David Forbes† gave the following results:

<table>
<thead>
<tr>
<th>Gold</th>
<th>Silver</th>
<th>Iron</th>
<th>Quartz</th>
<th>Loss</th>
<th>Specific Gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>84.89</td>
<td>13.99</td>
<td>0.34</td>
<td>0.43</td>
<td>0.35</td>
<td>15.79</td>
</tr>
</tbody>
</table>

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It will be noted that this analysis shows a much lower value than those of the vein-gold from Clogau cited above. This is due to the fact that none of the alluvial gold of the river Mawddach is derived from the Clogau lode, but in all probability arises from the degradation of the Gwyn-fynydd or neighbouring lodes, the gold of which is worth much less than that from Clogau, 8 miles to the south-east.

Scotland.
The earliest recorded notice of the occurrence of gold in Scotland is found in a grant of 1153 A.D. to the Abbey of Dunfermline of a tithe of all the gold which should accrue to David I. from Fife and Fothrif.‡ Gilbert de Moravia is said to have discovered gold at Duriness (Durness), in the north-west of Sutherland, in 1245. By an Act of May 26th, 1424, it was enacted in the Parliament of James I. that if "ony myne of golde or siluer be fundyn in ony lordis landis of the realme and it may be prowyt that thre halfpennys of siluer may be fynit owt of the punde of leide The

† Philosophical Magazine, 1867, vol. xxxiv., page 344.
‡ Registrant de Dunfermelyn, page 16; and Hailes Annals. 1819, vol. ii., page 461.

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Lordis of parliament consentis that sik myne be the kyngis as is vsuale in vthir realmys,"* an enactment which would indicate that the produce of precious metals in Scotland had hitherto been negligible.

With the discovery of the gold-mines of Crawford Moor in the reign of James IV. (1488 to 1513), we pass from the region of speculation to that of fact, for in the Treasurer's accounts for 1511, 1512, and 1513, are found many payments to Sir James Pettigrew for working the gold-mines of that region.† As early as 1513, an expert report was furnished to the King by John Damiane, Abbot of Tungland, whose expenses were met by the royal exchequer. After Flodden (1513), in which James IV. perished, the mines were controlled by the Queen Regent. Peculation and evasion of royalties was, even in those remote days, not unknown, for in 1542 a justice-ayre was held in Edinburgh to take cognizance of those who had broken the mining ordinances and had carried gold out of the kingdom.‡ In 1524, it was also enacted that the gold from Crawford Moor should be minted at the Cunyie House (the Scottish Mint). The Albany medal, struck in the same year, was made from gold found on Crawford Moor, as no doubt was much of the coinage of that period.

In July, 1526, a lease of all the mines of gold, silver and other metals was granted for 43 years to certain Germans and Dutchmen, Joachim Hochstetter, Gerard Sterk, Antony de Nikets, and others. To the same grantees, a license to coin was issued in the following year.§ But the results could not have been encouraging, for in 1531, a payment is recorded to “the Dutchmen quhill cam here for the myndis, at their departing hamewart.”‖ In 1535, a commission was appointed to enquire into the workings of the gold-mines, with the result that miners were imported from Lorraine in 1539.¶ It was to hunt over the bleak uninviting country of the Lowthers in the Crawford Moor district that James V., in 1537,

brought his court, largely composed of the train of his first wife Madeleine, the youngest daughter of the King of France. From this visit arose, an interesting story, illustrative of the then production of gold. Newly arrived as the courtiers were, from the sunny valleys of the Seine and the Loire, their disparagement of the bare uplands of the Glengonnar and Wanlock was loud and unsparing. Nettled by these complaints, the Scottish King wagered that at a forthcoming banquet he would produce from that unpromising countryside fairer fruit than ever grew on the smiling slopes of France—a wager, needless to say, immediately accepted. At the banquet, a covered dish was brought in, which on the removal of the cover by the Queen, was seen to be filled with newly-minted gold “bonnet-pieces,” a fruit held to be sufficiently goodly to justify the award of the wager to the King.

During the following 4 years, 41 ¼ ounces of native gold were used in making a crown for the King and 35 ounces for a crown for the Queen; 17 ounces were added to the King's great chain, and a belt made for the Queen (Mary of Guise) weighed 19 ½ ounces. Other articles of jewellery made at the same time from native gold were a “bairtuilthe” (a boar's tusk mounted in gold), a shrine for “ane bane of St. Audrian of May,” a gold whistle for the King, and “ane dragouin, an amulet, and ane target of the King’s awin gold for his Majesty.”

Though some of the early coins of Mary's reign are of native gold, there seems to have been nothing worthy of record about the mines until 1507 when one Cornelius de Vois, otherwise known as Cornelius De Vos, or Devoosse, who pursued, among other avocations, that of artist and painter to Queen Elizabeth, arrived in Scotland, with a recommendation from that Queen to the Scottish Court. “And then Cornelius went to view the mountains in Clydesdale and Nydesdale, upon which mountains he got a small taste of small gold. This was a whetstone to sharpen his knife on,” says the old historian (Stephen Atkinson), "and this natural gold tasted sweet as honeycomb to the mouth." Cornelius consulted with his friends in Edinburgh, and "by his persuasions provoked them to adventure with him." He showed them some samples of the gold, "it was in stems and some like unto bird’s eyes and eggs." Finally, the adventurers raised a capital of

about 5,000 pounds Scots or £416 sterling. The principal shareholders were the Earl of Morton, Secretary Ballantine and Abraham Peterson or Greybeard. Soon Cornelius had "six score at work in the valleys and dales" (at fourpence sterling per day., or at the rate of a merk to twenty shillings the ounce for gold, if paid by results): "he employed both lads and lasses, idle men and women, which afore went a-begging, and he profited by their work, and they lived well and contented." On one occasion, he sent to Edinburgh 8 pounds of gold worth £450—the produce of 30 days' work. This was there converted into the current gold coin of the realm—twenty pounds Scots gold pieces.
Within the next two or three years, the same Abraham Peterson or Abraham Greybeard, a Dutchman, obtained sufficient gold to make "a verie faire deepe bason" which contained by estimation within the brim thereof, an English gallon of liquor. The same bason was of clean, neat, natural gold; itself was then filled up to the brim with coined pieces of gold called unicorns; which bason and pieces both were presented unto the French King by the said regent, the Earl of Morton, who signified on his honour unto the King, saying 'My Lord, behold this bason and all that therein is, it is natural gold, gotten within the kingdom of Scotland, by a Dutchman named Abraham Greybeard'; and Abraham Greybeard, who was standing by, affirmed it on solemn oath, but he said unto the King that 'he thought it did engender and increase within the earth, and that he observed it soe to do by the influence of the heavens.' " Sir Walter Scott, however, tells the story in somewhat different fashion. He says that King James presented the vessel filled with gold bonnet-pieces to the French and Spanish ambassadors—a story which has the greater air of truth, for the Regent Morton is not likely to have met the French King. During the next thirteen or fourteen years, licenses to work the gold-mines of Scotland were successively assigned to Arnold von Bronchhorst, to Abraham Peterson (or Greybeard) and to Eustachius Roche (1583). The royalty demanded varied from 6 to 7 ounces per 100 ounces obtained, the remainder to be brought to the Cunyie House (the Scottish Mint) where £22 Scots was paid for the ounce of fine gold and 40 shillings Scots for the ounce of fine silver.

About 1578, Sir Bevis Bulmer appeared on the scene, who was destined to play a great part in the development and working of the Crawford Moor deposits. This "ingenious gentleman" was engaged by Thomas Foullis, a goldsmith in Edinburgh, to work his lead-mines in Lanarkshire, but appears to have devoted his attention entirely to the gold-deposits. The scenes of his operations lay principally on Mannock Moor, and Wanlock Water in Nithsdale, and on Friar's Moor and Crawford Moor, and the district in the Leadhills. He worked the deposits very systematically, constructing head-races and tail-races, and appears to have been fairly successful.

Atkinson says of Bulmer in this respect:—"On Wanlock Water, in Robert's Moor, he caused search diligently for natural gold, of which he got a pretty good quantity, and made watercourses to wash it . . . Some say, he found out the vein of gold Mr. Bowes had discovered. In Frier Moor in Glengonnar Water in Clydesdale Mr. Buhner got store of gold . . . By help of a watercourse he got much straggling gold, on the skirts of the hills; and in the valleys, but none in solid places, which kept him in great pomp, keeping open house for all comers, as is reported."

"On Short Cleuch Water, in Crawford Moor, he built another goodly watercourse, and intended to make several dams there, to contain water for the puddles, and sources, and for washing gold, of which he found store. . . . From Short Cleuch, he removed up the great hill to Lang Cleuch Head, to seek gold in solid places; whereof he discovered a spring, but there he wanted a watercourse to help him. This vein had the sapper stone plentifully in it, which sometimes held natural gold; but the salmoneer stones in that vein at Lang Cleuch Head held much silver and may prove a rich mine, if followed by such as know the nature of minerals. It is said that vein was powdered with gold, called small powdered gold. It was a vein and not a bed."

Bulmer's dumps or waste-heaps are still to be traced about the Gold Scaur, a rivulet falling into the Elvan Water. He built for himself a large house in Glengonnar, over the lintel of which he carved.
In Wanlock, Elwand and Glengonnar
I won my riches and my honour.

The largest nuggets recorded by him are of 6 ounces and 5 ounces respectively, of pure gold, found within 2 feet of the moss

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at Lang Clench Head. At the same place he found a piece of “sapper stone” (quartz) weighing 2 pounds from which 1 ounce of gold was obtained. (There is now in the Edinburgh Museum of Science and Art, a piece of white quartz from Lang Cleuch Burn showing free gold). At the place, Bulmer erected a stamping mill “called abroad anacanago,” from which he obtained “much small mealy gold.” From his own records, he appears to have been most successful on Henderland moor, in the Ettrick Forest, where he obtained much gold—“the like to it in no other-place of Scotland.” It was “like Indian wheat, or pearls, and black-eyed like beans.” On his return to England about 1595, he presented to Queen Elizabeth a porringer made of native Scottish gold on which was engraved:—

I dare not give, nor yet present,
But render part of that’s thy owne:
My mind and heart shall still invent
To seek out treasures yet unknowne!

Sir Bevis Bulmer appears to have been a man of indomitable energy. Not only did he thoroughly exploit the gold of Lanarkshire, but also the silver mines of Hilderstone, Scotland, the silver-lead-mines at Chewton, in the Mendips, and also of Combe Martin in Devon. His remarks anent mining are shrewd. “How long it” (the silver mine named God’s Blessing at Hilderstone) “will continue is known unto God, for mines are as uncertain as the life is to man, which is like a bubble on the waters to-day, to-morrow none.” Again, “a mineral man should be a hazard adventurer, not much esteeming whether he hit or miss.” Bulmer, from lavish hospitality, fell on evil days, but was appointed by James I., in 1605, to be “Chief Governor of the King’s Mines” which post he held until his death in 1613. In 1593, James VI. granted to Thomas Foullis, goldsmith, burgess of Edinburgh, in consideration of “the grite soumes of money restand awand be his Majestie and his darrest spous to him and for sindrie advancementis maid by thame to him in the quhilk nocht onlie hes he imployit ane grite parte of his awne substance bot alswa remains addebit to sindrie personis alsweill in England as in Scotland off the quhilks his Majesties officiaris ar nocht able to mak him presentlie payment be his Hienes fynanceis being swa exhaustit and swa spoillit be the moyane of

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inordinat suitaris . . . in speciall . . . The mynas on Glengonnar.” The sum advanced by Foulis was £14594. The mines so granted to him are the property of his descendants at the present day, Sir Robert Hope, an ancestor of the present Marquis of Linlithgow, having married a descendant of Thomas Foulis. In 1603, a sum of £200 was granted to Sir Bevis Bulmer, and in 1604, £300 to George Bowes to search for gold and other metals on Crawford Moor. Bowes' letters to the authorities are of
considerable interest. He describes the progress of his search with some detail, although it was fruitless. His chief endeavour was to find a vein of auriferous quartz in Glangrese gill, the existence of which had been reported to him by one who had seen specimens obtained from it by “the Dutchmen” (Cornelius de Vois and party), many years before. His mode of operation appears to have been hushing, or washing off the soil and exposing the underlying rock by sudden outbursts of water. He reported the discovery of an auriferous vein, but later was doubtful of it being so. Bowes gave up his work in 1604. A curious light is thrown on former methods of working by one passage in his letter —

“though I have not got the value of 80s. in gold, yet I doe assure you I have wrought more work than Mr. Bulmer hath done hetherto, resolving what gold I shall gett, faithfullie to deliver it to his Ma:h use, houlding it inconvenient to this service to bye gold and make shew thereof as gotten in these workes : my travill onelye tending for discouerie of a vaine of gold.” . . .

After Bowes' retirement, little appears to have been done till 1616, when a grant of the Scottish mines was made to Stephen Atkinson, an Englishman and a refiner in the Mint of the Tower of London. This man, it was, who endeavoured to persuade James VI. to adventure once again in the Scottish gold-mines. But James had spent about £3,000 (a vast sum in those days) in searching for gold on Carnworth Moor; and had obtained no more than 3 ounces, worth £12, an unfortunate speculation for a King whose regard for money was so notorious. To Atkinson’s representations, although attacking the King at his weakest point, that of cupidity, he therefore turned a deaf ear. Atkinson assured the King that if only the search were carried out properly the

result would make “his majesty the richest monarch in Europe, in all the world.” A subtle attack was also made in another quarter—“in respect,” says Atkinson, “of the wonderful resemblance which many of his majesty's gracious deeds have with the prophet David, and Solomon the wisest.” Astute as was Atkinson, the previous lesson had been too severe and James sought gold on Carnworth Moor no more. At the same time, he gave some countenance to Atkinson’s projects, for in 1616 we find an Order in Council instructing Atkinson “to move twenty-four gentlemen of England, of sufficent land, to disburse £300 each” for which service they were to be created knights of a new order, entitled “The Knights of the Golden Mines.” Atkinson’s plan appears to have failed, for Sir Bevis Bulmer and Sir John Claypool were the only two knights so created. By Atkinson’s licence he was to render to the Crown a tenth part of all the metal obtained.

The operations were apparently unsuccessful, for in 1621, a lease was granted to John Hendlie, physician, for a period of 21 years, and another in 1631 for 7 years to James, Marquis of Hamilton.

In 1633, a rare gold medal was struck to commemorate the coronation of Charles I. of Scotland, which bears the inscription

“EX AVRO VT IN SCOTIA REPERITVR.”

In 1649, grants are recorded in favour of Sir James Hope in respect of the Crawford Moor mines.

Certain manuscripts in the British Museum, written probably by George Bowes, throw considerable light on the subject* and show the author to have been a man of keen perception.


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He argues that the original sources of the gold "lyenge dispersed in Chevore rockes neear the topes and heighte of the mountaynes." He says that it was "in King James the Fourth his tyme about 80 years sythence the Scotishe mene did begyne to wash golde." (A date probably about 1520, if Bowes be the author.) Also that in the time of James V., some 300 people maintained themselves for several summers by washing and that the "golde gotten thearin" is "of greater valine than one hondred thousand poundes, yet in so many years and so many people workynge for goulde

* Early Records Relating to Mining in Scotland, by R. W. Cochran-Patrick, Pages 103 et seq.

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no vaynes of gold have byne knowne to be founde."* He furthure states that "gold hath byne gottene by washinge by the Lord Markiston (Merchistoun?) in Pentley Hyles distant from Leadhile house in Craforde More (28) myles, and great plente of gold hath byne gottene in Langham Water (14) myles, and Megget Water (12 myles) and over Phinland (16) myles distante from Leadshill house . . . golde hathe byne found in more then (40) severalle gylles falynge in to the fowere greatere waters of Alwyn [Elvan], Glangonar, Wanlock and Mannocke."

The author also states that one piece of 30 ounces and some of greater weight had been found, which were "ifie and myxed with spar and some with keele [earthy oxide of iron] and some wth brimstone . . . which shewe thear are vaines of gold from whence thos peices weare torne by the force of wateres eithere at Noes flood or by the vyolence of wateres synce that tyme." He also records that though he made many trials he found no gold on the higher slopes or tops of the hills, but only in or near the streams and that therefore "the same muste eithere growe theraboutes or by vyolente wateres be drivene out of higher places wheare they did growe wthin the circumference of those places wheare the gold is founde."

The following Scottish gold-localities, though they are undoubtedly unreliable in every respect, are nevertheless interesting. They are derived from a memorandum written during the reign of James V. and have been copied by Atkinson* and by Cochran-Patrick.† They were here inserted, on account of the comparative rarity of the works of these authors.

Ane Memorandum left by Robert Seton, commonly designed of Mexico, anent the Metals in Scotland, especially Gold.

Gold is found in the following places in Scotland :--

[1] In the Boggs of New-Lesly, upon the burn side; and at Drumgavan, where George Lesly did dwell, two miles from Drumdeer [Dunideer].‡


[3] In the Over hill, beneath the kyln, in the In-town, in the parish of Belhelvies.

‡ Ibid., page xxvii.

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And at Menzies, in the Golden-bank there, in the parish of Foveran [10 miles north-east of Aberdeen], and at the hill at South Fardin.*

And in ane fould, called the Peltones.

And in Dinrey hill in Carrick, not far from Mayboll.

And in Caylies moor within the burn, that is betwixt the Some and Machlin place.†

And in Henderland, Glengaber burn there.

And in Monbengar braes and burn there.

And in Dowglass braes, and at Dowglass craig.

And in Windie-Neil in Tweddale. It marches with the Black-house in Yarrow.‡

And in Borthwick hill, betwixt Hawick and Branxome.§

And in Longlie burn, in the north side of Selkirk.

And also at the New Town in Augen [Annan ?] Cait burn, in Annandale.

And in Over-Lochan burn. Alto y baxo, lacus aureus.

And in Bonarte hill in Fife, at Sarus Arrius.

Solway-sands, near to the new town of Annand, not far from Dumfries, Micie chiltir.

Durreness in Stranaver; it belongs to the Lord Ray. Ally ay una pedra muy relucente de noche tambien an ay Metall muy bueno.

In Glen-Yla, at Cassels, and there at Calderhall, and Over-Glen above St. Bride's Kirk. Plata de azur.

And at Normandhill, on the side of Camps water.

And in Annan water, and Cherries-braes. Laucla, Hoksay, and Longcleuch.

And at Bellyes baith and Jervies Mayr.

And in Glen-naip betwixt Carrick and Galloway.

And in Ruberlaw Hill, a mile from Bothwell.

And in Galloway, in the Barony of Tareagles, and in an hill called Colochen hill.ǁ

And in Largo Law in Fife. Plata.¶

And in Hara in Caithness, in the Laird of Rater's land.

Dumpender law. It belongs to Bothwell.

And in the Moir, or in Airlaw, beside Crichton dean. Oro.

And in the Laird of Down's land in Caithness.

And in my Lord Brotherstown's land : lead two miles from the sea.**

And in Courtoit burn.

In Galloway, in the hill of Skrill, in a strype of water. Mucho oro y grandes pedacos.

And in the water above Threpland miln, and in sundry other parts thereabout.

* This is noted by Col. Borthwick as a locality for silver and not for gold, Early Records relating to Mining in Scotland, page xxvi.

† Silver only, according to Col. Borthwick's Memorandum, ibid., page xxviii.

‡ Silver only, according to Col. Borthwick's Memorandum, ibid., page xxvii.

§ Copper only, according to Col. Borthwick's Memorandum, ibid., page xxviii.

ǁ Silver only in Col. Borthwick's Memorandum, ibid., page xxvii.

¶ Copper enough, Col. Borthwick, ibid., page xxvii.

** Lead only, Colonel Borthwick, ibid., page xxviii.

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And in a burn that runs from the head of Moffat water, or Annand water in Annandale. Oro.

And in Glencloucht, where the miners did find much gold, long since at the Kirkhill [. . . . toward the east side thereof].*

And in Long-Forglan moor, three miles from Dundee.

And at Stains hill.

And in James Crawford's at Muckert. Millen unelto Not far from Culross, three or four miles above Torie burn.

Further memoranda transmitted by “Colonell Borthwick who had the direction of the mines,” to Sir Robert Sibbald,† in 1683, declare that: —

Gold is found in severall places in Scotland; the most famous place is Crawford-moor, where it was found by King James the Fourth, and King James the Fifth, and is yet found by passing the earth through searches, and the same brought down with speats of raine. I have seen pieces of it as big as a cherry. It is exceeding fine Gold. The Ore, as it was tryed at the King's Mint in London afforded eleven parts of Gold, and the refuse was Silver.

A place called Dunideer is famous for Gold [several miles beyond Aberdeen] Some report, that at Clovo, at the head of South Esk, some eight miles from Killiemuir, there is found gold and silver. There is a gold Mine very rich, in a husband toun, called Overhill, in the parish of Belhelvie, that belongs to my Lord Glames, three fathoms, beneath the kyln that is at the head of the In-town.

A gold Mine was found in King James the Fifth's time, in Lamington burn. Gold is found at Kersop, upon Yarrow water, in Philiphaugh's ground.

At the present time, it is, of course, impossible to estimate with any approach to accuracy the quantity of gold yielded by the Crawford Moor alluvial deposits during the sixteenth and seventeenth centuries. Pennant, on what authority it does not appear, says "In the reigns of James IV. and James V., vast wealth was procured in the Leadhills, from the gold found in the sands washed from the mountains; in the reign of the latter not less than £300,000 sterling." Dr. Lauder Lindsay places the yield as still higher, namely, £500,000, but his authorities for this high sum are equally obscure. In a matter which, from the conditions of working, and from the lapse of time, must necessarily be of considerable uncertainty, it is advisable to follow those authorities who speak with the most immediate knowledge of the subject. In this case, the authority is the letter of George Bowes, quoted above. Bowes, speaking of the total produce of the Crawford Moor district, which took place during his own and part of

† Early Records relating to Mining in Scotland, pages xxv., xxvii and xxviii.

preceding generation, places the yield at £100,000 sterling, and even this is probably overstating rather than understating the amount.
Leadhills.—The district of Leadhills, southern Lanarkshire, (Fig. 6, Plate XVIII.), lies about 44 miles south-east by south from Glasgow. The village itself has an elevation of 1,300 feet, and is reputed to be the highest in Scotland. The surrounding country is barren and uninviting, running up on the south to the Lowther Hills (2,403 feet) and stretching away in the north to Crawford Moor. The high land in the immediate vicinity, which at its greatest elevation has a north-easterly trend from Cairn Hill (1,471 feet), in the Nith valley to Watchman Hill (1,487 feet) above Elvanfoot on the Clyde, serves as the main watershed of the district, from which flow branches both to the rivers Clyde and Nith. The two highest peaks on this range are Green Lowther (2,403 feet) and Lowther Hill (2,377 feet). Flowing to the north and north east, are the Potrail Water (which, with Daer Water, really forms the river Clyde), Elvan Water, Glengonnar (flowing through the village of Leadhills) and Snar Water (a tributary of Duneaton Water). Joining the Nith, and running as a general rule to the west and south-west are Wanlock Water, Menock Water, Enterkin Burn, and Carron Water. Access to the metalliferous district is now rendered easy by the recent construction of a light railway-line from Elvanfoot, running up the Elvan valley to the villages of Leadhills and Wanlockhead.

The auriferous area of the Leadhills lies almost entirely in rocks of Lower Silurian age—of Llandovery, Caradoc-Llandeilo, and Arenig time. The surface-contact line of the Llandovery mid the older underlying Caradoc-Llandeilo beds runs in this area approximately north-east and south-west, parallel with the course, and some little distance to the north, of the Potrail Water.

The oldest rocks in the district are pillowy diabase-lavas* which, with the overlying radiolarian cherts, are exposed in rapidly recurring folds wherever denudation has proceeded sufficiently far to remove the younger rocks. The folds are generally isoclinal, and relief is often obtained by the development of thrust-planes. Overlying the radiolarian chert (Lower Llandeilo) is a well defined but thin band of black shales—the Glenkiln shales (Upper Llandeilo). The fossils of these beds are graptolites (CCoenograptus gracilis, Didymograptus spp., Climacograptus spp., etc.). Overlying the Glenkiln shales, at a short interval, and without any stratigraphical break, are the Hartfell shales (Caradoc), also characterized by their graptolites (Pleurograptus linearis, Dicranograptus Clingani, Climacograptus Wilsoni, etc.). The Hartfell shales at the Leadhills occasionally give place to coarse grey-wackes, grits and conglomerates. It is in these arenaceous sediments alone that the metalliferous (galena) veins of the Leadhills are developed. As these veins approach the black shales, either laterally or in depth, they gradually become poorer, and finally, with contact, the galena disappears from the vein. In all probability, this peculiar distribution is due to an upward movement of precipitant solutions derived from the carbonaceous shales.


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[ Photograph: Fig. 13.—Wanlockhead Village, Lanarkshire.]
The gold of the Leadhills area is found in the streams, into which it has been washed from a gravelly clay, locally known as "till," which lies disposed on the slopes of the hills. The gold generally occurs as fine dust, but small nuggets of varying size have from time to time been observed. The largest on record weighed 27 ounces, and is, or was, in the collection of the Marquis of Linlithgow.* This nugget is said to have been discovered about 1502. It is bigger than the Wicklow nugget of 22 ounces, and is therefore the biggest recorded British nugget. Another also in the same cabinet weighs 1 ½ ounces. Gold-washing as an industry has been abandoned at Leadhills for many years, such gold as has been obtained during the last century having been collected for the purpose of making jewellery for wedding-presents, etc., to the proprietors. Dr. Lindsay† records that 975 grains of gold were collected, in 1862, for the Countess of Hopetoun, and that on another occasion 600 grains were collected in 6 weeks by 30 men working in their leisure-time. Between May and October 1863, three miners working at intervals collected 33 grains of gold from the "till" at a point about 120 feet above the bed of the stream and halfway down the Langcleuch burn, between Leadhills and Elvanfoot. They sold it to Dr. Lindsay at the rate of 7 ½ d. per grain. In the summer of 1862, the miners, by way of holiday work, frequently collected quantities of from 14 to 54 grains, for which the average price charged was 6d. per grain.‡

The gold from Wanlockhead is of the average quality of British gold, the following being an assay§:—Gold, 86.60; silver, 12.39; copper and iron, 0.35; loss, 0.66. The specific gravity was 16.50.

An analysis made by the late Prof. Heddleǁ of alluvial gold in small hackly scales and nuggets from Langcleugh burn, in the Leadhills district, differed but little from the above:—Gold, 87.32; silver, 11.80; ferric oxide, 0.41; silica, 0.22; and loss, 0.25. The specific gravity was 17.52. The value of the above gold ranged, therefore, from £3 13s. 6d. to £3 14s. per ounce.

In the Edinburgh Museum of Science and Art lies the "Gemmell nugget," over the nativity of which there has been a

* Report of the British Association, 1867, Dr. W. Lauder Lindsay, page 64.
‡ Ibid., page 110.
§ Chemical News, by Prof. Church, vol. xxix., page 209.
ǁ Edinburgh Museum of Science and Art.

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long, and at times acrimonious, newspaper discussion. It is not a nugget in the true sense, but a large fragment weighing probably about 3 pounds, of highly auriferous quartz. It was picked up by a miner named Gemmell on the roadside at Wanlockhead in 1872. The finder broke the specimen into several pieces and sold the fragments to various collectors. Owing to the exertions of Mr. Dudgeon of Cargen, the several pieces were collected, replaced in position and presented to the above museum.

The quartz sufficiently resembles that of the Leadhills to lend some colour to the theory of local origin, but the evidence

[Photograph: Fig. 14. —Leadhills, Lanarkshire.

brought out by the discussion referred to would on the whole favour an Australian origin. It appears that on the day prior to the discovery a handbarrow containing—among other effects
of a returned Australian miner who was “flitting” from one house to another in Wanlockhead—a number of specimens of Australian gold-quartz, was wheeled along the road. The presumption therefore is that the Gemmell nugget is one of these unnumbered and unmarked Australian specimens. The quartz certainly resembles that from many Victorian gold-fields. Gold has also been found in situ in the Leadhills district. In 1803, Prof. Traill records gold from a vein of quartz at Wanlockhead,

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and in the Edinburgh Museum of Science and Art there is a specimen of clean white quartz slightly waterworn, containing gold which shows a tendency to wiriness. A specimen in the Natural History Museum, South Kensington, labelled "Leadhills," is composed of a clean white quartz with a few grains of shotty gold. On the authenticity of this specimen, Dr. Lauder Lindsay throws some doubt, for, as he points out, in the case of the Leadhills gold, which commanded nearly more than double its intrinsic value, there was every incentive for the substitution of similar Australian and other auriferous quartz for that of local origin. It would further appear

[Photograph: Fig. 15.—Lead-mines, Wanlock Burn.]

that the South Kensington specimen was purchased from a London mineral dealer who had secured the whole cabinet of a gentleman "who had collected extensively in the Leadhills district." The quartz differs little in appearance from that of the Leadhills district, and the present writer is disposed to accept it as a genuine Leadhills specimen. It is a large piece of quartz containing visible gold in one corner only, and it seems very improbable indeed that an Australian miner would have carried for any length of time or for any distance so large a piece of valueless gangue when the corner containing the very small quantity of gold might easily have been broken from the

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specimen, and could then have been placed in, the waistcoat pocket. A specimen of auriferous quartz in the Edinburgh Museum of Science and Art, from Wingate burn, Leadhills, shows somewhat wiry gold but little waterworn, and is associated with a clean, milky-white quartz. It is evidently derived from adjacent vein. Another specimen from Stake burn, Wanlockhead, in the same museum, shows native gold disseminated throughout limonite and quartz.

Sutherland.—Though as far back as 1853,* a nugget weighing 1 ½ ounces† is recorded as having been picked up in 1840 in the Kildonan stream, and though, as we have already seen gold was reputed to have been obtained in 1215 by Gilbert de Moravia at Durness (a few miles south-east of Cape Wrath) gold was not known to occur in any quantity in Sutherland until November, 1868. As first suggested by the Rev. J. M. Joass, it is not at all improbable that the remnants of the numerous Pictish towers or brochs scattered over the hills of Strath Ullie and forming, when complete, a chain of strongholds from Dunnaie on the coast to Ben Ghriam-beg at the sources of the Ullie, indicate a means of defence for a digging population against the attacks of marauding bands of maritime rovers, attracted to the spot by the report of gold. It is noteworthy that the remains of these small forts are particularly
numerous in the immediate vicinity of the Suisgill and Kildonan streams, which are, so far as is at present known, the most highly auriferous in the district. In November, 1808, Mr. R. N. Gilchrist, a native of the county, was induced to try the various streams for gold. He had been for 17 years in Australia, where he had met with success as a gold-digger. He was led to the search, it is said, by the likely appearance of the gravels of the Ullie, but it is much more probable that traditions of the gold already found there, were in existence. His search soon resulted in the discovery of gold in Kildonan burn, a small tributary of the Ullie. Following up the discovery, gold was found in the neighbouring burns, and a rush to the neighbourhood took place. At one time, in 1809, no less than 400

* Gold Rock* of Great Britain, etc., 1853, by John Calvert, page 163.
† More than 1 ounce, according to David Forbes, Philosophical Magazine, 1869, vol. xxxvii., page 327.

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were employed in the diggings. That the work was remunerate for the time being, is evidenced by the continued payment during a year of the license-fee for each digger of £1 per month, besides the royalty of 10 per cent. demanded by the Government.

During the short period that these gravels were worked after the discovery of their auriferous character, royalty was paid on £3,000 worth of gold; but, as the temptation to conceal the greater portion of the gold discovered must have been almost irresistible, it is probable, as estimated by Dr. Joass, that the total amount recovered was not less than £12,000.*

Much of the gold from the Sutherland gold-field was purchased by Mr. P. G. Wilson of Inverness. In three weeks in February, 1869, he purchased respectively £28, £18 14s., and £14 worth of gold. By April 8th, he had purchased £431 worth, and by August 24th, between £5,000 and £10,000 worth;† The price was at first £4 per ounce, but it afterwards dropped to £3 10s. According to Dr. Lauder Lindsay, £15,000 worth of gold was obtained from Sutherland in 1809.

About the same time, gold was also discovered, but in smaller quantities in the Allt-Smeoral, or Gordon-bush burn, and in the Uisge Duibh or Blackwater, two streams falling into the head of Loch Brora. These were, however, worked for a very short time, since the license-fees obtained did not by any means compensate for the damage occasioned by the diggers to pastoral interests, by driving sheep away from the sheltered valley to the bleak moorland. Digging was therefore prohibited in the Brora district from January 1st, 1870, and has never been resumed.

The gold-fields of Sutherland are restricted to two main localities—to the tributary streams flowing from the north into the Ullie or Helmsdale, and to the two streams, already mentioned, flowing into Loch Brora.

All the former have their sources in the high lands running along the boundary between the counties of Sutherland and Caithness. The auriferous streams are, in order from the mouth of the Helmsdale upward, the Allt Torrish, Allt Breacich, Allt Duibh, Kildonan, Allt Ant' Fionnaraidh, Suisgill and Kinbrace (Cn Preas). The Craggie, flowing from the west into the Ullie, has also yielded alluvial gold.

* Geology and Scenery of Sutherland, by H. M. Cadell, page 95.
The whole country through which these streams run is typical moorland, with heatherclad lower hills and with extensive marshy ground at the sources of the streams in the high lands. The valleys of the streams have been cut down rapidly, and are narrow and fairly straight. Alluvial flats of any size are wanting along their course, and it is only in the main stream, the Ullie or Helmsdale, that such are developed.

The rocks of this district have been mapped by officers of the Geological Survey, and are, in the main, granites and schists (Fig. 7, Plate XIX.). The granites occur in mass only on the north-western and on the eastern boundaries of the area, the eastern development being prolonged to and forming the Ord of Caithness. The auriferous district is therefore almost wholly in the schistose rocks. These have been divided by the officers of the Geological Survey into quartz-schists, flaser-mica schists and granulitic biotite-schists, clearly representing original sandstones and shales, probably of Lower Silurian age. The quartz-schists occasionally pass in the mass into quartzite, of which there is an extensive development at Cnoc-an-Eiranneach, a hill 1,700 feet in height, at the head of the Suisgill and Kildonan burns. The schists are well exposed in the bed of the Ullie, just below Kildonan Lodge, and also in the bed of Kildonan burn, about 300 feet above the bridge. Their general dip is east north-eastward at high angle. They are here thinly-beded flaggy schists, with occasional bands more or less quartzose. Some of the latter pass into true quartzites. With the quartzose beds are thinner bands (4 to 6 inches thick) of highly micaceous (muscovite) schists. The flaser-mica-schists, which occur as very thin bands through the quartz-schists, in the lower courses of the Kildonan and Suisgill, have a much greater development toward the heads of these streams. Their mica is muscovite. The granulitic biotite-schists are grey rocks, made up of quartz and felspar-grains rudely oriented, together with an occasional grain of biotite-mica. The Kildonan, in the upper part, and the Suisgill for the main part of its course, flow over these rocks.

Overlying the metamorphic schists, and rendering it at all times difficult and in some cases impossible, to map out the boundaries of the rocks, is a heavy deposit of Glacial Drift, overlain in its turn by thick beds of peat. The Glacial Drift shows but little sign of stratification, and fine-grained sandy or clay-beds, are, as a rule, absent. The general constituent of the drift is a coarse gravel, through which are interspersed numerous small stones and boulders ranging from 6 inches to 2 feet in diameter. These boulders, so far as can be seen, are fragments of rocks which are all represented in situ in the immediate neighbourhood, and a comparatively local origin for the drift may therefore be assumed.

The gold is found as small grains in the beds of the streams, and in the gravel-banks along their courses. It is naturally most abundant in the rocky potholes and in the crevices afforded by the upturned edges of the flaggy schists, across the strike of which the streams run; but it appears to be also disseminated throughout the drift. Although most abundant in the lower courses of the streams it is not found there alone, but occurs right up to the heads of the burns, clearly demonstrating, either long-continued denudation, or more probably a concentration of
the gold in the drift which caps all but the highest hills. The grains of gold are generally flattened, and, except in the case of the larger nuggets, present very little evidence of rolling or attrition by the action of water. The heaviest nugget yet discovered here weighed 2 ounces 17 dwts. and was picked up by a man named Rutherford in April, 1809, shortly after the discovery of the gold-field. A model of this nugget is shown in

[Photograph: Fig. 17. — Loch Brora from the same Point as Fig. 16, looking South-eastward.] The matrix of the gold is to be sought for in the quartz-veins in the local schists, and possibly in similar veins in the granites to the north-west; but, in the latter case only where they are adjacent to, or intersec the schists. A careful examination of the beds of the streams disclosed several quartz-veins, apparently striking and dipping with the country-rock. The quartz of these veins is white and opaque, resembling very much in character the quartz-veins in the phyllites and similar metamorphic schists of Otago, New Zealand, from the denudation of which and the manifold concentrations of the residual debris have resulted the extremely rich fluvial auriferous deposits of that region.

The following percentage analyses of the gold of Sutherland have been made: —

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* Specimen in Edinburgh Museum of Science and Arts.

In the early days of the gold-field, small nuggets weighing 1 2, 3, and even up to 5 dwts., were not uncommon. Mr- Gilchrist, the original discoverer, had in his possession five nuggets varying from ¼ ounce up to 1 ounce troy weight.

The minerals which accompany the gold, and are left behind in the dish on panning off, are almandine-garnets, muscovite-mica, ilmenite, magnetite and iron-pyrites. According to David Forbes* the magnetic particles have the following composition: — Oxide of iron, 91.26; titanic acid, 8.03; and silica, 0.70; while their specific gravity is 5.08.

The Kildonan veins, according to the late Prof. Heddle, have indeed yielded gold, and there is in the Edinburgh Museum of Science and Art a small bead, said to have been obtained from
quartz-veins in the Kildonan area. This bead represented a yield of 392 grains of gold per ton, and was contained in an electrum of 28.57 per cent. of gold and 71.43 per cent. of silver. It would appear, however, that the method of separation used was that of amalgamation, and it is difficult to account for the extremely high proportion of silver, except on the supposition that it came from the mercury used; more particularly as it does not appear that special precautions were taken to ensure the absolute purity of the mercury nor the freedom from gold of the materials used for crushing. Nor does it appear that the vein itself contained galena (the only mineral likely to furnish silver). Taking everything into consideration, this particular result must be regarded with some suspicion. As already seen, the alluvial gold of the district is about 800 fine.

Judging from analogy with alluvial gold derived from similar rocks in other parts of the world, the richness of the Sutherland alluvia will depend almost entirely on the conditions of concentration, and but little on the comparative richness of the parent quartz-veins. As a case in point, the extremely rich alluvial deposits of the Clutha river in New Zealand have been derived from veins, the remnants of which are far too poor to work at the present time. Numerous examples of a similar kind


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might be adduced to show that without an absolute knowledge of the conditions of alluvial deposition, no inference can be drawn as to the richness or poverty of the parent-reefs of the Kildonan area.

As already stated, the petrological and lithological characters of the schists leave but little doubt of their sedimentary origin: and, such being the case, it would seem that it is in the metamorphic schists that the parent auriferous veins must be sought for. Only on such an assumption can the local distribution of the gold be satisfactorily explained, for the gold would naturally be concentrated in leads (in this case littoral rather than fluviatile, and corresponding on the whole to modern beach-sands) in the old sediments as they are in those of the present day. Notwithstanding the fact that gold appears to have been obtained attached to granite, the source of the vein-gold of Kildonan is to be ascribed not to the granites of the area, but to the schists. At the same time it must be stated that an occurrence of gold in the quartz of granite as a primary constituent is reported from Sonora, Mexico.*

[Photograph: Fig.18.—Suisgill and Gold Burns, Kildonan.]


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As will be seen from Appendix II., numerous assays have been made of the rocks of Sutherland in the hope of determine the source of the gold. These were conducted with large samples, no less than 200 grammes (3,086.4 grains) of each rock being taken. Extreme care was taken to ensure the absolute purity of the fluxes used, and especially of the litharge. The beads obtained being far too minute to be weighed, or in some cases to be seen with the naked eye, were measured with a
standardized eye-piece micrometer in a powerful microscope, and their weight was calculated from their diameter. By this means, beads representing 0.01 grain per ton, or 1 part in 1,568,000,000 may easily be determined, certain necessary refinements in the methods of treating the minute beads having been adopted. Though the results set forth herein are negative, they have yet a certain value, and are by no means useless.

With reference to the profitable working of the alluvial deposits of Kildonan, it must be said that the prospects of success do not appear alluring. Neither could a head of water sufficiently great to command the gravels be obtained, nor is the water in the immediate neighbourhood sufficiently plentiful to work the gravels on such a scale as the economics of the scheme would demand. The over-burden (large stones and boulders) of the Glacial Drift is very heavy, and sluicing operations of any kind would probably be impracticable during 2 or 3 months in the year, owing to the inclemency of the winter season. But probably, the greatest obstacle to working such a deposit on a large scale lies in the fact that the salmon-fishings in the lower portion of the Helmsdale would be injured—if not altogether destroyed—and the prospective revenue from royalties, etc., on gold would certainly not compensate for that loss.

The Sutherland County Council in 1890, endeavoured to reopen the diggings, and with the consent of the owner set several men to work in Suisgill burn. Table V. shows the quantities of gold obtained.*

This result would indicate a yield of 13 grains of gold per diem, or nearly 2s. in value, a result clearly unprofitable. The experiment naturally led to no further trials. In this connection, however, it must be stated that local opinion as to the experiment (on apparently no better ground than that of innate belief in the richness of the field) explains this poverty of return by the assumption that not all the gold obtained was reported to the authorities.

The two auriferous localities at Loch Brora are the Allt Smeoral, or the Gordon-bush burn, and the Uisge Duibh, or Blackwater. The former flows from the north into the loch about 1 mile from its head. In the ravine, where crossed by the bridge, a good section of the rocks is displayed. They are Lower Silurian flaggy quartzites and micaceous schists dipping southeastward from 40 to 60 degrees. Though the whole course of the stream lies in the above rocks, the eastern boundary of its watershed lies along the Old Red Sandstone, here represented in the mass by conglomerates through which run gritty bands of sandstone. Ben Smeoral (1,592 feet) is composed of this rock, which here dips southeastward at low angles from 10 to 20 degrees. Granite-dykes and quartz-veins are common

* A Treatise on Ore-Deposits, by Mr. J. Arthur Phillips; second edition, 1896, by Prof. H. Louis, page 320.
in the upper waters of the Allt Smeoral. The gold is found both in terraces and in the flats of the stream, in the bottom-stratum of coarse grit lying on the rock, and is overlain by a deposit of reddish clay and sand, much of which has been obviously derived from the Old Red Sandstone area.

The Uisge Duibh, or Blackwater, flows into the head of Loch Brora, in the upper part of its course, over Lower Silurian rocks precisely similar in composition to those noted above, and through an alluvial flat for more than 2 miles of its lower course. A short distance above its junction with the Brora river, 2 miles from the Loch, gold has been found. Here the burn runs across the strike of the rocks, which dip south-eastward at angles of about 20 degrees. The micaceous schists and quartzites are seamed by numerous narrow dykes of granite. The gold occurs in a bluish sandy clay, together with rolled fragments of red granite and quartz, and is somewhat coarse in character. There is, however, little alluvium in the stream after it leaves the flat formed by the filling of Loch Brora.

Other Localities.—The other undoubted Scottish localities in which gold has been discovered may be grouped into three divisions:—

(a) Occurrences which may be associated with the Leadhills alluvial deposits. These are, besides the streams already mentioned as flowing from the high land in the vicinity of Leadhills (Shortcleuch, Leadburn, Elvan, Langcleuch, Glengonnar, Wan-lock), those flowing into the Tweed (Manor Water, Meggat, Yarrow and Glengaber), and those flowing into the Annan (Moffat Water and Dobbs Linn). All the above occurrences are alluvial but auriferous pyrites is recorded from Torbockhill, near Annan.* This on analysis yielded 4 dwts. of gold and 10 ounces of silver per ton. The auriferous pyrites was taken from an old working called "the cave," which was worked in the eighteenth century by Germans.

(b) Perthshire occurrences (Breadalbane area), about Loch Tay and the headwaters of the Tay. According to Dr. Lauder Lindsay, a nugget found here in former times weighed 2 ounces. He also records gold in its matrix from Tyndrum, at the head of Strathyilan, western Perthshire, where argentiferous galena occurs in mica-slate near its junction with quartzite. In 1861, James Tennant found gold in quartz, associated with iron-pyrites at Taymouth (Fig. 8, Plate XIX.).

Gold has also been recorded by various observers from other parts of Perthshire; from galena-veins at Lochearnhead near the railway station† where arsenical pyrites yields at the rate of 6 ounces to the ton, and where particles of native gold have been found in the gossan;‡ Glen Lednoch;§ Ardvorlich, south side of Loch Earn, in mining for argentiferous galena; Cornebruchill, on the southern side of Loch Tay, opposite Ben Lawers;‖ Glenturret;¶ Glenalmond; ** and Glenquaich, near Loch Freuchie.††

* St. James' Gazette, June 15th, 1901.
† Murchison.
§ Ritchie.
There is in the Natural History Museum at South Kensington, a nugget weighing 1,010 grains from Turrerich, Glenquaich, Breadalbane. It is of a, brassy-yellow colour, and is apparently of very poor quality. It contains about one-third of its weight of quartz. The gold is extremely cavernous, and shows a tendency to crystallization, though no distinct crystal-faces are to be seen.

Small quantities of alluvial gold have been recorded from the tributaries of the Lee, at Braemar and Invercauld, and in the sea-sand of the coast, about Aberdeen.*

In 1869, gold-dust in considerable quantity was found in the alluvium of the headwaters of the Errick (Ericht?) and Nairn rivers in Inverness† and were also washed from the granites there by Dr. Bryce in 1870.

Dr. W. Lauder Lindsay, from ancient manuscripts, infers that gold has been worked at times in the Clova district and the Braes of Angus in Forfarshire.

Gold was reported to have been found in Unst (Shetland) at Ureh, near Braewick, but a close examination of the locality failed to discover the slightest traces of that metal.‡

In May, 1852, considerable excitement was caused in Fifeshire by the reported discovery of gold in that county, and no less than 300 men were engaged on these diggings for the better part of a month. The rush had its origin in the letter of a convict in Australia to his friends in Kinnesswood, stating that certain rocks near his native village were very similar to those being worked for gold in Australia. The chief scene of their labours appears to have been in a quarry of Carboniferous Limestone on the south base of the West Lomond hill, overlooking Loch Leven. Overlying the fossiliferous limestone is a bed of haematitic clay containing huge globular masses of iron-pyrites, which were carried away by the diggers in the belief that they were nuggets of gold.

Ireland.

There is no actual knowledge of the discovery or working of gold-deposits in Ireland before 1765. Inferentially, however, from the great numbers of golden ornaments known to have been in existence in the early Christian ages, it may, with

* Leask.
† Dr. James Bryce, Report of the British Association, 1870, page 70.
been found, but also the implements for smelting the metal. Here and there, scattered throughout the ancient annals, are more or less reliable records of the presence of gold in Ireland. In the Annals of the Four Masters, and also in the Book of Leacan, it is recorded that Tighernmas (a.m. 3656) first smelted gold in Ireland at Foithre-aithir-liffe. This is the main ridge of the Wicklow mountains, and its proximity to the Ovoca auriferous district would suggest a local source for the gold. Keating, in his History of Ireland, states also that this king was "the first who discovered gold-ore in Ireland." The inhabitants of Leinster were called "Laighnigh-an-Oir," i.e., the Lagenians of the Gold, "because it was in their country that gold was first discovered." Giraldus Cambrensis (Gerald Barry), writing in the thirteenth century, states that Ireland abounded in gold. Gerard Boate, in his Natural History of Ireland, written in 1652, mentions the occurrence of alluvial gold in the Mayola (Miola) river, which flows into Lough Neagh through a portion of Londonderry county. Since the rocks through which this river runs are mica-slates of Silurian age—already seen to be exceptionally favourable for the occurrence of gold in the British area—some credence may be placed in the statement. The more so, since he explicitly states the amount (1 dram) gathered from the sands. But if auriferous deposits were known in the early and middle ages, it is quite certain that their exact positions were forgotten in the eighteenth century—a fact not surprising, when the troublous times through which Ireland had passed are taken into consideration.

It would appear that the first well-authenticated discovery of gold in Ireland was made about 1765. This was a small nugget picked up from the Ballinvalley brook, flowing into the Aughrim river, near its junction with the Ovoca. Five years later another small nugget was found in the same stream by a boy while fishing, but it was not until September, 1795, that it became generally known that the gravels of this stream (then called the

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Aughatinavought, but afterwards called by Mr. Thomas Weaver the Ballinvalley or Gold-mine river) were more or less auriferous throughout its whole course. A rush to the spot naturally followed, and in a very short time a great concourse of peasants (men, women and children) were engaged in the arduous and unaccustomed work of gold-washing, using the crudest of appliances. In October, 1795, when the news of the discovery came to the ears of the authorities, a strong force of Kildare Militia was sent to turn away the peasants, who, driven from Ballinvalley and Ballinasilloge, the richest spots on the Aughatinaought, flocked to the neighbouring streams, but these apparently

[Photograph: Fig. 21.—Eastern Stream, Gold-mine River, looking Southward.]

did not prove as rich as that first exploited, for work in them ceased after a time. The Treasury, having received an Enabling Act from the Irish Parliament, proceeded to work the auriferous deposits at Ballinvalley, rather, it would seem, for the purpose of exhausting the easily available gold in order that no temptation might he left for the peasants to assemble and congregate in great numbers, than in the hope of remunerative working; for the directors, Messrs. King, Weaver & Mills were instructed to continue to work the deposits only until the great depth of overlying gravels would preclude the possibility of success from individual and spasmodic efforts.

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Government operations were suspended in May, 1798, when the works were destroyed by the rebels and the workings were deserted for more than 2 years. During the period of working the directors had obtained 555 ounces 17 dwt. 22¼ grains of gold valued at £2,140 15s. The cost was £1,815 16s. 5d., and thus, as Mr. Weaver says,* "Government had fully reimbursed its advances, the produce of the undertaking having defrayed its own expenses, and left a surplus in hand." On the resumption of work in 1801, the directors recommended a search for gold in its matrix, and extensive exploratory works were carried out by trenching and costeaneing, and by driving levels, but these failed in every case to reveal the existence of an auriferous vein. Streaming operations, carried on at the same time in the branches of the Gold-mine river and in adjacent streams, yielded 388 ounces 6 dwt. 16¾ grains, valued at £1,528 12s. 11½d. so that the total quantity of gold recovered by the Government operations was 944 ounces 4 dwt. 15 grains, of the value of £3,675 7s. 11½d.

In 1803, the difficulty of working increasing and the auriferous gravels becoming poorer, the directors advised an abandonment of operations, to which recommendation effect was immediately given. For some time afterwards, a guard of militia was stationed at the spot, and on their withdrawal, the peasants again invaded the stream and for a time vigorously carried on sluicing and washing operations. It has been estimated that not less than £2,000 were annually obtained by them for some years, but this is probably far too high an estimate, since the carefully considered exploitation by Messrs. King, Weaver & Mills in earlier years had failed to yield anything like this amount.

In 1840, Messrs. Crockford & Company obtained the rights, to the auriferous deposits and worked them energetically for a period of nearly 4 months, during which time they obtained no less than £1,800 worth of gold, including one nugget of 11 ounces and another of 4 ounces 12 dwts. 12 grains. It seems curious that, notwithstanding this apparently profitable return, the enterprise should have been abandoned so quickly, and that, if we except more or less surreptitious working by the peasants, no


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attempt was made to recover the gold of the Gold-mine river until 1862, when the Carysfort Mining Company leased the gold-royalties. This company appears to have devoted its attention rather to the discovery of auriferous veins in the neighbourhood, than to the working of the stream-gravels; but its operations in the former respect were no more successful than were those of Messrs. King, Weaver & Mills in the early years of the century. The company ceased active work in 1865, having obtained only £203 5s. worth of gold. Since that time, with the exception of some desultory streaming by Mr. F. Acheson from 1876 to 1879, no work has been done on these gravels.

[Photograph: Fig. 22. — Eastern Stream, Gold-mine River, looking Northward.]

Table VI., prepared by Mr. G. H. Kinahan,* shows the gold-production of the Ovoca gravels. The total produce since 1795 is, therefore, estimated at from 7,440 to 9,590 ounces; and a value between £28,855 and £36,185; but, as will be seen, the estimated amount bulks very largely in these totals and the total produce is probably much less than that stated.

Though, so far as is yet known, no other auriferous deposits of economic value occur in Ireland, the presence of gold has been detected in various places, both in veins and in alluvial sands. Under the latter head are the sands of the Glendun river, county Antrim, which enters the sea at Cushendun, and flows from the flanks of Slieve-an-Orra;* the sands of the Dodder river above Rathfarnham, which yielded the two small nuggets picked up many years ago on Stephen's Green, Dublin;† Balliscomey Gap, county Dublin;‡ and the "black sand" deposit near Greystones, county Wicklow. This last deposit appears to have resulted from the concentration, by wind and by wave-action, of the heavier constituents of the drift-sands that are here exposed on the beach. It extended along the beach for several hundreds of feet and was, when examined, several inches in thickness. It contained 21.5 per cent. of magnetic material (magnetite, chromite and ilmenite), together with red and brown haematite, iron-pyrites, rutile, cassiterite and garnets. On washing and panning 7 ½ pounds of black sand, 37 colours of very finely divided gold were left in the dish. Indeed, "gold was found in small quantities in all the specimens of black sand taken from the beach."* Gold, in situ, has also been reported from several localities, namely, from Bray Head, county Wicklow,† from the gossan of the Dhurode copper-lode, Carrigacat, county Cork;‡ and from the pyrites and gossan of the mineral lodes in the Ballymurtagh, Cronebane and Connary mines in the Vale of Ovoca, several miles to the north of the Gold-mine river. The pyrites-lodes of the last mentioned district have long been known to carry a small quantity of gold. Mr. Thomas Weaver§ states that the silver from Cronebane contained 6 ¼ per cent. of gold, and recent assays of that complex sulphide (kilmacooite) from Connary, and of copper-pyrites

† Ibid.
‡ Ibid.

[Photograph: Fig. 23. - Looking up the Eastern Stream, from the Junction.]
from the Ballygahan copper-mine show in each case 12 grains of gold per ton.*

Assays for gold in the rocks in the neighbourhood of Dublin have been made by, or rather for, Prof. J. P. O’Reilly. From time to time, with somewhat astonishing results. A greenstone or diorite, from the quarries about Montpelier and Bohernabreena, county Dublin, and used for the paving of Dublin streets yielded at the rate of 2 dwts. of gold per ton.† From this single assay is ingenuously estimated that the quantity of gold laid down since 1851, in the streets of Dublin is worth £196,224. At the same time, it must not be forgotten that these are the rocks over which lies the course of the Dodder river, from the sands of which, as has already been seen, two small nuggets were obtained. It is also of importance to note that these rocks "nearly always contain pyrites," and therefore have been subjected to a secondary impregnation. Iron-pyrites from lenticular diorite masses in the Lower Silurian clay-slate of Crokling Hill, Brittas valley, county Dublin, yielded to the same assayer 6 grains of gold per ton. The diorite-rock itself, on analysis, yielded a maximum of 2 grains of gold per ton. Traces of gold were also found in the rocks from various other places. In the absence of details as to the method of conducting the assay and of ensuring the purity of the fluxes used, and regard being had to the nature of the rock analysed, it would appear advisable to receive the above results with some degree of caution.

From the foregoing it will be at once apparent that the only occurrence worthy of detailed description is that of the Gold-mine and adjacent valleys in Wicklow (Fig. 9, Plate XIX.).

The Gold-mine river flows into the Aughrim river, at Wooden-bridge, just above the junction of the latter with the Ovoca. Its sources are on the southern and eastern slopes of Croghan Kinshelagh mountain, 1987 feet high, and the highest eminence in the vicinity. For the greater part of its course it flows through a miniature ravine, with steep, well-wooded sides, excavated for itself in the slaty rocks. These narrow trench-like valleys are characteristic, not only of the tributary streams, but also of the main rivers the Aughrim and the Ovoca. About ¾ mile above the confluence of the Gold-mine river with the Aughrim, the former is augmented in volume by the Eastern stream, also auriferous. All the other auriferous streams lie to the west of the Gold-mine river and are tributaries of the Aughrim. They are the Ballintemple, 1 mile above Woodenbridge; the Clone; and the Coolbawn which flows also from the slopes of Croghan Kinshelagh but to the northwest. Gold in small quantities has also been reported from the Ballythomas stream, still further to the west.

All these streams run mainly through an area of Lower Silurian (or Cambro-Silurian) grey, green and dark slates; sandy shales;

[Photograph: Fig. 24.—Lyra, at the Forks of the Eastern and Western Streams.]
and grits, belonging probably both to the Caradoc and to the Llandeilo beds. They have, in the
district under discussion, a general north-east to south-west strike and a dip southeastward of
70 to 80 degrees. One of the best exposures of the sedimentary rocks is seen in an abandoned
quarry on the Eastern auriferous stream. Here the rocks are very fissile, dark blue and brown
slates, showing a thickness in section varying from 40 to 50 feet. In places, the slates show
evidences of extensive exposure to metamorphic agencies.
To the west and north-west of the Gold-mine river, and forming the high lands of the Croghan
Kinshelagh (1,987 feet),

Monayteigue (1,892 feet) and Ballycoog (1,169 feet) hills, occurs a great development of
plutonic and volcanic rocks. Both appear at the surface with outcrops elongated in a general
north-easterly and south-westerly direction. The plutonic rocks occur as narrow dykes or
masses, and are essentially microgranites. They are best developed on the western and
south-western flanks of Croghan Kinshelagh. According to Dr. Hatch* “they are essentially
granitoid rocks of rather fine grain. In colour the specimens from the large masses vary from
a creamy-white to a yellowish-brown; but those obtained from the dykes are of a more bluish-
white or grey. They are usually spotted over with small aggregations of a dark mineral (biotite,
sometimes altered to chlorite). Examination under the microscope shows that these rocks
consist essentially of quartz, orthoclase and plagioclase, together with a small quantity of mica,
in holocrystalline and granitic aggregation. Sphene occurs as an accessory constituent in
small grains.” In the microgranite of Croghan Kinshelagh there appears a micropegmatitic or
granophyric arrangement of the quartz and felspar.
The volcanic rocks are developed farther to the north-east than the microgranites, but
preserve in the outline of their exposures the same general north-east to south-west
elongation noted in the case of the microgranites. They are mainly epidiorites, quartz-
and augite-diorites, and dolerites. The main mass of Croghan Kinshelagh is an epidiorite†—
dolerite altered by contact or dynamic metamorphism or perhaps by a combination of both.
The special feature of the epidiorite is the complete paramorphism of the augites of the dolerite
to hornblende. The gold of the Croghan Kinshelagh area is in all cases found in the gravels in
the beds of the streams. Since, in Wicklow, the river-valleys are extremely narrow and
 correspondingly deep, it follows that concentration of the gravels has been restricted, at any
rate, since the initiation of the present valley-system, to the well-defined lines represented by
the present courses of the streams; and also that the fluviatile plains, or even the small flats,
so characteristic of the alluvial deposits of other countries, are here absent. Under these
conditions, the maximum or mechanical concentration may be expected. The gravels contain

* Memoirs of the Geological Survey of Ireland, Explanatory Memoir to accompany Sheets 138
and 139, page 53.
† Ibid.

numerous rounded boulders of the plutonic and volcanic rocks—the microgranites and the
epidiorites—of Croghan Kinshelagh. The richest deposit is here, as in most alluvial gold-fields,
at the base of the gravels, and rests immediately on the underlying Lower Silurian slates.
The concentration of heavier metals and minerals at the base of such deposits is not due to
the gravels of the stream having been deposited over already concentrated sands, but to the
natural tendency of the heavier minerals to settle in obedience to the force of gravity.* According to Mr. G. A. Kinahan, who saw those workings when exposed by Mr. Acheson, the auriferous

[Photograph: Fig. 25.—Looking up Ballinvalley Stream, from the Red Hole.]

black sands were disposed in parallel lines along the master-joints of the slate, which apparently were coincident with the course of the stream.† Where cross-joints, transverse to the course of the stream, occurred, there was generally a concentration of black sand; and as both master-joints and cross-joints are regular and

* A striking illustration of this property recently came under the writer's observation. A large phial, containing osmiridium, platinum and gold, mixed with sand, from the Hunter river, New South Wales, had lain for many years in a mineral cabinet in London, and subject to repeated vibrations from passing traffic On inspection, it was found that the heavier minerals had concentrated on the lower side of the phial to such an extent as to form a clearly denned zone much darker in colour than the overlying sand. In water, this action is, of course, facilitated by the buoyant action of the water on the sand-grains.
† Manual of the Geology of Ireland,, by Mr. G. H. Kinahan, page 344.

frequent in occurrence, the gold is found at points disposed after a regular pattern, at the intersections of the lines of a chess board. These joints also acted as natural riffles, as is apparent from the fact that the gravels were richest where the Ballinvalley stream crossed the strike of the rocks. The gravels were naturally also more productive where, from any cause, such as a bend of the stream, a reduction of its slope, or the confluence of two streams, the velocity of the current was checked. In the very early days of the workings, it was recognized that the slack water behind a large boulder was favourable to the deposition of heavy minerals; and when such were found in the course of

[Photograph: Fig. 26.—The Red Hole and Ballinvalley Stream, looking Northward.]

working the gravels, rich deposits were generally expected on the lower or downstream side. The black sand is composed mainly of magnetite, ilmenite, haematite and iron-pyrites, but cassiterite, galena, wolfram, molybdenite, gold, copper-pyrites and oxides of manganese also occur in the sand. The late Mr. W. Mallet* records having obtained from a washing of 150 pounds no less than 3 ½ pounds of stream-tin, in all sizes from small grains up to pebbles ½ inch in diameter, and of the variety known as wood-tin.
The gold of the gravels is generally in fine grains, presenting evidences of considerable attrition, especially in the lower portions

of the streams. Mr. Thomas Weaver,* however, noted gold "crystallized in octahedrons, and also in elongated garnet dodecahedrons," and "frosted" or crystallized gold has been remarked by various observers from the upper portions of the valleys.

The biggest nugget found at Wicklow was picked up by a party of peasants, in or about September, 1795, and weighed 22 ounces. Its subsequent history is somewhat obscure, but it would appear that it was bought by Mr. Turner Carnac for £80 12s. for presentation to George III., who had the nugget, or part of it, made into a snuff-box. A smaller nugget of 4 ounces 8 dwt., was for long in the Royal Dublin Society's museum, but was stolen in 1865. Fourteen other nuggets from Wicklow, ranging in weight from 3 ounces 2 dwts. 14 ½ grains, to 1 dwt. 4 grains are recorded from the Dublin Museum of Science and Art, from the Edinburgh Museum of Science and Art, and from the Jermyn Street museum.

The following are various assays of Wicklow gold: —

[Table, of composition of 5 samples, omitted.]

Disregarding No. 1 sample, the low specific gravity of which was due to the cellular nature of the nugget, the average fineness is 90.74 in gold and 7.73 in silver, representing at the present time a value of £3 17s. 3d. per ounce.

The richest deposit appears to have occurred in the upper course of the Western auriferous stream (also called, by Mr. Thomas Weaver, the Ballinvalley stream) about ½ mile below Ballinagore bridge. Here, at the Red Hole, and for some 1,200 feet below, the most remunerative results were obtained by the peasants, by Messrs. King, Weaver & Mills, and by all later workers. From the Red Hole, the old workings extend down stream nearly to the junction with the Eastern stream. The


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Eastern stream, especially below the confluence of the Killahurler brook and the stream running down from Slieve Foore (1,356 feet), carries a fair quantity of gold, as also do the streams coming- m on the right bank below the deserted quarry. At Lyra, the junction of the Eastern and Western streams, a rich deposit was found containing much coarse gold. This was perhaps only to be expected, for at Lyra is to be found the first alluvial flat that occurs in the downward course of either stream. At Lyra, and as far as Rostigah, the gravels of the main stream were productive; but, below Rostigah, they became too poor, and the overburden proved too heavy to work.

[Photograph: Fig. 27. Ballivalley Stream, showing the Ravine.]

The Ballintemple brook, flowing into the Aughrim from the north-western flank of Croghan Kinshelahgh, was worked by Messrs. Crockford & Company, and subsequently by the Carysfort Mining Company, in both cases yielding gold, both fine and coarse. In the Coolbawn stream, flowing northward to the Aughrim from Croghan Kinshelahgh, Mr. Thomas Weaver found a 2 ½ ounces nugget—the largest discovered anywhere except in the Ballinvalley stream.
On the source of the alluvial gold of Wicklow, there is much room for speculation. The results of all Mr. Thomas Weaver’s, Messrs. Crockford & Company’s and the Carysfort Mining Company’s examinations of the quartz-veins of the vicinity would point to a source far removed from Croghan Kinshelagh as a matrix for the gold. Mr. Thomas Weaver, as has already been indicated, vigorously prosecuted a search in the vicinity for auriferous veins. Struck by the fact that on the three main branches of the Gold-mine river, the gold ceased at points which were in straight line transversely crossing the streams, and pointing to the existence of the vein-matrix along that line, he trenched, costeaned and drove levels in various directions, but without being rewarded by the glimpse of the smallest speck of gold; and that although some fifty or sixty quartz-veins were intersected in a single level, driven 1,068 feet to the north-west at Ballinagore. Costeaning by Messrs. Crockford & Company and by the Carysfort Mining Company was no more successful, the latter company, according to Capt. Philip Argall, having crushed 300 or 400 tons of quartz from Monayteigue and Ballintemple, without obtaining a single particle of gold.

Notwithstanding the above evidence, it appears to the writer that the matrix of the gold is, or more probably, was, in the immediate vicinity of Croghan Kinshelagh, and that the present auriferous deposit in fact represents the concentrates of a pyritous lode which has suffered degradation. It need not necessarily have been, and indeed was probably not, rich. The enormous amount of concentration that has taken place in these valleys—their narrowness and the condition of the bottom admirably adapting them to play the part of natural sluices—would certainly point either to poverty, or to scarcity of auriferous quartz. A further piece of evidence, though not an important one, as to an immediately local origin is the occurrence of fragments of quartz containing gold. By far the most important corroboration, however, is that afforded by Mr. E. St. John Lyburn, who in April, 1899, assayed quartz from a vein, 8 inches wide, and in the immediate vicinity of the old Government workings, with a yield at the rate of 4 dwts. of gold to the ton.* The assays appear to have been performed with every care, the fluxes—a fruitful source of error—having been previously assayed with negative results. The assays were also performed in this case in triplicate. Further assays from the quartz-veins in the immediate vicinity of the Gold-mine valley yielded, in every case, traces of gold.


It has been hinted, rather than suggested by various writers, that the matrix of the alluvial gold may have been the outcrops of the pyrites-lodes of Ballymurtagh, Cronebane and Connary, which are known to be auriferous;* and that, either by fluviatile or by glacial action the precious metal has been transported to its present position. But a consideration of the physiographical features of the district would appear to preclude this source and these modes of transport. From the fact that the observed glacial striae are, generally speaking, parallel with the courses of the present streams, it would appear that the present valley-system was initiated anterior to the occupation of the valleys by

[Photograph: Fig. 28.—The Gold-mine River, at Lyra.]
glaciers. The natural course, therefore, at Woodenbridge, of fluviatile or glacial debris from the Upper Ovoca was, not to the south-west to the Gold-mine river, but to the east with the valley of the Ovoca; and it is indeed difficult to see how, in any case, detritus from the Ovoca could be deposited in the Gold-mine valley. Moreover, assuming that the sources of the gold were the pyrites-lodes of Cronebane, auriferous deposits intermediate in position between Cronebane and Woodenbridge would naturally be expected.

* At a Swansea copper-works, 3 tons of residues from Wicklow pyrites, after treatment with sulphuric acid, assayed 8 ounces of gold and 154 ounces of silver to the ton, or a value of £74 per ton. The Wicklow pyrites furnished by Messrs. Williams, Foster & Co., contains ¼ to ½ ounce of gold per ton.—Mining Journal, 1849, page ?

Consideration of the conditions under which gold is found in Wicklow does not favour the assumption of yet undiscovered rich deposits, to be profitably worked in the future. As has already been pointed out, the parent-veins, if portions of them still exist, are in all probability too poor to be worked. The narrow, trench-like nature of the auriferous valleys would also indicate the improbability and indeed the impossibility of extensive high-level auriferous gravels, for high-level terraces demand a broad valley with more or less sloping sides. The hope of payable gravels on the broad hills between the valleys is rendered slender by the presence of the glacial striae indicating, of course, a complete sweeping of the country by ice. Finally, it would appear that the best hope of future profitable working lies in the deep gravels that cover the floor of the lower portion of the Gold-mine valley and of the Ovoca below Woodenbridge. So far as the writer is aware, no attempts have been made in this direction and the potentialities of these gravels are absolutely unknown.

Conclusion.

In reviewing the geological distribution of the known auriferous veins of Great Britain (Merioneth, Leadhills, North Molton and Cornwall) the most striking feature is their more or less intimate connection with the older Palaeozoic rocks. Further, in the case of the alluvial auriferous deposits of Sutherland and Wicklow, where the parent-veins have not been located; the available evidence leads to the inference that these veins also are, or have been, located in Lower Silurian areas. And an inspection of the various auriferous localities described has forced the writer, somewhat against his preconceived ideas, to the belief that it is in the older Palaeozoic sedimentary rocks, and not in the often associated igneous intrusions, that the former locus of the gold, which is now found in veins or in alluvial deposits, must be placed. On no other supposition can the restriction of the auriferous veins in geological time be so satisfactorily accounted for, as by the assumption that many of the sandstones and shales of the Cambrian and Silurian seas were derived from the denudation of an auriferous area, the metallic contents of the derived sedimentary rocks being subsequently leached into, and concentrated in convenient fissures.

To connect the various auriferous occurrences with the presence of local igneous rocks would necessitate the granting of so many postulates, themselves of dubious value in the present state of knowledge of the conditions of ore-deposition, as entirely to deprive the suggestion of any scientific value. Moreover, the igneous rocks present in the various areas differ widely in
petrological character and there are many areas in which the same conjunction of igneous and sedimentary rock may be found, but which are yet not auriferous. Although it cannot be granted that the igneous rocks have in this case yielded the gold of the veins, yet it is very probable that the local heat furnished by their intrusion caused the formation and circulation of the solvent agencies that leached the gold from the sedimentary rocks and deposited it in the fissures.

The total yield of gold in Great Britain and Ireland may, with the exception of that from the Leadhills, be computed with sufficient approach to accuracy, to give a considerable degree of value to the estimation. The yield for each country has already been dealt with under its respective heading and is as follows: —

<table>
<thead>
<tr>
<th>Country</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>England : North Molton</td>
<td>£581</td>
</tr>
<tr>
<td>Wales: since 1844</td>
<td>£280,547</td>
</tr>
<tr>
<td>Scotland: Leadhills</td>
<td>£100,000</td>
</tr>
<tr>
<td>Scotland: Sutherland (1868-1869)</td>
<td>£3,000</td>
</tr>
<tr>
<td>Ireland</td>
<td>£28,855</td>
</tr>
<tr>
<td>Total</td>
<td>£412,983</td>
</tr>
</tbody>
</table>

Of this sum, almost all, except that from the Leadhills, has been obtained during the nineteenth century, and nearly half of it (£208,855) during the last 14 years. The outlook for the present century is by no means so promising. Little or nothing may be, for reasons already set forth, expected from Wicklow, Sutherland, Leadhills or Cornwall. From the auriferous district of North Wales, the outlook is much more hopeful. The veins here yield somewhat high-grade bonanzas, and while they must be regarded always as speculations rather than as commercial investments, yet there is no reason why (provided always that a large reserve-fund is set aside when a bonanza is encountered, in order to carry on that vigorous prospecting which should be the distinctive feature of “patchy” mines) their working should not result in commercial success. With water-power, cheap labour,

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the absence of serious difficulties in metallurgical treatment, and exceptional facilities for mining, there seems no reason why the present low cost of treatment, already under 9s. per ton, should not be yet further reduced. But the prime factor in the successful working of the Welsh gold-mines must be the recognition of the axiom that the more patchy the vein, the greater the necessity for building up a large reserve-fund to be devoted to prospecting for further bonanzas; and also that the exploratory work must be carried on at the same time as the working of the bonanza.

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1814. Kane, Sir Robert, Industrial Resources of Ireland, page 208.

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APPENDIX II. Rock-assays.

[Table, of results of 38 assays of rock from different localities, omitted.]

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[Table continued]

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[Table continued]

The President (Sir Lindsay Wood, Bart.) moved a vote of thanks to Mr. Maclaren for his interesting paper.

Mr. W. O. Wood seconded the resolution, which was cordially approved.

The Chairman (Sir Lindsay Wood, Bart.) moved that the thanks of the members of the North of England Institute of Mining and Mechanical Engineers be accorded to the Cumberland Coal-owners Association; to the owners of the collieries, mines, quarries and works which had been thrown open for their inspection; to the Cockermouth, Keswick and Penrith, and London and North-Western Railway companies; and to the members of the Committee, especially those resident in Cumberland, for making such excellent arrangements for that meeting.

Mr. T. E. Forster seconded the resolution, which was most cordially approved.

[Plates XVI. to XIX., Maps to illustrate the locations mentioned in the paper on “The Occurrence of Gold in Great Britain and Ireland”]

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THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.
EXCURSION MEETING,
Held in Cumberland, June 10th, 11th and 12th, 1903.

The following notes record some of the features of interest seen by the visitors to collieries, mines, works, etc., which were, by kind permission of the owners, open for inspection during the course of the meeting:—

SAINT HELENS COLLIERS.
The St. Helens Colliery and Brickworks Company, Limited, have two collieries in the vicinity of Workington: the No. 3 pit being situated on the sea-shore at Siddick, about a mile to the north-east of Workington harbour; and the No. 2 pit, about 1 ½ miles farther east, near the village of Flimby. The former has an output of 250,000 tons per annum; and at the latter the shafts have only recently been re-opened and deepened to the lower seams.
The leasehold royalties have an area of about 9,000 acres. The coal-field is cut up by faults, into a series of irregular parallel lanes, with a northerly and southerly course and varying considerably in width. There are also occasional cross faults.
The seams worked include the Ten-quarter, 2 feet 8 inches thick; the Cannel-and-metal, 7 feet thick; the Little Main, 2 feet 2 inches thick; and the Lickbank, 2 feet 2 inches thick. The depths to the seams at the No. 3 pit are 504 feet, 714 feet, 918 feet and 1,020 feet respectively; and at No. 2 pit they are 316 feet, 508 feet, 697 feet and 802 feet respectively. Some of the workings extend beyond low-water mark. The general dip is about 1 in 10, westward towards the sea.
All the seams are worked on the longwall system. Until recently the Cannel-and-metal seam, in which there is a band of dirt about 3 ½ feet thick, separating the Metal from the Cannel seam, was worked by the pillar-and-stall method. It is now however, worked successfully on the longwall system. The face of the lower or Cannel seam is kept in advance of the upper or Metal seam and the intervening stratum of dirt is left in situ.

No. 3 or Siddick Colliery.—The downcast shaft is 10 feet 9 inches in diameter and the upcast shaft 11 feet 8 inches in diameter. At the downcast shaft, the coupled horizontal winding-engine has two cylinders, each 30 inches in diameter by 5 feet stroke, the valves are of Cornish type, and the drum is 15 ½ feet in diameter. At the upcast shaft, the coupled horizontal winding-engine has two cylinders, each 26 inches in diameter by 5 feet stroke, the valves are of Cornish type, and the drum is 14 feet in diameter. The cages on the downcast shaft have four decks, and those on the upcast shaft three decks. Each deck carries one tub, having a capacity of 11½ cwt.
The Cornish pumping-engine, at the upcast shaft, has a cylinder 60 inches in diameter with a stroke of 9 feet. The pumps are in two lifts, each 252 feet long. The ram of the top set is 18 inches in diameter, and of the bottom set 10 inches.
The Guibal fan, 30 feet in diameter and 12 feet wide, is driven by a non-condensing engine, with a duplicate cylinder. The horizontal, cross-compound, condensing hauling-engine has two cylinders, 16 inches and 30 inches in diameter respectively by 30 inches stroke. It is placed on the pit-bank, and drives, by means of band-ropes, the haulage-drums at the underground
stations; it also gives motion to the various endless-haulage ropes radiating from these stations.

Air, which is used underground for dip pumping, is compressed by a horizontal non-condensing engine having two steam and two air-cylinders, each 24 inches in diameter by 4 feet stroke.

The exhaust-seam from the non-condensing engines is passed through a Berryman heater, and raises the temperature of the feed-water to over 200° Fahr.

The coal-output is screened by four shaking-screens. Each screen discharges the screened coal upon its own travelling-belt, and the dirt is picked out by hand. The small coal is carried by a scraper-conveyor to the washery, where it is sized by a twin vibromotor-screen, and, afterwards, treated in a Coppee washery, the nut and coking coals being automatically discharged into the several bunkers, ready for loading into railway-wagons and coke-oven bogies.

The coking coal is treated in 24 Coppee ovens, and the gases therefrom are used to fire three Babcock-and-Wilcox water-tube boilers, which supplement eight double-flued Lancashire boilers, fired by hand.

The surface-plant and the various underground eyes and shaft-sidings are electrically lighted.

No. 2 Colliery.—The downcast shaft has a diameter of 17 feet 6 inches, and the upcast shaft is 10 feet 6 inches in diameter. The downcast winding-engine has two cylinders, each 36 inches in diameter by 5 feet stroke, with Cornish valves, and drums 16 feet in diameter. At the upcast shaft, the winding-engine has two cylinders, each 24 inches in diameter by 4 feet stroke, and the winding-drum is 10 feet in diameter.

The Cornish pumping-engine, with overhead beam, has a cylinder 50 inches in diameter by 8 feet stroke. There are two lifts of pumps: the top set is placed in a small shaft inside the engine-house, and is coupled to the cylinder-end of the beam; while the bottom set is placed in the main shaft, and is attached to the pit-end of the beam.

The Guibal fan is driven by a horizontal non-condensing engine with a duplicate cylinder.

The surface-plant, underground eyes and shaft-sidings are electrically lighted.

The coal-tubs when they reach the surface are carried along an endless-rope tramway to the screens and washery, situated alongside the public railway at a distance of about 1,200 feet from the shafts. In the screen-house, there are two shaking-screens, which will ultimately be increased to six, with accompanying picking-belts. The coal-tubs run into and out of the tipplers by gravity-roads. The small coal from the screens is carried by a conveyor to the Coppee washery, where it is sized and washed.

At the brick-works, situated near the screens, common red wire-cut bricks are made from surface-clay.

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WHITEHAVEN COLLIERIES.

The Croft, Wellington and William collieries stand as grimy outposts of industry to the north and south respectively, when seen from the northern pier of Whitehaven harbour. The position of the William pit recalls the position of the Kent collieries at Dover, but there all resemblance ends, for the William pit is drawing 1,000 tons a day.
The Croft, Wellington and William pits are each sunk 840 feet to the Six-quarter coal-seam, and each work the Main Band coal-seam at a depth of 600 feet. With the exception of a small district in the Croft pit, the whole of the coal is won under the sea, by the bord-and-pillar system, the average distance from the pit to the working-face being about 3 miles.

The Main Band seam, dipping westward at 1 in 12, with a roof of blue metal, has the following average section: —

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
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</thead>
<tbody>
<tr>
<td>COAL, little</td>
<td>0</td>
<td>6</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>COAL, bearing top</td>
<td>1</td>
<td>2</td>
<td>COAL, spar</td>
<td>1</td>
</tr>
<tr>
<td>COAL, main top</td>
<td>3</td>
<td>1½</td>
<td>COAL, benk</td>
<td>2</td>
</tr>
<tr>
<td>Black slate</td>
<td>0</td>
<td>0½</td>
<td>Metal</td>
<td>0</td>
</tr>
<tr>
<td>COAL, laying-in</td>
<td>1</td>
<td>4</td>
<td>COAL, mother</td>
<td>0</td>
</tr>
<tr>
<td>Metal</td>
<td>0</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COAL, 4 inches</td>
<td>0</td>
<td>6</td>
<td>Total</td>
<td>12</td>
</tr>
</tbody>
</table>

**Croft Pit.**

The Croft pit is situated at Sandwith, a short distance from Whitehaven. A stone-drift, 8,900 feet long, is being made to shorten the haulage-road. The shot-holes are made with Grant electric rock-drills. The drills are of the rotary type, and are carried on a steel column, which is set between the floor and the roof and securely fixed by tightening-screws. The drill is carried on a horizontal arm extending from the main column, and can be adjusted at any required angle. The motor rests on trunnion-bearings, and is placed on a turntable carried on an ordinary colliery-wagon. The power is transmitted from the motor to the drills by means of telescopic shafting, with universal joints at either end. Two drills are in use, and a single motor is placed between them; and while one is at work the other is being adjusted for the next hole. Usually, fourteen to eighteen holes, varying in depth from 5 ½ to 8 feet, are drilled by one setting of the machine, keeping four men employed from 3 to 4 hours. As soon as the machines have finished drilling the

round of holes, the drilling-plant is removed outbye from the face of the drift. The actual size of the drift-cut is 16 ½ feet by 9 feet and the average progress is 30 feet per week. The drift is being driven in the Mountain or Carboniferous Limestone, underlying the Coal-measures, which will be entered when the drift cuts a dip fault. Steel rails, weighing 80 pounds per yard, supported on wooden props or on steel plugs driven into the sides, are used to support the roof.

**Wellington Pit.**

The vertical double-handled winding-engine has a cylinder, 34 inches in diameter by 6 feet stroke, fitted with double-lift steam-valves (8 inches in diameter), two discharge-valves (10 inches in diameter), a drum (13 feet in diameter), and a brake wheel (31 ½ feet in diameter). The flat winding-ropes are 4 inches wide by 11/16 inch thick, and are fitted with King safety-hooks to prevent over-winding. The depth of the shaft to the Main Band coal-seam is 600 feet, it is 9 feet in diameter and fitted with wooden conductors. The weight of a cage and short chains is 1 ton 15 cwts. The cages have three decks, with a single tub on each deck. The
wooden tubs, weighing 4f 5/8 cwts., carry 12 cwts. of coal. The output is about 800 tons per day of 10 hours.

The horizontal single-stage air-compressor has two steam-cylinders, each 26 inches in diameter by 4 feet stroke, and two air-cylinders, each 24 inches in diameter, cooled by water-jackets. The air is compressed to 60 pounds per square inch, and passes down a main pipe, 6 inches in diameter, placed in the downcast shaft; it is then conducted by branch pipes, 4 inches in diameter, a mile inbye to two pumps.

The horizontal hauling-engine has two cylinders, each 32 inches in diameter by 5 feet stroke, supplied with steam at a pressure of 60 to 80 pounds per square inch; it is geared 1 ½ to 1; the fly-wheel, 12 feet in diameter, weighs 13 tons; and the driving drum is 8 feet in diameter. The steel rope, 33,000 feet long and 1 ½ inches in diameter, weighs 34 tons, and has 4 ½ turns on the drum. This haulage-engine also works two branch ropes, 1 ¼ inches in diameter, each 3,000 feet long. The terminus wheel of the main rope and the driving wheels of the branch ropes are keyed to the same shaft.

The Guibal fan, 36 feet in diameter and 12 feet in width, is driven direct by a single cylinder, 30 inches in diameter by 30 inches stroke, with piston-valves. Steam is supplied at a pressure of 70 pounds per square inch, from two Galloway boilers, 26 feet long and 7 feet in diameter. The fan exhausts 54,000 cubic feet of air per minute at 3.2 inches of water-gauge when running at 60 revolutions per minute.

The Cornish pump and engine has a vertical inverted cylinder 90 inches in diameter by 10 feet stroke, and runs 5 strokes per minute. Steam is only admitted to the top side of the cylinder at a pressure of 40 pounds per square inch. There is a set lifting from a depth of 162 feet, with a bucket, 20 inches in diameter, and two forcing sets, each of 345 feet, with rams, 19 inches in diameter. The wet rods are 10 inches square, and the dry rods are 15 inches square, all of pitchpine. This engine raises 620 gallons per minute, to a height of 852 feet. The crab for lifting the rods, etc., has two cylinders, each 10 inches in diameter by 2 ½ feet stroke, and the drum, 6 feet in diameter, is geared 36 to 1. The steam-generating plant comprizes six Lancashire boilers, 30 feet long and 7 ½ feet in diameter, hand-stoked, and fitted with Caddy movable fire-bars.

The screening and cleaning plant includes a shaking screen, driven by a vertical engine, with two cylinders, each 10 inches in diameter, and 18 inches stroke; a picking-table, 54 feet long, and 4 ½ feet wide, driven by a horizontal engine, with two cylinders, each 10 inches in diameter by 18 inches stroke; and four Shepherd bash-washers, driven by a horizontal engine, with a cylinder 16 inches in diameter by 32 inches stroke.

The fitting-shop contains two screw-cutting lathes, with 10 ½ inches and 11 inches centres, and as they are placed together end to end, any length can be turned up to 20 feet; a planing-machine, with a table, 10 feet by 3 feet, driven by a treble-thread screw and quick-return motion; a double-gated vertical drilling-machine: a screwing machine, to screw and tap from 3/8 inch up to 1 ½ inches, is fitted with an automatic release-motion for the dies; a slotting-machine, with 12 inches stroke, and quick-return motion; and a shaping-machine, with two travelling-tables, a stroke of 13 inches, and a quick-return motion. The various tools are driven by a horizontal engine, with a cylinder 12 inches in diameter.

The blacksmiths' shop contains a steam-hammer, with a
stroke of 18 inches: the force of the blow being equal to 4 cwts.; a Schiele fan, 2 ½ feet in diameter, to blow the fires; and a levered punching-and-shearing machine, with engine, will punch and shear plates up to 7/8 inch in thickness.

The saw-mill contains a circular saw and bench, 6 feet long by 3 feet wide. The saw, 3 ½ feet in diameter, is driven by a horizontal engine, with a cylinder 14 inches in diameter.

William Pit.
The horizontal winding-engine has two cylinders, each 32 inches in diameter by 6 feet stroke, and a drum 18 feet in diameter. The shaft, 600 feet deep to the Main Band seam, is 12 feet in diameter, and fitted with steel-rail conductors. The round steel rope is 1 ¾ inches in diameter. The weight of the cages and short chains is 2 tons. The iron tub weighs 7 cwts., and the wooden tub, 5 cwts. The average load of the iron tub is 14 ½ cwts.; and that of the wooden tub, 11 ½ cwts. of coal. Each cage carries four tubs. The winding-engine is fitted with a steam-brake, and Walker detaching-hooks are fitted to prevent over-winding. About 800 tons are drawn per day of 10 hours.
The two-stage air-compressor, with two steam-cylinders, each 42 inches in diameter by 6 feet stroke, runs at 30 revolutions per minute. The low-pressure air-cylinder, 54 inches in diameter, compresses the air to 25 pounds per square inch; and the high-pressure air-cylinder, 36 inches in diameter, compresses the air to 60 pounds per square inch. The air is passed from the low-pressure cylinder into a cooler and from the cooler to the high-pressure air-cylinder, thence into the main, 20 inches in diameter, down the upcast shaft, whence it is passed for 3 ½ miles through a main, 15 inches in diameter, to the Countess district haulage; and thence a pipe, 4 inches in diameter, is used for a further distance of about 1 mile to the dip pumps.
The haulage-plant worked by compressed air comprizes a hauling-engine with two cylinders, each 20 inches in diameter by 30 inches stroke, geared 15 to 1, working an endless-haulage rope, 19,500 feet long and 1 ¼ inches in diameter; a hauling-engine, with two cylinders, each 9 inches in diameter by 12 inches stroke, geared 20 to 1, working an endless-haulage rope, 6,000 feet long and ¾ inch in diameter; two double-acting ram-pumps, 4 inches in diameter; and a hauling-engine, with a cylinder 8 inches in diameter, used for driving the new engine-plane.
The main-road haulage is worked by a hauling-engine, with two cylinders, each 24 inches in diameter by 30 inches stroke geared 4 to 1, with a drum 6 feet in diameter, working an endless rope, 25,000 feet long by 1 ¼ inches in diameter and weighing about 28 tons. This hauling-engine also drives an endless rope about 10,500 feet long and 1 ¼ inches in diameter in the Delaval district: this rope is worked by a wheel and clutch on the terminal shaft of the main-road haulage.
A Walker fan, 22 feet in diameter and 7 feet wide, is driven by an engine with a cylinder 86 inches in diameter by 40 inches stroke, with cut-off valves. The driving wheel, 18 feet in diameter, is grooved for ten cotton driving-ropes, 1 ¾ inches in diameter; the pulley on the fan-shaft is 7 ½ feet in diameter, or speeded 2.4 to 1 of the engine. The engine is run at about 50 revolutions and the fan at about 120 revolutions per minute, produces 60,000 cubic feet per minute at 6 inches of water-gauge. The upcast shaft is 13 feet in diameter.
The horizontal duplex ram-pumps, 10 inches in diameter, are driven by two steam-cylinders, each 30 inches in diameter by 18 inches stroke. These pumps are placed at the shaft-bottom, working against-a head of 600 feet.
An engine, placed at the shaft-bottom, with two cylinders, each 9 inches in diameter, works the tub-creeper for the transit of the empty tubs. The coal is screened on two jigging-screens, driven by an engine, with two cylinders each 9 inches in diameter. The cleaning-table, about 70 feet long and 4 feet wide, is driven by an engine, with a single cylinder, 8 inches in diameter. The washyery is of the Coppee type, with seven bashes. The coke-ovens, 125 in number, are of the beehive type. Seven Lancashire boilers, 30 feet long and 8 feet in diameter, are hand-fired: nine similar Lancashire boilers are gas-fired; and two Babcock-and-Wilcox water-tube boilers are fired by the waste-gases from the coke-ovens.

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**THE MONTREAL MINES.**

The Montreal mines and colliery occupy lands in three adjoining parishes near Whitehaven. Previous to Mr. Stirling taking a lease of this royalty, it was in possession of Mr. Litt, who sank a shaft on the eastern boundary, the machinery consisting of a horizontal drum, or gin worked by a horse. This shaft, at a depth of about 72 feet, penetrated a gravel-bed, and tapped a large feeder of water which prevented further sinking. The shaft was timbered on the joggling system, notched at each corner. The present-day shafts are mostly close-timbered throughout their depth, thus preventing broken measures from falling from the sides.

In 1859, Mr. John Stirling leased the Montreal royalty, and immediately commenced several bore-holes, proving the presence of several ore-beds at various levels. In 1860, the first shaft was sunk, and passed through several ore-beds varying from 10 to 40 feet in thickness, and having a total thickness of 120 feet. Haematite was discovered at the Montreal mines on October 30th, 1861, and from that time onward it has been constantly found in large and small quantities.

The ore-deposits are clearly divided from the Coal-measures by an east-and-west fault, dipping northward at an angle of about 45 degrees, with a downthrow in the measures of between 1,400 and 1,650 feet. About a mile nearer the west coast, there is another fault; this reverses the situation by an upthrow of about 1,500 feet, and the Coal-measures crop out close at hand (Fig. 1, Plate XXVII.).

In the haematite-deposits, there are several faults, but only one is noteworthy: it runs almost at right-angles to the fault dividing the Coal-measures from the ore-measures. This, fault haves at an angle of 65 degrees, and has an easterly downthrow of 293 feet.

On carefully examining the fault which divides the Coal-measures from the iron-ore, it is invariably found that the ore-measures approaching within 60 feet of the fault rapidly alter their gradients from 18 to about 60 degrees; and should a shale-bed, intervening between the limestone-beds, be tilted in the manner described, it is sometimes thought that it is a fault, unless the contents are carefully examined.

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The surface-area of the Montreal mines embraces about 64 acres. Upward of 200 bore-holes, varying from 250 to 1,000 feet, have been put down from the surface by lever or diamond core-cutters at a considerable expense.

About twenty shafts have been sunk for the purpose of working the iron-ore and coal: five shafts have been sunk on the Coal-measures side of the divisional fault, averaging 480 feet
in depth. Three shafts were sunk wholly in Coal-measures, two have passed through 120 feet of Coal-measures, and then passed through the fault into the Limestone-measures. Ten shafts have been sunk to an average depth of 800 feet in the Limestone-measures on the opposite side of the fault; and five shafts averaging 120 feet, have been sunk for ventilating purposes and reducing the labour involved in carrying heavy timber into the rise-workings.

The mines now in operation comprize Nos. 4, 5, 6, 10 and 12. The No. 4 and principal plant is situated about 4 miles southeast of Whitehaven, and ¼ mile north of Moor Row Station on the Whitehaven, Cleator and Egremont Railway. The weekly output is about 1,000 tons of haematite and 500 tons of coal.

No. 4 Mine.—The winding and downcast shaft, at which coal and haematite are raised, was sunk in 1870-1871, through Coal-measures to a depth of 480 feet or thereabouts. It measures 14 feet by 7 feet, and is lined throughout with timber. The upcast shaft, about 150 feet northeast of No. 4 shaft, 12 feet by 6 feet and 480 feet deep, is lined with pitchpine, 4 inches thick. The winding shaft is divided into three compartments, two for cages and one for pumps. The No. 4 winding-engine has two horizontal cylinders, each 22 inches in diameter by 5 feet stroke, and a cylindrical drum, 11 feet in diameter by 4 feet wide, with a double-breast brake worked by a hand-lever. Each cage carries two tubs on one deck. The wooden tubs, with iron axles and steel wheels, carry 5 cwts. of coal and 10 cwts. of iron-ore. The crucible-steel winding-ropes, 3 ¾ inches in circumference, are fitted with King hooks. There are two pitchpine conductors to each cage. The cages are fitted with safety-apparatus, consisting of a ratchet-plate, placed behind the whole length of each conductor, two spring-boxes each with 12 indiarubber-springs, and two pawls which rest on the ratchet-edges whenever the rope is slackened or a breakage occurs.

The upcast winding-engine has two horizontal cylinders, 14 inches in diameter by 18 inches stroke, gearing 1 to 4, and two drums, 6 feet in diameter. The pumping-engine has one horizontal cylinder, 28 inches in diameter by 5 feet stroke, steam at an initial pressure of 40 pounds is cut off at half stroke by an expansion-slide, and a flywheel, weighing 8 tons. This engine is arranged to work either high-pressed or condensing: a separate double-acting condenser is provided with a ram, 9 inches in diameter and a steam-cylinder 8 inches in diameter by 12 inches stroke. The pump-rods are actuated by a horizontal connecting-rod and two cast-iron quadrants. The engine raises water in two lifts from the Main Band seam: the top lift, 240 feet long, has a hollow ram, 12 inches in diameter by 4 feet stroke; and the bottom lift, also 240 feet long, has a hollow ram, 12 inches in diameter by 4 feet stroke. The hollow ram, fitted with a valve at the top with a vertical lift of 3 inches, and a packing-gland like an ordinary ram, raises the water at the upstroke. The engine is worked day and night at the rate of 10 revolutions per minute, giving a displacement of 190 gallons per minute, the maximum speed being 12 revolutions. In case of accident to this engine or the pumps, the water is raised in boxes by the winding-engine: a box of 350 gallons' capacity, connected to the bottom of the cage, being filled and discharged automatically. The crab-engine for the pumps, with a horizontal cylinder, 6 inches in diameter by 12 inches stroke, is double-geared, the drum is 30 inches in diameter, cleaded with timber, and has a plough-steel rope 4 inches in circumference.

The hauling-engine, on the surface at the upcast shaft, with two horizontal cylinders 14 inches in diameter by 18 inches stroke, geared 1 to 4, has two drums, 4 feet in diameter, for main- and tail-rope haulage. The crucible-steel hauling-ropes, 2 ¼ inches in circumference, are
taken down the upcast shaft to work the haulage-road in the Main Band seam. This road is about 1,500 feet long, and sets of twenty tubs are run in and out alternately on the single road. Another hauling-engine, placed in the Main Band seam about 1,800 feet west of the shaft, has a horizontal cylinder, 8 inches in diameter by 18 inches stroke, geared 5 to 1, with two drums, 4 feet in diameter, and is actuated by compressed air. It hauls sets of five tubs from a double road dipping westward 1 in 2, the empty set descending while the full set ascends. A third hauling-engine, placed about 300 feet to the south of the main haulage-road, of the same dimensions as the second engine, works another road dipping heavily about 1 in 1 ¼ westward. It draws up two full tubs, and two empty tubs descend at the same time into the workings. The full tubs are taken to the branch-end siding to make up the train of twenty tubs, which is then conveyed to the shaft by the first-named engine. This engine is also worked by compressed air at a pressure of 58 pounds to the square inch.

A duplex pump, placed in the coal-pit at a distance of 720 feet down the first-mentioned dip-drift, is actuated by compressed air at a pressure of 58 pounds per square inch, with two cylinders, 7 inches in diameter, and rams, 4 ½ inches in diameter by 10 inches stroke. The water is raised a vertical height of 120 feet to the top of the incline, and flows by gravity to the shaft-sump. The pump is worked 6 hours daily.

The air-compressors have two steam-cylinders, 16 inches in diameter, and air-cylinders, 13 inches in diameter by 3 ½ feet stroke. The steam-pressure is 35 pounds, and the air-pressure 60 pounds per square inch. The front piston-rods are attached to cranks set at right-angles to each other on the flywheel-shaft, the flywheel weighing 5 tons. The compressed air is taken down the pit and inbye to the hauling-engines, a distance of 1,800 feet, through malleable-iron pipes, 4 inches in diameter, with Eadie joints.

The Guibal fan, 18 feet in diameter and 5 feet wide, is driven by a vertical engine having a cylinder 20 inches in diameter by 12 inches stroke. The fan produces 30,000 cubic feet per minute at 0.80 inch of water-gauge, when running at 60 revolutions per minute.

Seven cylindrical boilers raise steam at a pressure of 40 pounds per square inch. The upper side of the boilers is arched over with brickwork, so as to leave an annular space of 6 inches over the boiler, and part of the flame from the flash-flue passes and superheats the steam. The boilers are supplied with water by a self-acting high-pressure injector, with a donkey-pump, with a cylinder 8 inches in diameter, and a ram 4 inches in diameter by 10 inches stroke in reserve, to pump a cold-water feed when required.

No. 5 Mine.—The shaft measures 12 feet by 5 feet, and is 300 feet deep. The winding-engine has two horizontal cylinders 16 inches in diameter by 3 feet stroke, two drums 6 feet in diameter, and a breast-brake and hand-lever. A bogie, containing 10 cwt.s. of ore, is raised in each cage. The safety-cages in use are the same as at No. 4 pit. The winding-ropes of crucible steel, 3 inches in circumference, are fitted with King safety-hooks. Water boxes underneath the cages are used to assist the pumps in wet weather.

The horizontal compound condensing pumping-engine, with Hathorn-Davey differential gear, has a high-pressure cylinder, 15 inches in diameter by 4 feet stroke, supplied with steam at an initial pressure of 100 pounds per square inch, and a low-pressure cylinder 30 inches in diameter by 4 feet stroke. There is a separate condenser, similar to that at No. 4 mine. The
engine is attached by a horizontal connecting-rod to two cast-iron quadrants and works two lifts of pumps, each 10 inches in diameter and 300 feet long, fitted with hollow rams, 12 inches in diameter by 4 feet stroke and similar to those at No. 4 mine. Each lift raises the water from the shaft-bottom to the surface. The engine is in operation for 14 out of 24 hours, and, at present, makes 10 strokes per minute. The crab-engine has one horizontal cylinder, 6 inches in diameter by 12 inches stroke, with double gear, and a rope-barrel 18 inches in diameter. Two Lancashire boilers, each 30 feet long and 7 feet in diameter, with cross tubes, supply steam at a pressure of 50 pounds per square inch to the winding-engine. Two Cornish boilers 26 feet long and 6 feet in diameter, with cross tubes, supply steam at a pressure of 100 pounds per square inch to the pumping-engine. The upper side of each boiler is covered with brickwork, leaving an annular space of 3 inches over the boiler, and acts as a protection from the weather.

No. 6 Mine.—The shaft, 9 ¼ feet by 5 feet, is sunk to a depth of 264 feet. The horizontal winding-engine, with two cylinders, 14 inches in diameter by 3 feet stroke, and drums 6 feet in diameter, raises one bogie in each cage. The other particulars are the same as at No. 5 mine.

No. 10 Mine.—The shaft, 12 feet by 5 feet, is sunk to a depth of 498 feet. The horizontal winding-engine, with two cylinders,

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14 inches in diameter by 3 feet stroke, has drums 6 feet in diameter. The ropes, safety-cages and conductors are similar to those in use at Nos. 5 and 6 mines.

Two cylindrical boilers, 30 feet long by 5 feet in diameter at No. 6 mine, and two of the same dimensions at No. 10 mine are provided with flues and coverings similar to those at No. 4 mine.

No. 12 Mine.—The shaft, 14 feet by 7 feet, is sunk to depth of 636 feet. A stone-drift driven between the coal workings of No. 4 mine and the haematite-workings of No. 12 mine enables coal or haematite, or both, to be raised at No. 4 and No. 12 shafts at pleasure. The horizontal winding-engine has two cylinders, each 20 inches in diameter by 5 feet stroke, and two drums, 10 feet in diameter by 4 feet wide, with a breast-brake in the centre. The cages, safety-apparatus, ropes, tubs and conductors are similar to those in use at No. 4 mine.

The horizontal compound condensing pumping-engine, with Hathorn-Davey differential gear, has a high-pressure cylinder 22 inches in diameter by 6 feet stroke, the initial steam-pressure being 50 pounds per square inch; the low-pressure cylinder, 40 inches in diameter by 6 feet stroke, is placed 4 feet behind the former. The engine works, by a horizontal connecting-rod, two quadrants made of wrought-iron plates, filled in with pitchpine, and these actuate three lifts of pumps. The top and middle lifts are each 228 feet long, respectively, and the bottom lift, 180 feet long, or 636 feet in all. Each lift is worked by two hollow rams, each 9 inches in diameter by 6 feet stroke, and the rising-main for each lift is 9 inches in diameter. The engine works, at present, for 13 out of 24 hours, at eight strokes per minute, equal to a displacement of 256 gallons. The water raised is chiefly derived from old workings, having communication with the surface. In winter, water-boxes are frequently attached below the cages, in order that the winding-engine may assist the pumps, which are then running at 10 strokes per minute during the whole of the 24 hours. The horizontal condenser is placed on one side and below the low-pressure cylinder; and the air-pump, 17 inches in diameter by 2 ½ feet stroke, is
worked by a wrought-iron connecting-rod from an arm on the quadrant-spindle. The steam-crab, with two vertical cylinders, 7 inches

[Plate XXVII.: Plan and Sections of the Montreal mines.]

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in diameter by 12 inches stroke, is geared by means of a worm and a worm-wheel, and two teethed wheels. The drum, placed on the third-motion shaft, is 2 feet in diameter.

Figs. 4 and 5 (Plate XXVII.) represent the method of working a vertical deposit of haematite at the No. 4 pit. The deposit was worked, from below upwards, in horizontal slices, 6 feet high. The empty space, from which the haematite has been removed, was filled with stowing, poured in from the surface, and levelled so that the workmen standing upon it, could reach the working-face. The haematite was teamed down a chute, and filled into tubs at the lower level.*

ULLCOATS MINE.

The Ullcoats mine lies at a much higher elevation, nor is it so deep as the Egremont mine, and accordingly the water-feeder is not so heavy, although two hollow rams, 11 ½ inches in diameter, are kept constantly raising 9,000 gallons per hour from a depth of 50 fathoms. The direct-acting pumping-engine has a cylinder 24 inches in diameter by 4 feet stroke. The winding-engine has two cylinders, each 10 inches in diameter by 3 feet 8 inches stroke, and a drum 8 feet in diameter. The sinking of this pit occupied three years, and occasioned a good deal of difficulty, a bed of quicksand being encountered.

The No. 2 shaft, a few hundred feet to the south-west of the No. 1 shaft, will be sunk to a depth of about 480 feet. The winding-engine will have two cylinders, 20 inches in diameter by 4 feet stroke and a drum 10 feet in diameter. The engine will be supplied with steam by two Galloway boilers, working at a pressure of 120 pounds per square inch.

WYNDHAM MINES.

The Wyndham Mining Company, Limited, has been in existence since 1877, and the first haematite was raised in 1879.


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The early mining operations were confined to an area bounded on one side by the main street of Egremont and on the other side by the river. In course of time, the river was moved and a new course made for it; and then, as the town could not be moved, a considerable quantity of haematite was left beneath it. The ore, at the outcrop, is only covered by surface-measures of gravel and Boulder-clay, from 70 to 80 feet thick, and is almost vertical for a depth of about 180 feet. The ore-deposit flattens westward with a dip of about 1 in 10, and occasional drops of from 30 to 120 feet each, forming a series of steps downward from a depth of 250 feet on the east to 800 feet on the west, towards the Helder pit at Oregill. The ore-deposit, at a depth of 800 feet, is about ½ mile distant from the Falcon pit, where it is raised to the surface.

About 1,500,000 tons of haematite have been worked, and the existence of ore having been proved in depth, the Helder shaft is being sunk to a depth of 1,260 feet.
At No. 3 pit, the winding-engine has two cylinders 16 inches in diameter by 4 feet stroke, with a drum 9 feet in diameter. The Cornish pumping-engine, with a cylinder 72 inches in diameter and 9 feet stroke, raises on an average 700 gallons of water a minute. The Helder pit, at Oregill, will be sunk, 17 feet by 7 ½ feet, to a depth of 1,200 feet; and, when completed, it will be one of the deepest pits in West Cumberland. The water-feeder has given much trouble. The Evans pump has raised as much as 400 gallons per minute. A Cornish pumping-engine, with a cylinder, 80 inches in diameter, is in course of erection.

MESSRS. CHARLES CAMMELL, LAIRD & COMPANY, LIMITED: DERWENT IRON AND STEEL WORKS.

There are five blast-furnaces, with stoves, and ore, limestone and coke-bins on one side, and pig-beds on the other. A range of seventeen boilers is fired with blast-furnace gas, and a battery of self-stoking Babcock-and-Wilcox boilers is fired with coal. Six pairs of vertical blowing-engines are erected in a large building. There are ten converters, eight for rail-steel and two for fish-plates; five semicircular casting-pits; two rail-mills and a fish-plate mill: the ingots being transferred by locomotive cranes and hand to re-heating furnaces. The rolls are arranged in three groups, one in front of the other, the rail being completed from the ingot in one heat: rails weighing up to 120 pound per yard can be rolled. Beyond the mill are the great hot and cold banks for the temporary storage and finishing of the rails. The weekly output varies from 5,000 to 7,000 tons of rails, including 450 tons of fish-plates; the blast-furnaces furnish 4,500 tons of pig-iron; and the remainder is obtained from the Maryport furnaces, owned by the company, and in the open market.

SANDWITH QUARRIES COMPANY, LIMITED.

Sandwith quarries are situated just over the ground rising seaward from Croft pit; they are connected by a siding with the railway, and occupy an imposing position at the brink of St. Bees cliff, along which they extend for about ½ mile. The thickness of the stone is 300 feet. The quarry is equipped with steam-cranches, steam-drills, steam dressing-machines and saws: these are served by an overhead steam-gantry with a span of 50 feet. Some drilling is done by hand and some by steam. The circular holes are nicked by a reamer on the line in which the stone is to be cut, and just sufficient powder is used to cut the stone without shattering it: consequently it breaks away in fine blocks. About 13,000 tons of stone were loaded last year. The stone is a red sandstone of agreeable and uniform colour and a good grain, and is derived from the Permian formation.

THRELKELD QUARRIES.

These quarries and works are described in a paper written by Mr. G. H. Bragg.*

THE THIRLMERE WATER-WORKS OF THE MANCHESTER CORPORATION.

Thirlmere, situated in Cumberland, at the foot of Helvellyn, alongside the road from Keswick to Grasmere, is about 3 miles long and ¼ mile across at the widest part. At the southern end, the land is flat, and appears to have been covered with water in olden times. At the north-eastern corner, there is a narrow gorge forming the outlet through which the St. John's beck finds its way to the river Greta, and ultimately through Derwentwater and by the river Derwent to the sea at Workington. The surrounding hill-sides, being steep, are covered with little verdure. They consist of Silurian rock, and the rain, falling from the clouds, finds its way at once into the lake. The gorge enabled an embankment or dam to be readily constructed, and the level of the water to be raised as required.

The natural level of the lake above sea-level is 533 feet 2 ½ inches: the level, when raised 20 feet for the supply to Manchester of the first instalment of 10,000,000 gallons a day, is 554 feet; and the level, when raised to the full extent of 50 feet, is 584 feet. The length of the lake when raised 20 feet, is 3 miles 1,500 feet, and, when raised 50 feet, 3 miles 3,300 feet. The natural drainage-area is 7,400 acres, and the additional drainage-area to be hereafter diverted into the lake is 3,600 acres. The natural surface-area of the lake is 330 acres; when raised 20 feet, the area is 505 acres, and the capacity 2,534,000,000 gallons: and when raised to the full extent of 50 feet, the area is 565 acres, and the capacity 8,135,000,000 gallons. The quantity of compensation-water discharged into the St. John's beck before the diversion of the additional drainage-area into the lake is 4,120,125 gallons per 24 hours; and when the lake is raised to the full extent of 50 feet, 5,520,487 gallons per 24 hours.

The level of the lake is raised by means of an embankment constructed at the outlet into the St. John's beck. The top of the embankment is 6 ¼ feet above the level of the lake when fully raised; the length of the embankment is 857 feet: the width at the top of the embankment is 18 ½ feet, and the greatest height of the embankment from the foundation is 104 ¼ feet. The length of new roads constructed on the west side of the lake is 5 miles 2,895 feet: on the east side of the lake, 2 miles 720 feet, and across the embankment 5,049 feet.

The aqueduct, with a diameter of 7 feet, and a fall of 20 inches per mile, is constructed to convey 50,000,000 gallons a day. The length from Thirlmere to Manchester is about 90 miles, namely, tunnels, 14 1/8 miles; cut-and-cover, 36 ¾ miles; and pipes, 45 miles. The diameter of the straining-well for the admission of water into the aqueduct is 37 ½ feet, and the depth 65 feet.

The rainfall over the watershed varies from 52 to 137 inches per annum. The storage, when all the works are completed, will provide 50,000,000 gallons of water per day for 100 days, even if no rain falls during that time, without drawing the water below the original margin of the lake. It is intended to provide the full supply by instalments of 10,000,000 gallons a day, at such intervals of time as may be found necessary.

The purchase of the watershed, including the lake: the way-leave for the tunnels, the cut-and-cover, and for the laying of five lines of siphon-pipes across the valleys from Thirlmere to Manchester, and the works at present carried out, including the tunnels, cut-and-cover or concrete tunnel, to convey 50,000,000 gallons per day; and one line of pipes to convey 10,000,000 gallons per day to Manchester, have cost over £2,700,000. When five lines of pipes have all been laid, and the level of the lake raised 50 feet, it is estimated that the cost will be about £5,000,000.
The laying of the second line of pipes of the aqueduct was completed and brought into use in November, 1904.

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[i]

[Drawing of Neville Hall.]

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[Graph showing the membership of the Institute, 1853 – 1902.]

[iii]

THE NORTH OF ENGLAND INSTITUTE
OF
MINING AND MECHANICAL ENGINEERS.

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ANNUAL REPORT OF THE COUNCIL AND
ACCOUNTS FOR THE YEAR 1902-1903;
LIST OF
COUNCIL, OFFICERS AND MEMBERS,
FOR THE YEAR 1903-1904;
THE CHARTER AND BYE-LAWS; Etc.

---------------

1902-1903.

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[Coat of Arms

LONDON AND NEWCASTLE-UPON-TYNE: ANDREW REID & CO., LTD., PRINTERS AND PUBLISHERS,
1903

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CONTENTS.

Report of the Finance Committee ix.
Treasurer's Accounts x.
Account of Subscriptions xii
The Jubilee of the Institute was celebrated in the Wood Memorial Hall on September 16th, 1902. The members were received by the President, Sir Lindsay Wood, Bart., who delivered an address; and at his invitation, a conversazione was held in the Museum of the Natural History Society of Northumberland, Durham and Newcastle-upon-Tyne, by permission of that Society. A large number of members and representatives from other societies attended.

The Institution of Milling Engineers held their Annual General Meeting in Newcastle-upon-Tyne on September 17th, 18th, and 19th, in conjunction with the Jubilee Meeting of this Institution. The large number of members present necessitated the congress being held in two sections. The best thanks of the members are due to the committee who made the arrangements, to the owners of collieries and works open for inspection, and to all those who by their services contributed to the holding of that successful meeting.

The following table shows the progress of the membership during the past few years:

<table>
<thead>
<tr>
<th>Year ending August 1st.</th>
<th>1893</th>
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<th>1903</th>
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<td>921</td>
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<td>115</td>
<td>112</td>
</tr>
<tr>
<td>Associates</td>
<td>47</td>
<td>103</td>
<td>161</td>
</tr>
<tr>
<td>Students</td>
<td>34</td>
<td>51</td>
<td>69</td>
</tr>
<tr>
<td>Subscribers</td>
<td>22</td>
<td>22</td>
<td>23</td>
</tr>
</tbody>
</table>
The members are to be congratulated upon the increase in the membership of the Institute;--155 members of all classes have been added to the register during the past year, and after a allowing for losses by deaths and resignations, there is a net increase of 74 members.

The deaths (18) include the following:--Patron and Honorary member, The Right Honourable The Earl of Ravensworth.


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The Library has been maintained in an efficient condition during the year; the additions by donation, exchange and purchase, include 449 bound volumes, 123 pamphlets, reports, etc.; and the Library now contains about 9,392 volumes and 2,763 unbound pamphlets. A card-catalogue of the books, etc., contained in the Library renders them readily available for reference.

Members would render useful service to the profession, by presentations of books, reports, plans, etc., to the Institute, to be preserved in the Library and available for reference.

The courses of lectures for colliery-engineers, engine-wrights and apprentice-mechanics have been continued at the Durham College of Science. The lectures are delivered on Saturday afternoons, and the three years' course embraces the following subjects:


Several colliery-owners have paid the fees (£1 10s. 0d. per annum) and railway expenses of pupils attending the classes from their collieries. During the past year, the lectures of the Michaelmas Term on the Transmission of Power were attended by 61 students, and Pumping
and Ventilation by 65 students, 52 sat for examination and 39 passed; and during the Epiphany Term, the lectures on the Metallurgy of Iron and Steel were attended by 61 students, and Mining Machinery (chiefly used underground) by 59 students, 43 were examined and 28 passed. Prizes were awarded to Messrs T. H. Bolton and J. H. Thompson. Certificates have been awarded to the following students who have completed the three years' course:—Messrs. T. H. Bolton, G. T. Hughes, S. Hutchinson, H. Nicholson and R. D. Oswald.

A loyal and dutiful address was forwarded to His Majesty, King Edward the Seventh, and Her Majesty Queen Alexandra, on the occasion of Their Majesties' Coronation on August 9th, 1902.

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The G. C. Greenwell bronze medal has been awarded to Mr. A. A. Atkinson (H.M. Inspector of Coal-mines, New South Wales), for his paper upon "Working Coal under the River Hunter, the Pacific Ocean and its Tidal Waters, near Newcastle, in the State of New South Wales."

The Council have decided to publish a supplementary volume to An Account of the Strata in Northumberland and Durham, as proved by Borings and Sinkings, and members are desired to send copies of any unpublished sections on strata in these counties, or their section-books, to the secretary on loan. A small tracing from the 6 inches Ordnance Map, showing the position of any shaft or bore-hole, if not already fixed by previous publications, will greatly facilitate the work.

Mr. John Daglish continues to represent the Institute as a governor of the Durham College of Science, which was jointly founded in 1871 by the University of Durham and the North of England Institute of Mining and Mechanical Engineers. Mr. T. E. Forster, in conjunction with the President (Sir Lindsay Wood, Bart.), represents the Institute on the Council of the Durham College of Science.

Mr. J. H. Merivale will again represent the Institute at the Conference of the Corresponding Societies of the British Association for the Advancement of Science, to be held in Southport, commencing on September 9th, 1903. Mr. W. Cochrane represents the Institute upon the Board of Directors of the Institute and Coal Trade Chambers Company, Limited.


An exchange of Transactions has been arranged, during the year, with the Cuerpo de Ingenieros de Minas del Peru.

The following presentations have been received:—Mr. C. W. Anderson, portrait of Mr. William Anderson (Chairman of the preliminary meeting at which the Institute was formed on July 3rd, 1852); Mr. Thomas Douglas, Past-President, portrait of himself; Mr. Robert Laverick Davy safety-lamp used by the late Mr. John Buddle; Mr. J. A. G. Ross, photogravure group of members of the Institute; and Mr. H. S. Willis, model of a lead-ore crushing-and-dressing plant, made in 1830.

Prizes of books have been awarded to the writers of the following papers communicated to the members during the year 1901-1902:—
"A Method of Socketing a Winding-rope and its Attachment to a Cage without the Use of Ordinary Chains." By Mr. W. C. Blackett, M.I.M.E.

"Mechanical Undercutting in Cape Colony." By Mr. John Colley, M.I.M.E.


"Electric Pumping-plant at South Durham Collieries." By Mr. Fenwick Darling, M.I.M.E.

"Some Silver-bearing Veins of Mexico." By Mr. Edward Halse, M. I. M. E.

"Apparatus for Closing the Top of the Upcast-shaft at Woodhorn Colliery." By Mr. C. Liddell, Stud.I.M.E.

"A Visit to the Simplon Tunnel: the Works and Workmen." By Dr. Thomas Oliver.

"The Carboniferous Limestone Quarries of Weardale." By Mr. A. L. Steavenson, M.I.M.E.

"Auriferous Gravels and Hydraulic Mining." By Mr. W. S. Welton, M.I.M.E.

"Tapping Drowned Workings at Wheatley Hill Colliery." By Mr. W. B. Wilson, jun., M.I.M.E.

The papers printed in the Transactions during the year are as follows:

"Working a Thick Coal-seam in Bengal, India," By Mr. Thomas Adamson, M.I.M.E.

"The Use of Carboniferous Plants as Zonal Indices." By Mr. E. A. Newell Arber.


"Improved Offtake-socket for Coupling and Uncoupling Hauling-ropes." By Mr. VV. C. Blackett, M.I.M.E.

"Description of the Lead-ore Washing-plant at the Greenside Mines, Patterdale." By Mr. Wm. H. Borlase, M.I.M.E.

"Granite-quarrying, Sett-making and Crushing: and the Manufacture of Concrete-flags and Granitic Tiles." By Mr. Geo. H. Bragg.

"The Gases enclosed in Coal." By Dr. Broockmann.

"The Gypsum of the Eden Valley." By Mr. D. Burns, M.I.M.E.

"Sinking by the Freezing Method at Washington, County Durham." By Mr. Mark Ford, M.I.M.E.

"The Crumlin Meteorite." By Principal H. Palin Gurney, Hon. M.I.M.E.

"Some Silver-bearing Veins of Mexico." By Mr. Edward Halse, M.I.M.E.

"Air-compression by Water-power: The Installation at the Belmont Goldmine." By Mr. D. G. Kerr, M.I.M.E.

"Ambulance-instruction at Mines." By Mr. William Lekk, M.I.M.E.

"The Occurrence of Gold in Great Britain and Ireland." By Mr. J. Malcolm Maclaren, M.I.M.E.

"Report of the Delegate to the Conference of Delegates of Corresponding Societies of the British Association for the Advancement of Science, Belfast, 1902." By Mr. J. H. Merivale, M.I.M.E.
The rooms of the Institute have been used during the year by the Newcastle Philharmonic Society.

Excursions have been made to the Newbottle Collieries of the Lambton Collieries, Limited, and to mines and works in the neighbourhood of Cleator Moor, Keswick, Whitehaven and Workington, and the thanks of the members have been accorded to the owners of these mines and works.

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The Committee appointed to "investigate and report, on labour-saving machines and tools used in cutting and boring coal and rock" will shortly issue their first report.

The Coal-mines Regulation Act (1887) Amendment Act, which has recently received Royal assent, will enable the holder of a diploma in scientific and mining training, after a course of study of at least two years, at any University, University College, Mining School or other Educational Institution, to be approved of by a Secretary of State, or of a degree of any University to be so approved of, which includes scientific and mining subjects, after having had practical experience in a mine for at least three years, to sit for a Certificate of Competency as Manager or Under-manager under the Coal-mines Regulation Act, 1887.

REPORT OF THE FINANCE COMMITTEE.

The Finance Committee submit herewith a statement of accounts for the twelve months ending June 30th, 1903, duly audited.

The total receipts were £2,888 5s. 2d. Of this amount, £69 18s. was paid for life-compositions in lieu of annual subscriptions, and £78 10s. as subscriptions in advance, leaving £2,739 17s. 2d. as the ordinary income for the year, compared with £2,675 16s. in the previous year.

The total expenditure was £3,726 4s. 1d., as compared with £2,443 9s. 4d. for the previous year. The principal item in this increase is the sum of £1,006 3s. paid on account of the alterations to the Lecture Theatre: £118 2s. 11d. was expended in connection with the Jubilee Meeting, and £42 4s. on behalf of the Coal-cutting Committee; medals costing £67 8s. 4d. have been purchased out of the Greenwell Prize Fund; and the contributions to The Institution of Mining Engineers show an increase of £104 5s. 9d., due to the larger membership. From the figures shown above, it will be seen that the total expenditure during the year exceeded the income by £837 19s. 2d., and deducting this amount from the balance in hand at the
beginning of the year, there is a sum of £169 7s. 10d. to carry forward. There still remains about £160 to be paid in connection with the alterations and furnishing of the Lecture Theatre, and this will be met out of the revenue for the ensuing year.

The names of 38 persons have been struck off the membership-list, in consequence of non-payment of subscriptions. The amount of subscriptions written off was £160 14s., of which £81 8s. was for sums due during the year ending June 30th, 1903, and £79 6s. for amounts which had fallen due in previous years. The recovery of these amounts has been placed in the hands of the Solicitors, and the amounts obtained by them will be placed to the credit of the account in future years.

John G. Weeks.

August 1st, 1903.

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ACCOUNTS.

The Treasurer in Account with The North of England Institute of Mining and Mechanical Engineers,

For the year ending June 30th, 1903

Dr.

June 30th. 1902.
To Balance at Bankers £ 949 17 6
. . . . in Treasurer's hands 56 8 6
. . , Outstanding Accounts due from Authors for Excerpts 1 1 0
---------- 1,007 7 0

June 30th, 1903.
To Dividend of 7 ½ per cent. on 179 Shares of £20 each in the Institute and Coal-trade Chambers Company, Limited, for the Year ending June 30th, 1903 £268 10 0
Less—Repaid on purchased Shares 9 0 0
---------- 259 10 0
. . , Interest on Mortgage of £1,400 with the Institute and Coal-trade Chambers Company, Limited 49 0 0
---------- 308 10 0

To Sale of Transactions 18 9 2

To Subscriptions for Year 1902-1903 as follows:

726 Members @ £2 2s. 1,524 12 0
83 Associate Members @ £2 2s. 174 6 0
105 Associates @ £1 5s. 131 5 0
59 Students @ £1 5s. 73 15 0
77 New Members @ £2 2s. 161 14 0
3 New Members (not yet elected) @ £2 2s. 6 6 0
16 New Associate Members, @ £2 2s. 33 12 0
30 New Associates @ £1 5s. 37 10 0
28 New Students @ £1 5s. 35 0 0
---------- 2,178 0 0

23 Subscribing Firms
96 12 0
----------
To Life Compositions:

1. Member £24 0 0
2. New Members 45 18 0

-------------
69 18 0

Less—Subscriptions for Current Year at the end of Last Year

106 12 0

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2,237 18 0

Add—Arrears received

244 18 0

2,482 16 0

-------------
Add—Subscriptions paid in advance during the Current Year

78 10 0

-------------
2,561 6 0

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£3,895 12 2

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Cr.
June 30th. 1903.

By Annual Report £35 6 9
" Banker's Charges 21 9 10
" British Association for the Advancement of Science: Expenses of Delegate 8 6 7
" Circulars, etc. 48 8 5
" Cleaning Wood Memorial Hall, Offices, etc. 37 19 6
" Coal-cutting Committee 42 4 0
" Electric Light and Gas 45 15 10
" Expenses of Jubilee Meeting, etc. 118 2 11
" Fire Insurance 12 13 10
" Fuel 18 12 0
" Furniture and Repairs 48 5 0
" George Clementson Greenwell Prize Fund: Medals 67 8 4
" Incidental Expenses 8 12 5
" Lecture Theatre: Alterations 1,006 3 0
" Library—Binding £67 12 9
" " Books 37 16 10

-------------
105 9 7

" Petty Cash 3 9 10
" Postages—Circulars £35 9 0
" " Correspondence 19 15 8
" " Publications 24 2 9

-------------
79 7 5

" Prizes for Papers 22 1 0
" Bates and Taxes 6 8 3
" Rent of Offices 24 7 10
" Reporting of General Meetings 12 12 0
" Salaries, Wages, Auditing, etc. 487 17 4
" Stationery, etc. 24 10 10
" Subject-Matter Index 84 8 5
We, having examined the above account with the books and vouchers relating thereto, certify that, in our opinion, it is correct.

JOHN G. BENSON AND SONS.
Chartered Accountants.
Newcastle-upon-Tyne, August 1st, 1903.

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The Treasurer in Account with subscriptions, 1902-1903.

<table>
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<th>Dr.</th>
<th>£</th>
<th>s.</th>
<th>d.</th>
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<td>To 893 Members.</td>
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<tr>
<td>101</td>
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<td>100</td>
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<td>0 0</td>
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<td>120</td>
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<td>150</td>
<td>0 0</td>
</tr>
<tr>
<td>To 66 Students</td>
<td>at £1 5s.</td>
<td>82</td>
<td>10 0</td>
</tr>
<tr>
<td>To 23 Subscribing Firms</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>96</td>
<td>12</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>To 77 New Members</td>
<td>at £2 2s.</td>
<td>161</td>
<td>14 0</td>
</tr>
<tr>
<td>To 2 New Members who have paid Life Compositions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>18</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>To 3 New Members, not yet elected</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
To 16 New Associate Members @ £2 2s. 33 12 0  
To 30 New Associates @ £1 5s. 37 10 0  
To 28 New Students @ £1 5s. 35 0 0  

To 3 0 New Associates @ £1 5s. 37 10 0  
To 28 New Students @ £1 5s. 35 0 0  

To Arrears, as per Balance Sheet 1901-1902 319 3 0  
Add—Arrears considered irrecoverable, but since paid 66 19 0  

To Subscriptions paid in advance 78 10 0  

<table>
<thead>
<tr>
<th>Cr.</th>
<th>Paid</th>
<th>Unpaid</th>
<th>Struck off list</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>£ s. d.</td>
<td>£ s. d.</td>
<td>£ s. d.</td>
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<tr>
<td>By 726 Members, paid</td>
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<td>1,524 12 0</td>
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<tr>
<td>By 97 „ „ unpaid</td>
<td>@ £2 2s.</td>
<td>203 14 0</td>
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<tr>
<td>By 2 „ dead</td>
<td>@ £2 2s.</td>
<td>4 40</td>
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<tr>
<td>By 26 „ struck off list</td>
<td>@ £2 2s.</td>
<td>54 12 0</td>
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<tr>
<td>851</td>
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<tr>
<td>By 1 Member, paid Life Composition</td>
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<td>By 83 Associate Members, paid</td>
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<tr>
<td>By 11 „ „ unpaid</td>
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<td>23 2 0</td>
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<td>By 7 „ „ struck off list</td>
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<tr>
<td>100</td>
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<td>By 105 Associates, paid</td>
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<td>By 8 „ „ unpaid</td>
<td>@ £1 5s</td>
<td>10 0 0</td>
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<tr>
<td>By 7 „ „ struck off list</td>
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<td>8 15 0</td>
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<tr>
<td>120</td>
<td></td>
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<tr>
<td>By 59 Students, paid</td>
<td>@ £1 5s</td>
<td>73 15 0</td>
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<td>By 6 „ „ unpaid</td>
<td>@ £1 5s</td>
<td>7 10 0</td>
<td></td>
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<td>1 5 0</td>
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<tr>
<td>66</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>By 23 Subscribing Firms, paid</td>
<td></td>
<td>96 12 0</td>
<td></td>
</tr>
<tr>
<td>By 77 New Members, paid (a. £2 2s.</td>
<td>@ £2 2s.</td>
<td>161 14 0</td>
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<tr>
<td>By 2 New Members, paid Life Compositions</td>
<td></td>
<td>45 18 0</td>
<td></td>
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<tr>
<td>By 3 New Members, not yet elected. paid</td>
<td>@ £2 2s.</td>
<td>6 6 0</td>
<td></td>
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<tr>
<td>82</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>By 16 New Associate Members, paid</td>
<td>@ £2 2s.</td>
<td>33 12 0</td>
<td></td>
</tr>
<tr>
<td>By 30 New Associates, paid</td>
<td></td>
<td>37 10 0</td>
<td></td>
</tr>
<tr>
<td>By 28 New Students, paid</td>
<td>@ £1 5s</td>
<td>35 0 0</td>
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</table>

£3,134 16 0
### GENERAL STATEMENT, JUNE 30th 1903.

#### LIABILITIES.

<table>
<thead>
<tr>
<th>Description</th>
<th>£</th>
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<tr>
<td>Subscriptions paid in advance during the current year</td>
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<td>10</td>
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<tr>
<td>Ditto. in previous year</td>
<td>4</td>
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<tr>
<td>The Institution of Mining Engineers</td>
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<td>The George Clementson Greenwell Prize Fund.</td>
<td>100</td>
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<tr>
<td>Less-Paid for Medals 67</td>
<td>67</td>
<td>8</td>
<td>4</td>
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<tr>
<td>Mr. Clarence R. Claghorn: Prize for Essay</td>
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<td>0</td>
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<td>Capital</td>
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#### ASSETS.

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<th>Description</th>
<th>£</th>
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<tr>
<td>Balance of Account at Bankers</td>
<td>103</td>
<td>5</td>
<td>7</td>
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<tr>
<td>* in Treasurer's hands</td>
<td>61</td>
<td>9</td>
<td>6</td>
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<tr>
<td>Author's Excerpts</td>
<td>4</td>
<td>12</td>
<td>9</td>
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<tr>
<td>Arrears of Subscription</td>
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<tr>
<td>179 Shares in the Institute and Coal-trade Chambers Company,</td>
<td>4</td>
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<tr>
<td>Limited (at cost)</td>
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<td>Investment with the Institute and Coal-trade Chambers Company,</td>
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<td>400</td>
<td>0</td>
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<tr>
<td>Limited (Mortgage)</td>
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<tr>
<td>£11,478</td>
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By Arrears

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<tr>
<td></td>
<td>244</td>
<td>18</td>
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By Subscriptions paid in advance

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<th>s.</th>
<th>d.</th>
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<tr>
<td></td>
<td>78</td>
<td>10</td>
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£3,134 16 0
(Of the above amount, £1,484 is due to Life Subscriptions Account.)

Value of Transactions and other Publications, as per Stock Account  

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<th>Description</th>
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<tr>
<td>Books, Pictures, Maps, Furniture and Fittings</td>
<td>£5,150 0 0</td>
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<td></td>
<td>353 5 6</td>
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<td></td>
<td>11,478 17 4</td>
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</table>

We, having examined the above account with the books, vouchers and securities relating thereto, certify that, in our opinion, it is correct. We have accepted the assets, books, pictures, maps, etc., and Transactions and other Publications as valued by your Officials.

JOHN G. BENSON AND SONS,
CHARTERED ACCOUNTANTS.

Newcastle-upon-Tyne,
August 1st, 1903.

[xv]

LIST OF COMMITTEES APPOINTED BY THE COUNCIL, 1903-1904.

<table>
<thead>
<tr>
<th>Committee</th>
<th>Members</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finance Committee</td>
<td>Mr. T. W. Benson, Mr. T. E. Forster, Mr. J. B. Simpson</td>
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<tr>
<td></td>
<td>Mr. W. Cochrane, Mr. J. B. Simpson, Mr. J. G. Weeks</td>
</tr>
<tr>
<td></td>
<td>Mr. J. Daglish, Mr. J. G. Weeks, Sir Lindsay Wood, Bart</td>
</tr>
<tr>
<td></td>
<td>Mr. T. Douglas, Mr. J. H. Merivale, Sir Lindsay Wood, Bart</td>
</tr>
<tr>
<td>Library Committee</td>
<td>Mr. T. E. Forster, Mr. J. H. Merivale, Sir Lindsay Wood, Bart</td>
</tr>
<tr>
<td></td>
<td>Mr. George May, Mr. J. G. Weeks, Sir Lindsay Wood, Bart</td>
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<tr>
<td></td>
<td>Mr. R. S. Anderson, Mr. J. H. Merivale, Sir Lindsay Wood, Bart</td>
</tr>
<tr>
<td></td>
<td>Mr. T. Y. Greener, Mr. John Shiel, Sir Lindsay Wood, Bart</td>
</tr>
<tr>
<td>Prizes Committee</td>
<td>Mr. R. Donald Bain, Mr. T. E. Forster, Mr. J. H. Merivale, Sir Lindsay Wood, Bart</td>
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<tr>
<td></td>
<td>Mr. T. W. Benson, Mr. C. C. Leach, Mr. F. R. Simpson</td>
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<tr>
<td>Arrears Committee</td>
<td>Mr. W. Armstrong, Mr. M. H. Douglas, Mr. John Simpson</td>
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<td></td>
<td>Mr. R. Donald Bain, Mr. T. E. Forster, Mr. J. G. Weeks</td>
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<td></td>
<td>Mr. T. W. Benson, Mr. John Morison, Mr. J. G. Weeks</td>
</tr>
<tr>
<td>Coal-cutting Committee</td>
<td>Mr. R. Donald Bain, Mr. M. H. Douglas, Mr. John Simpson</td>
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<td></td>
<td>Mr. E. Bainbridge, Mr. T. E. Forster, Mr. John Morison</td>
</tr>
<tr>
<td></td>
<td>Mr. W. C. Blackett, Mr. T. Y. Greener, Mr. J. H. Nicholson</td>
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</table>
Mr M. Walton Brown.  Mr. Philip Kirkup.  Mr. Henry Palmer.
Mr. H. F. Bulman.  Mr. C. C. Leach.  Mr. R. F. Spence.
Mr. C. S. Carnes.  Prof. H. Louis.  Mr. E. O. Southern.
Mr. Fenwick Darling.  Mr. George May.  Mr. J. G. Weeks.

Reference Committee for Papers to Read.

(a) Coal Mining.
Mr. W. C. Blackett.  Mr. W. Logan.  Mr. John Simpson.
Mr. Benjamin Dodd.  Mr. George May.  Mr. A. L. Steavenson.
Mr. C. C. Leach.  Mr. Henry Palmer.

(b) Metalliferous Mining.
Mr. R. Donald Bain  Mr. W. Cochrane.  Mr. J. H. Merivale.
Mr. T. W. Benson.  Mr. J. J. C. Fernau.  Mr. A. L. Steavenson.
Prof. H. Louis.

(c) Geological.
Mr. R. Donald Bain  Prof. H. Louis.  Mr. John Simpson.
Prof. G. A. Lebour.  Mr. J. H. Merivale.  Mr. Jethro J. H. Teall

(d) Mechanical and Electrical Engineering.
Mr. W. C. Blackett.  Mr. C. C. Leach.  Hon. C. A. Parsons.
Mr. J. K. Guthrie.  Mr. J. H. Merivale.  Mr. A. L. Steavenson.
Mr. H. Lawrence.  Mr. John Morison.

(e) Civil Engineering.
Mr. W. Cochrane.  Prof. H. Louis.  Mr. J. B. Simpson.
Mr. T. E. Forster.  Mr. M. W. Parrington.  Mr. A. L. Steavenson.

(f) Chemical.
Prof. P. P. Bedson.  Mr. W. Cochrane.  Prof. H. Louis.
Sir Lowthian Bell, Bart.  Mr. Benjamin Dodd.

N. B. — The President is ex-officio on all Committees,

[xvi]

OFFICERS, 1903-1904.

---------

PAST-PRESIDENTS (ex-officio).
Sir LINDSAY WOOD, Bart., The Hermitage. Chester-le-Street.
Mr. JOHN DAGLISH, Rothley Lake, Cambo. R.S.O., Northumberland.
Sir ISAAC LOWTHIAN BELL, Bart., D.C.L., F.R.S., Rounton Grange, Northallerton.
Mr. WILLIAM COCHRANE. Oakfield House, Gosforth, Newcastle-upon Tyne.
Mr. JOHN BELL SIMPSON, Bradley Hall, Wylam-upon-Tyne.
Mr. ADDISON LANGHORNE STEAVENSON, Durham.
Mr. THOMAS DOUGLAS. The Garth, Darlington.
Mr. GEORGE MAY, The Harton Collieries, South Shields.
Mr. WILLIAM ARMSTRONG. Wingate, County Durham.
Mr. JOHN GEORGE WEEKS, Bedlington, R.S.), Northumberland.

PRESIDENT.
Mr. WILLIAM OUTTERSON WOOD, South Hetton, Sunderland.

VICE-PRESIDENTS.
Mr. RICHARD DONALD BAIN, H.M. Inspector of Mines, Durham.
Mr. CUTHBERT BERKLEY, Highfield House, Durham.
Mr. WILLIAM CUTHBERT BLACKETT, Acorn Close, Sacriston, Durham.
Mr. THOMAS EMMERSON FORSTER, 3, Eldon Square. Newcastle-upon-Tyne.
Mr. WILLIAM LOGAN, Langley Park, Durham.
Mr. JOHN HERMAN MERIVALE, Togston Hall, Acklington, Northumberland.

RETIRING VICE-PRESIDENT (ex-officio).
Mr. THOMAS WILLIAM BENSON, 24, Grey Street, Newcastle-upon-Tyne.

COUNCILLORS.
Mr. ROBERT SIMPSON ANDERSON, Benwell View, Bentinck Road. Newcastle-upon-Tyne.
Mr. BENJAMIN DODD, Bearpark Colliery, near Durham.
Mr. MATTHEW HECKELS DOUGLAS, Usworth Colliery, Washington, R.S.O., County Durham.
Mr. THOMAS YOUNG GREENER, West Lodge, Crook, Darlington.
Mr. JAMES KENNETH GUTHRIE, 73. Cleveland Road, North Shields.
Mr. THOMAS EDGAR JOBLING, Bebside, Northumberland.
Mr. HENRY LAWRENCE, 7 and 8, Post Office Chambers, Newcastle-upon-Tyne.
Mr. CHARLES CATTERALL LEACH, Seghill Colliery, Northumberland.
Mr. HENRY LOUIS, 11, Windsor Terrace, Newcastle-upon-Tyne.
Mr. JOHN MORISON, Cramlington House, Northumberland.
Mr. J. H. NICHOLSON. Cowpen Colliery Office, Blyth, Northumberland.
Mr. HENRY PALMER, Medomsley, R.S.O., County Durham.
Mr. MATTHEW WILLIAM PARRINGTON, Wearmouth Colliery, Sunderland.
Mr. JOHN SHIEL, Sniperley Hall, near Durham.
Mr. FRANK ROBERT SIMPSON. Hedgefield House, Blaydon-upon-Tyne.
Mr.-JOHN SIMPSON, Heworth Colliery, Felling, R.S.O., County Durham.
Mr. R. F. SPENCE, Backworth, R.S.O., Northumberland.
Mr. RICHARD LLEWELLYN WEEKS, Willington, County Durham.

TREASURER.
Mr. REGINALD GUTHRIE, Neville Hall, Newcastle-upon-Tyne.

SECRETARY.
Mr. M. WALTON BROWN. Neville Hall. Newcastle-upon-Tyne.
AUDITORS.
Messrs. JOHN G. BENSON and SONS, Newcastle-upon-Tyne.

BANKERS.
Messrs. LAMBTON and COMPANY, Newcastle-upon-Tyne,

LIST OF MEMBERS.
AUGUST 1. 1903.

PATRONS.
His Grace the DUKE OF NORTHUMBERLAND.
The Most Noble the MARQUIS OF LONDONDERRY.
The Right Honourable the EARL OF LONSDALE.
The Right Honourable the EARL OF DURHAM.
The Right Honourable the EARL GREY.
The Right Honourable the EARL OF WHARNCLIFFE.
The Right Reverend the LORD BISHOP OF DURHAM.
The Very Reverend the DEAN AND CHAPTER OF DURHAM.
WENTWORTH B. BEAUMONT, Esq.
BARON BARNARD.

HONORARY MEMBERS.
* Honorary Members during term of office only.

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Date of Election</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>J. B. ATKINSON, H.M. Inspector of Mines</td>
<td>Aug. 4, 1888</td>
</tr>
<tr>
<td></td>
<td>2, Devonshire Terrace, Newcastle-upon-Tyne</td>
<td></td>
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<tr>
<td>2</td>
<td>W. N. ATKINSON, H.M. Inspector of Mines</td>
<td>Aug. 4, 1888</td>
</tr>
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<td></td>
<td>Barlaston, Stoke-upon-Trent</td>
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<tr>
<td>3</td>
<td>R. DONALD BAIN, H.M. Inspector of Mines</td>
<td>Dec. 12, 1896</td>
</tr>
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<td></td>
<td>Durham</td>
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<tr>
<td>4</td>
<td>Prof. P. PHILLIPS BEDSON, Durham College</td>
<td>Feb. 10, 1883</td>
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<td></td>
<td>of Science, Newcastle-upon-Tyne.</td>
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<td></td>
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<td>Public Library, Newcastle-upon-Tyne</td>
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<td>5</td>
<td>THOMAS BELL, 15, The Valley, Scarborough</td>
<td>Dec. 12, 1896</td>
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<td>6</td>
<td>Prof. G. S. BRADY, Durham College of</td>
<td>Nov. 6, 1875</td>
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<td>Transactions, etc., sent to Mowbray Villa,</td>
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<td></td>
<td>Sunderland</td>
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<td>7</td>
<td>JOSEPH DICKINSON, 3, South-Bank, Sandy</td>
<td>Dec. 13, 1852</td>
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<td>Lane, Pendleton, Manchester</td>
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<td>Prof. WILLIAM GARNETT, 116, St. Martin's</td>
<td>Nov. 24, 1894</td>
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<td>9</td>
<td>Sir ARCHIBALD GEIKIE, Director-General of</td>
<td>Jun. 11, 1898</td>
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<tr>
<td></td>
<td>the Geological Survey of the United</td>
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<td></td>
<td>Kingdom, 28, Jermyn Street, London, S.W.</td>
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<td>10</td>
<td>JOHN GERRARD, H.M. Inspector of Mines</td>
<td>Jun. 11, 1892</td>
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<td>Worsley, Manchester</td>
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<td>11</td>
<td>FREDERICK AUGUSTUS GRAY, H.M. Inspector</td>
<td>Jun. 14, 1902</td>
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<tr>
<td></td>
<td>of Mines, 7, Victoria Square, Penarth,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>near Cardiff</td>
<td></td>
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<td>12</td>
<td>Rev. H. PALIN GURNEY, Principal, Durham</td>
<td>Jan. 19, 1895</td>
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<tr>
<td></td>
<td>College of Science, Roseworth, Gosforth,</td>
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<td></td>
<td>Newcastle-upon-Tyne</td>
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<td>13</td>
<td>HENRY HALL, H.M. Inspector of Mines</td>
<td>Mar. 4, 1876</td>
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<td>Rainhill, Lancashire</td>
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<td>14</td>
<td>Prof. A. S. HERSCHEL, Observatory House,</td>
<td>Aug. 3, 1872</td>
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<td></td>
<td>Slough, Bucks</td>
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<td>15</td>
<td>Prof. G. A. LEBOUR, Durham College of</td>
<td>Nov. 1, 1879</td>
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<td></td>
<td>Transactions, etc., sent to Radcliffe</td>
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<tr>
<td></td>
<td>House, Corbridge-upon-Tyne</td>
<td></td>
</tr>
</tbody>
</table>
MEMBERS.
Marked * have paid life composition.

Date of Election.

1 Aburrow, Charles, P.O. Box 534, Johannesburg, Transvaal
Feb. 13, 1892
2 Adams, Henry Hopper, Takapuna, Auckland, New Zealand
April 10, 1897
3 Adams, Phillip Francis Burnet, Surveyor-General for the Orange River Colony,
Government Office, Bloemfontein, Orange River Colony, South Africa
Oct. 12, 1901
4 Adamson, Thomas, Kurhurbaree Colliery, Giridih, Bengal, India
Feb. 10, 1894
5 Aitken, Ernest, Mo i Ranen, Helgeland, Norway
Aug. 5, 1899
6 Aitken, Henry, Falkirk, N. B.
March 2, 1865
7 Aitken, Henry, Falkirk, N. B.
March 2, 1865
8 Aitken, Henry, Falkirk, N. B.
March 2, 1865
9 Allan, John F., Apartado de Correos, No. 121, Mexico, D.F.
A.M. Feb. 10, 1883
10 Allison, J. J. C., Woodland Collieries, Butterknowle, R.S.O., Co. Durham
A.M. Feb. 13, 1886
11 Allison, J. J. C., Woodland Collieries, Butterknowle, R.S.O., Co. Durham
A.M. Feb. 13, 1886
12 Anderson, C. W., Cleadon Park, Sunderland
Aug. 21, 1852
13 Anderson, R. Hay, Apartado Postal, 806, Mexico, D.F.
Aug. 4, 189
14 Anderson, R. S., Benwell View, Bentinck Road, Newcastle-upon-Tyne (Member
of Council)
S. June 9, 1883
A.M. Aug. 4, 1888
15 Andrews, Arthur, 20, Carlyon Street, Sunderland
Aug. 2, 1902
16 Angwin, B., 7, Dean Terrace, Liskeard, Cornwall
Nov. 24, 1894
17 Appleby, Harry Walton, The Robinson Randfontein Gold Mining Company,
Limited. Mine Office, Randfontein, Transvaal
Oct. 8, 1898
18 Appleby, W. R., Minnesota School of Mines, The University of Minnesota,
Minneapolis, Minnesota, U.S.A.
April 14, 1894
19 Archer, T., 11, Regent Terrace, Gateshead-upon-Tyne
July 2, 1872
20 Archer, William, Victoria Garesfield, Lintz Green, Co. Durham
A. Aug. 6, 1892
M. Aug. 3, 1895
21 Armstrong, Henry, Collingwood Buildings, Collingwood Street, Newcastle-upon-Tyne
   A. M June 8, 1889
22 Armstrong, William, Wingate, Co. Durham (Past-President, Member of Council)
   M. April 14, 1883
23 Ashcroft, Edgar Arthur, 82, Victoria Street, London, S.W.
   S. April 7, 1867
24 Ashmore, G. Percy, 59, Lansdowne Street, Hove, Sussex
   M. Aug. 6, 1870
25 Ashworth, John, S. Kino-Street, Manchester
   Feb. 13, 1897
26 Atherton, James, 13, Mawdsley Street, Bolton
   April 25, 1896
27 Atherton, Thomas William Turner, Rosslyn, Elmers End Road, Anerley, London, S.E.
   A.M. June 11, 1898
28 Atkinson, John Boland, H.M. Inspector of Mines, 2, Devonshire Terrace,
   Newcastle-upon-Tyne
   M. Dec. 10, 1898
29 Atkinson, R. H. M. Buddle
   Oct. 11, 1902
30 Aubrey, R. G, Belgrave, Trent Valley Road, Lichfield
   Date of Election and
   of Transfer.
31 Austin, W. Lawrence, P.O. Box 941, Denver, Colorado, U.S.A.
   Aug. 3, 1895
32 Auton, Robert, Birtley, Co. Durham ..
   A.M. June 7, 1879
33 Bailes E. T., Wingate, Ferryhill
   M June 8, 1889
34 Bailes, T., Jesmond Gardens, Newcastle-upon-Tyne
   Oct. 7, 1858
35 Bailey, Archibald Duncan, c/o The Tharsis Sulphur and Copper Company,
   Limited, 136, West George Street, Glasgow
   Oct. 8, 1898
36 Bailey, Edward Trenholm, Padang-Sidempoean, Sumatra
   A.M. June 13, 1896
   M June 12, 1897
38 Bain, R. Donald, H.M. Inspector of Mines, Durham (Vice-President, Member of Council)
   S. March 1, 1873
39 Bainbridge, Emerson, 4, Whitehall Court, London, S.W.
   M. Aug. 5, 1876
40 Bainbridge, Emerson Muschamp, Ashfield House, Sutton Road, Hucknall
   Huthwaite
41 Baldwin, Ivo William, Oakleigh, Ruardean, Gloucestershire
   Feb. 10, 1900
42 Banks, Thomas, 60, King Street, Manchester. Transactions sent to 17, Park
   Avenue, Eccles, near Manchester
43 Barber, George Marriott, 51a, Waldeck Avenue, Bedford
   Aug. 4, 1877
44 Barnard, Robert, Bhalgara, Jharia P.O., E.I. Railway, Bengal, India
   April 28, 1900
45 Barrass, Matthew, Wheatley Hill Colliery Office, Thornley, R.S.O., Co. Durham
   Dec. 11, 1897
46 Barrett, C. R., Whitehill Hall, Chester-le-Street
   S. Nov. 7, 1874
47 Barrow, William, Seaton Burn Colliery, Dudley, R.S.O., Northumberland
   A.M. Aug. 7, 1880
48 Bartholomew, C. W., Blakesley Hall, near Towcester, Northants
   M. Dec. 11, 1886
49 Barton, Henry, Central Bank Chambers, Leeds
   Feb. 8, 1902
50 Batchelor, Owen Salusbury, Kamloops, British Columbia
   Dec. 4, 1875
51 Bates, Sidney, The Grange, Prudhoe-upon-Tyne
   Oct. 13, 1900
52 Batchelor, Owen, newly elected.
   June 8, 1901
53 Batchelor, Owen, newly elected.
   M. June 8, 1895
52 Bates, Thomas L., Cranbrook, Corrimal Street, Wollongong, New South Wales
Feb. 12, 1898
53 Batey, John, St. Edmunds, Coleford, Bath
Dec. 5, 1868
54 Batey, John Wright, 8, The Terrace, Ovingham-upon-Tyne, Northumberland
Feb. 9, 1901
55 Baumgartner, W. O., South Hetton, Sunderland
S. Sept. 6, 1879
M. Aug. 3, 1889
56 Bawden, James Barnet, 142, Vickery's Chambers, 82, Pitt Street, Sydney, New South Wales
Dec. 11, 1897
57 Bayldon, Daniel Henry, 13, Austin Friars, London, E.C.
Feb. 8, 1890
58 Bayliss, Ernest J., No. 12, Castello, Madrid, Spain
April 13, 1901
59 Bell, Joseph Fenwick, Harraton, Chester-le-Street, Co. Durham
April 12, 1902
60 Bell, Sir Isaac Lowthian, Bart., D.C.L., F.R.S., Rounton Grange, Northallerton
July 6, 1854
61 Bell, Reginald, The Equitable Coal Company, Limited, Barakar, E.I.R., Bengal, India
Dec. 13, 1902
62 Bell, Walter, c/o Pyman, Bell and Company, Hull
S. Oct. 8, 1889
M. Feb. 10, 1894
63 Bennett, Alfred H., Dean Lane Collieries, Bedminster, Bristol
A.M. April 10, 1886
M. June 8, 1889
64 Bennett, Henry, Rio Tinto Mines, Huelva, Spain
Dec. 9 1899

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65 Benson, J. G., 12, Grey Street, Newcastle-upon-Tyne
Nov 7, 1894
66 Benson, T. W., 24, Grey Street, Newcastle-upon-Tyne. (Retiring Vice-President, Member of Council)
Aug. 2, 1866
67 Berkley, Cuthbert, Highfield House, Durham (Vice-President, Member of Council)
Aug 21 1852
68 Berkley, Frederick, Hamsterley Colliery, Ebchester, R.S.O., Co. Durham
A.M. Dec. 9, 1882
M June 8, 1889
A.M. Aug. 7, 1880
M June 8, 1889
69 Berkley, P. W., Marley Hill, Swalwell, R.S.O., Co. Durham
S.Feb. 14 1874
A.M. Dec. 9, 1882
M June 8, 1889
A.M. Aug. 7, 1880
M June 8, 1889
70 Bigg-Wither, Harris, The Mount, Cathurst, near Wigan, Lancashire
Jan 19 1895
71 Bigland, Hubert Hallam, The Stones, Whitley, R.S.O., Northumberland
Dec. 14 1901
72 Bigland, J., Henknowle, Bishop Auckland
June 3, 1857
73 Binks, John Charles, Desford Coal Company, Limited, Bagworth, near Leicester
April 28, 1900
74 Black, W., Lovaine House, Lovaine Place, Newcastle-upon-Tyne
April 2, 1870
75 Blackburn, William Stevenson, Aire Villas, Astley, Woodlesford, near Leeds
Dec. 10, 1887
76 Blackett, W. C., Acorn Close, Sacriston, Durham (Vice-President, Member of Council)
S. Nov. 4, 1876
A.M. Aug. 1, 1885
M. June 8, 1889
77 Blaiklock, Thomas Henderson, Newton Cap Colliery, near Bishop Auckland
April 13, 1901
78 Blakemore, W., 10, St. Luke Street, Montreal, Canada
Oct. 12, 1895
79 Bledsoe, John Frank, P.O. Box 996, Seattle, Washington, U.S.A
Aug. 2, 1902
80 Bolam, Philip, Seaton Burn Colliery, Newcastle-upon-Tyne
Dec. 12, 1891
M. Aug. 3, 1891
81 Bolton, Edgar Ormerod, Executor of Colonel Hargreaves, Colliery Offices, Burnley
April 12, 1890
82 Bolton, H. H., Newchurch Collieries, near Manchester
Dec. 5, 1868
83 Borlase, W. H., Greenside Lodge, Glenridding, near Penrith. Aug. 4, 1894
84 Bousfield, Thomas, Wallsend Colliery, Wallsend, New South Wales. June 14, 1902
85 Bowles, Joseph George, Lyle Street, Ladysmith, Natal, South Africa. Oct. 12, 1901
86* Bracken, Thomas Wilson, 5, North Terrace, Newcastle-upon-Tyne. Oct. 14, 1899
87 Bradford, George, Newton House, Darlington. Oct. 11, 1890
89 Bramwell, Hugh, Great Western Colliery, near Pontypridd, Glamorganshire. S. Oct. 4, 1879
90 Braschi, Victor M., Bajos de Portacoeli, No. 11, Apartado, Mexico, Mexico. A.M. Feb. 12, 1898
91 Breakell, Thomas, Brassington, near Derby. Feb. 11, 1893
92 Brewer, William Morten, P.O. Box, 571, Victoria, British Columbia. April 2, 1898
93* Brinell, Johan August, Fagersta, Sweden. June 9, 1900
94 Britten, T. J., P.O. Box 494, Johannesburg, Transvaal. June 21, 1894
95 Broad, Wallace, Department of Mines, Imperial Chinese Railway and Mines Administration, 111, Bubbling Well Road, Shanghai, China. April 28, 1900
96 Broja, Geheimer Bergrath Richard, 77, Kaiser-Wilhelm-strasse, Breslau, Germany. Nov. 6, 1880.
97 Bromly, A. H., Oakley, Snakes Lane, Woodford Green, Essex. Nov 24, 1894
98 Broome, George Herbert, Adstock, Adelaide Road, Brockley, London, S.E. Oct. 9, 1897

99* Brough, Bennett H., Cranleigh House, near Addlestone, Surrey. A.M. Dec. 10, 1887
100 Brough, Thomas, New Seaham Colliery, Sunderland. M. June 8, 1889
101 Brown, Douglas Philip. June 11, 1898
102 Brown, Jethro Longridge, Murton Colliery, Sunderland. Aug. 3, 1901
103 Brown, Myles, Shampore Colliery, Nirshachatti P.O., via Barakar, E.I.R., Bengal, India. June 8, 1901
104 Brown, M. Walton, 10, Lambton Road, Newcastle-upon-Tyne (Secretary, Member of Council). S. Oct. 7, 1871
105 Brown, Richard Henry, Sydney Mines, Cape Breton, Nova Scotia, Canada. Feb. 9, 1901
106 Brown, Robert Oughton, Elswick Collieries, Newcastle-upon-Tyne. S. Oct. 8, 1892
107 Brown, Thomas Forster, Springfort, Stoke Bishop, Bristol. A. Aug. 3, 1895
108 Brown, Westgarth Forster, Cefn Coed, Malpas, near Newport, Monmouthshire. M. Oct. 12, 1901
109 Bruce, John, Port Mulgrave, Hinderwell, R.S.O., Yorkshire. Aug. 1, 1861
110 Bryham, William, Bank House, Wigan. S. Aug. 6, 1887
111 Buckle, Christopher Ernest, Egerton Place, 71, Rouge Bouillon, St. Heliers, Jersey. M. Aug. 5, 1893
112 Buglass, J., Stobswood, via Acklington, Northumberland. S. Feb. 14, 1874

[xxi]
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<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Address</th>
<th>Date of Election and Transfer</th>
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<tr>
<td>113</td>
<td>Bulman, E. H.</td>
<td>The Red and White Rose Gold Mining Company, P.O. Box 414, Bulawayo, Rhodesia, South Africa</td>
<td>Feb. 13, 1892</td>
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<tr>
<td>114</td>
<td>Bulman, Harrison Francis</td>
<td>Barcus Close, Burnopfield, R.S.O., Co. Durham</td>
<td>S. May 2, 1874</td>
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<td>A.M. Aug. 6, 1881</td>
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<td>M. June 8, 1889</td>
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<td>115</td>
<td>Bunkell, Henry B.</td>
<td>P.O. Box 1463, Johannesburg, Transvaal</td>
<td>April 8, 1893</td>
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<td>116</td>
<td>Bunning, C. Z.</td>
<td>c/o The British Consular Agent, Constantinople, Turkey</td>
<td>S. Dec. 6, 1873</td>
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<td>A.M. Aug. 5, 1882</td>
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<td>M. Oct. 8, 1887</td>
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<td>A. Aug. 4, 1894</td>
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<td>M. Aug. 3, 1895</td>
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<td>118</td>
<td>Burn, Frank H.</td>
<td>Bolam Hall, Meldon, Morpeth, Northumberland</td>
<td>S. Oct. 11, 1873</td>
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<td>M. Aug. 4, 1877</td>
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<td>119</td>
<td>Burns, David</td>
<td>Vallum View, Burgh Read, Carlisle</td>
<td>May 5, 1877</td>
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<td>120</td>
<td>Burrows, J. S.</td>
<td>Green Hall, Atherton, near Manchester</td>
<td>S. Oct. 11, 1873</td>
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<td>M. Aug. 4, 1877</td>
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<td>121</td>
<td>Burton, Joseph James</td>
<td>Rosecroft, Nunthorpe, R.S.O., Yorkshire</td>
<td>April 12, 1902</td>
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<td>122</td>
<td>Butt, Thomas Philip Edward</td>
<td>P.O. Box 538, Johannesburg, Transvaal</td>
<td>Dec. 11, 1897</td>
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<td>123</td>
<td>Burrows, J.</td>
<td>20, Bishopsgate Street Within, London, E.C</td>
<td>Feb. 10, 1894</td>
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<td>124</td>
<td>Cameron, Ian</td>
<td>The Tharsis Sulphur and Copper Company, Limited, 136, West George Street, Glasgow</td>
<td>Aug. 4, 1891</td>
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<tr>
<td>125</td>
<td>Campbell, H. H.</td>
<td>Sutton Hall, St. Helen's, Lancashire</td>
<td>Jan. 19, 1895</td>
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<td>126</td>
<td>Cameron-Johnston, R. C.</td>
<td>Nelson, British Columbia</td>
<td>Nov. 24, 1894</td>
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<td>127</td>
<td>Carey, Gaspard</td>
<td>Nile Valley Company, c/o Bank of Egypt, Assouan, Egypt</td>
<td>Oct. 12, 1901</td>
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<td>Oct. 11, 1902</td>
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<td>128</td>
<td>Carnes, Charles Spearman</td>
<td>Howlish Hall, Bishop Auckland</td>
<td>Aug. 1, 1891</td>
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<td>129</td>
<td>Carr, Wilson Story</td>
<td>Collingwood Buildings, Newcastle-upon-Tyne</td>
<td>Dec. 14, 1901</td>
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<td>130</td>
<td>Carroll, James</td>
<td>Charters Towers, Queensland, Australia</td>
<td>Dec. 10, 1898</td>
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<td>131</td>
<td>Chambers, Arthur Leo</td>
<td>P.O. Box 83, Gwelo, Rhodesia, South Africa</td>
<td>Dec. 9, 1893</td>
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<td>132</td>
<td>Chambers, J. S.</td>
<td>5, Jorkovskaja, St. Petersburg, Russia</td>
<td>Feb. 8, 1902</td>
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<td>135</td>
<td>Champneys, Arthur Thornton</td>
<td>Tower Hill, Middleton St. George, R.S.O., Co. Durham</td>
<td>S. Nov. 6, 1880</td>
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<td>136</td>
<td>Chandley, Charles</td>
<td>120, Musters Road, West Bridgford, Nottingham</td>
<td>A. Aug. 3, 1889</td>
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<td>M. Apr 4, 1903</td>
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<td>Dec. 13, 1902</td>
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143 Chappel, Walter Richard Haighton, Batu Gajah, Perak, Straits Settlements  Feb. 14, 1903
144 Charlton, A. G., 5, Avonmore Road, Kensington, London, W.  Aug. 6, 1892
145 Charlton, William, Guisbrough, Yorkshire  Feb. 12, 1898
146 Charlton, William, Linares, Provincia de Jaen, Spain  April 8, 1893
147 Charlton, William John, Ashtoning Colliery, Morpeth, Northumberland  April 25, 1896
148 Cheesman, E. Taylor, Claravale Colliery, Ryton-upon-Tyne  A. Aug. 2, 1890
           M. Aug. 6, 1892
149 Cheesman, Herbert, Hartlepool  Aug. 6, 1892
150 Cheesman, I. T., Throckey Colliery, Newburn, R.S.O., Northumberland  Feb. 1, 1873
151 Cheesman, Nicholas, Throckey Colliery, Newburn, R.S.O., Northumberland  Dec. 8, 1900
152 Chester, Edward Descou, 120, Bishopsgate Street Within, London, E.C.  Aug. 3, 1901
153 Childe, Henry S., 59, Westgate, Wakefield  A.M. Feb 12, 1887
           M. Aug. 3, 1889
154 Claghorn, Clarence R., Wehrum, Indiana County, Pennsylvania, U.S.A.  Aug. 5, 1899
155 Clark, Henry, Inglenook, Norton, Stockton-upon-Tees  April 8, 1899
156 Clark, Robert, Hyderabad Deccan Company, Limited, Secunderabad, India  Feb. 15, 1896
157 Clark, R. B., Springwell Colliery, Gateshead-upon-Tyne  S. May 3, 1873
           M. Aug. 4, 1877
158 Clark, William, Cranbury Lodge, Park Lane, Wigan  Dec. 10, 1898
159 Clark, William Henry, 108, Cantonment, Kamthee, Central Provinces, India  April 28, 1900
160 Claudet, Arthur C., 6 and 7, Coleman Street, London, E.C.  Aug. 3, 1895
161 Clough, James, Bomarsund House, Bomarsund, Bedlington, R.S.O., Northumberland  S. April 5, 1873
           A.M. Aug. 3, 1878
           M. June 8, 1889
162 Clough, Ralph, Kilton Mines, Brotton, R.S.O., Yorkshire  Feb. 14, 1903
163 Cochrane, B., Low Gosforth House, Newcastle-upon-Tyne  Dec. 6, 1866
164 Cochrane, W., Oakfield House, Gosforth, Newcastle-upon-Tyne (Past-President, Member of Council)  Aug. 1, 1861
165 Cochlan, F. M., Catorce, S.L. P., Mexico  Dec. 9, 1893
166 Colley, John, Green Mine, Indwe, Cape Colony, South Africa  Feb. 9, 1901

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167*Collins, Horatio, Paarl Central Gold Mining Company, Limited, P.O. Box 245, Johannesburg, Transvaal  Aug. 4, 1894
168*Collins, H. B., Auchinbothie, Kilimacolm, R.S.O., Renfrewshire  April 14, 1894
169 Colquhoun, T. Grant, Peal Bank House, Acklington, Northumberland  Dec. 14, 1898
170 Commans, R. E., 6, Queen Street Place, London, E.C.  Nov. 24, 1894
175 Cook, J. Watson, Binchester Hall, Bishop Auckland  Oct. 14, 1893
176 Cooke, Henry Moore Annesley, The Ooregum Gold Mining Company of India, Limited, Oorgaum, Province of Mysore, India  Dec. 12, 1896
177 Corbett, V. W., Chilton Moor, Fence Houses  Sept. 3, 1870
178 Corlett, George Stephen, Wigan  Dec. 12, 1891
179 Corning, Christopher Robert, 36, Wall Street, New York City, U.S.A  June 14, 1902
180 Coste, Eugene, 34, Madison Avenue, Toronto, Ontario, Canada  June 9, 1900

Date of Election and of Transfer.
181 Coulson, F., Sherburn. Durham  
S. Aug. 1, 1868  
M. Aug. 2, 1873  
June 8, 1889  

182 Coulthard, Francis, c/o Pure Salt, Limited, Remolinos. Por Pedrola, Zaragoza, Espana  
April 8, 1899  

183 Coulthard, John, Brunnton, Greymouth, New Zealand  
Dec. 9, 1899  

184 Cowper-Coles, Sherard Osborn, Grosvenor Mansions, Victoria Street, Westminster, London, S.W.  

185 Cox, John H., 10. St. George's Square, Sunderland  
Feb. 6, 1875  
Aug. 5, 1899  
Dec. 8, 1900  

186 Crankshaw, Joseph, 11, Ironmonger Lane, London, E.C.  

187 Craster, Walter Spencer, P.O. Box 326, Bulawayo, Rhodesia, South Africa  
June 8, 1889  

188 Craven, Hiram. Jun., Sunderland  
April 12, 1890  

189 Crawford, James, Mill, Shildon House, Shildon, Co. Durham  
Feb. 14, 1903  

190 Crighton, John, Bramhall House, Hazel Grove, Stockport  
Dec. 9, 1899  

191 Crofton, Charles, 17, Albany Gardens, Whitley, R.S.O., Northumberland  
Oct. 11, 1902  

192 Crookston, Andrew, P.O. Box 326, Bulawayo, Rhodesia, South Africa  
Dec. 8, 1900  

193 Currie, Walter, P.O. Box 220, Bulawayo, Rhodesia, South Africa  
Dec. 14, 1895  

194 Crosby, Arthur, Douglas Colliery, Limited, Balmoral, Transvaal  
A. M. Aug. 7, 1897  
M. April 12, 1902  

195 Cross, William Haslam, 77, King Street, Manchester  
Feb. 8, 1902  

196 Croudace, Thomas, Lamton Lodge, Lamton, Newcastle, New South Wales  
Nov. 6, 1862  

197 Cruz y Diaz, Emiliano de la, Ribas, Provincia de Gerona, Spain  
June 14, 1902  

198 Currie, Walter, P.O. Box 220, Bulawayo, Rhodesia, South Africa  
April 25, 1896  

199 Curry, John, The Lyons, Hettonde-Dole, R.S.O., Co. Durham  
Dec. 13, 1902  

200 Cutten, William Henry, Dunedin, New Zealand  
Aug. 5, 1899  

201 Daggar, Henry James, c/o W. D. Jones, High Street, Marrickville, New South Wales  
Oct. 12, 1901  

202 Daglish, John, Rothley Lake, Cambo, R.S.O., Northumberland (Past-President, Member of Council)  
Aug. 21, 1852  

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<table>
<thead>
<tr>
<th>Name</th>
<th>Date of Election and Transfer</th>
<th>Date of Transfer</th>
<th>Date of Transfer</th>
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<tbody>
<tr>
<td>204 Daglish, William Charlton, Littleburn Colliery, near Durham</td>
<td>Dec. 12, 1896</td>
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<td>206 Dale, Sir David, Bart., West Lodge, Darlington</td>
<td>Feb 5, 1870</td>
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<td>207 Dan, Takuma, Mitsui Mining Company, 1, Suruga-cho, 70 Nihonbashi-ku, Tokyo, Japan</td>
<td>April 14, 1894</td>
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<td>208 Daniel, Peter Francis, Greymouth, New Zealand</td>
<td>April 8, 1893</td>
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<td>209 Danes, Andrew, P.O. Box 83, Newcastle, Natal, South Africa</td>
<td>Aug. 3, 1901</td>
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<td>210 Darby, J. H., Pen y Garth, Brymbo, Denbighshire</td>
<td>Feb. 9, 1895</td>
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<td>211 Darling, Fenwick, Eldon Colliery, Eldon, Bishop Auckland</td>
<td>Nov. 6, 1875</td>
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<td>212 Darlington, James, Black Park Colliery, Ruabon, North Wales</td>
<td>S. Nov. 7, 1874</td>
<td>M. Aug 4, 1877</td>
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<td>213 Davey, George, c/o The Mount Boppy Gold Mining Company, Limited, Boppy Mount, New South Wales.</td>
<td>June 10, 1893</td>
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<td>214 Davies, David, Cowell House, Llanelly, South Wales</td>
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<td>215 Davies, Thomas William, P.O. Box 5207, Johannesburg, Transvaal</td>
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<td>216 Davies, William, Llanhilleth House, Llanhilleth, R.S.O., Monmouthshire</td>
<td>Dec. 13, 1902</td>
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<td>217 Davies, William Stephen, The Poplars, Mountain Ash.</td>
<td>Feb 14, 1903</td>
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<td>218 Davis, Charles Henry, 99, Cedar Street, New York City, U.S.A</td>
<td>Oct. 13, 1900</td>
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<td>219 Davis, Kenneth. Bebside Colliery, Northumberland</td>
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220 Daw, Albert William, 11, Queen Victoria Street, London, E.C. June 12, 1897
222 Dees, J. Gibson, Floraville, Whitehaven Oct. 13, 1883
223 Dees, R. R., Newcastle-upon-Tyne Oct. 7, 1891
                       New South Wales
                      Square, Johannesburg, Transvaal
226 Dickinson, Arthur, Warham Road, South Croydon, Surrey April 14, 1894
                       .
228* Dingwall, William Burlston-Abigail, Apartado, 113, Matehuala, S.L.P., Aug. 4, 1900
                  Mexico
229 Ditmas, Francis Ivan Leslie, Rosedale Abbey, near Pickering, Yorkshire A. June 11, 1898
                       M. June 14, 1902
230 Dives, Robert, Industries Office, Acutts Arcade, Durban, Natal, South Africa Feb. 8, 1902
231 Devon, D. W., Lumphsey Mines, Brotton, Saltburn-by-the-Sea Nov. 2, 1872
233 Dixon, Joseph Armstrong, Shilbottle Colliery, Lesbury, R.S.O., Dec. 14, 1901
                       Northumberland
234* Dixon, James S., Fairleigh, Bothwell, N.B. Aug. 3, 1878
235 Dixon, R., Sankey Wire Mills and Ropeworks, Warrington June 5, 1875
236 Dixon, William, Cleator, Cumberland April 10, 1897
237 Dobb, T. G., Brick House, West Leigh, near Manchester Dec. 8, 1894
238 Dobbs, Joseph, Jarrow Colliery, Castlecomer, Co. Kilkenny April 14, 1894
239 Dodd, Benjamin, Bearpark Colliery, near Durham (Member of Council) S. May 3, 1866
                       M. Aug. 1868
240 Dodd, M . A.M. Aug. 7, 1880
                       M. June 8, 1889
241 Doise, Sosthenes, Chaton (Seine et Oise), France June 14, 1902
242*Donkin, W., Vereeniging Estates, Vereeniging, Transvaal S. Sept. 2, 1876
                       A.M. Aug. 1, 1889
                       M. June 8, 1889
243 Dormand, Ralph Brown, Cambois House, Cambois, Blyth A. Dec. 9, 1893
                       M. Aug. 3, 1901

244* Douglas, C. P., Thornbeck Hill, Carmel Road, Darlington March 6, 1869
245 Douglas, James, 99, John Street, New York City, U.S.A. Oct. 14, 1899
                       (Member of Council) M. Aug. 3, 1889
247 Douglas, T., The Garth, Darlington (Past-President, Member of Council) Aug. 21, 1852
248 Doyle, Patrick, Indian Engineering, 7, Government Place, Calcutta, India. A.M. March 1, 1879
                      Transactions sent to c/o F. E. Robertson, 8, Great George Street, Westminster, M. Aug. 3, 1889
                      London, S.W
249 Dunbar-Anderson, Kingsley, The Bungalow, Pretoria Street, Johannesburg, Dec. 8, 1900
                       Transvaal
250 Dyson, T. Ingleby, The Lloyd Copper Company, Limited, Burraga, New South Feb. 9, 1895
                       Wales
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<th>Date of Election</th>
<th>Date of Transfer</th>
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<td>251</td>
<td>Eastlake, Arthur W.</td>
<td>Caenwood House, Grove Road, Clapham Park, London, S.W</td>
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<td>Alliance Jute Mills, Samnugger, Bengal, India</td>
<td>Dec. 14, 1901</td>
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<td>253</td>
<td>Ede, Henry Edward</td>
<td>c/o C. A. Gibbes, English Club, Iquique, Chile</td>
<td>July 14, 1896</td>
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<td>254</td>
<td>Eden, C. H.</td>
<td>Penalit, Sketty, R.S.O., Glamorganshire</td>
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<td>Maindy Pit, Ocean Coal Company, Ton Pentre, South Wales</td>
<td>Feb. 9, 1895</td>
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<td>Edwards, Herbert Francis</td>
<td>104, Stanwell Road, Penarth, Glamorganshire</td>
<td>Oct. 12, 1901</td>
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<td>Eissler, Manuel</td>
<td>46, Rue Vital, Passy, Paris</td>
<td>Feb. 15, 1896</td>
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<td>258</td>
<td>Eliet, Francis Constant Andre Benoni</td>
<td>Elie du, Controleur des Mines, Ambelaramo, Province de Fianarantsoa, Madagascar</td>
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<td>Ellis, W. R.</td>
<td>, Wigan</td>
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<td>Eltringham, George</td>
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<td>Brandon Colliery, Durham</td>
<td>Oct. 13, 1888</td>
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<td>Embleton, H. C.</td>
<td>Central Bank Chambers, Leeds</td>
<td>April 14, 1894</td>
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<td>264</td>
<td>Embleton, T. W.</td>
<td>The Cedars, Methley, Leeds</td>
<td>S. Sept, 2, 1865</td>
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<td>Engel, Konrad Ernst Richard</td>
<td>Friedrichstrasse, 2, Essen, Ruhr, Germany</td>
<td>Apr 28, 1900</td>
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<td>266</td>
<td>English, John</td>
<td>Garesfield Colliery, High Spen, Lintz Green, R.S.O., Co. Durham</td>
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<td>Epton, W. Martin</td>
<td>Government Inspector of Machinery, Mines Department, Winchester House, Johannesburg, Transvaal</td>
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<td>268</td>
<td>Esuman-Gwira, John Buckman</td>
<td>Cape Coast Castle, West Africa</td>
<td>April 2, 1898</td>
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<td>270</td>
<td>Evans, George Henry</td>
<td>Breckenridge, Colorado, U.S.A.; and Bohemian Club, San Francisco, California, U.S.A.</td>
<td>June 9, 1900</td>
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<td>271</td>
<td>Evans, Lewis</td>
<td>New Modderfontein Gold Mining Company, Limited, Mine Office, Benoni, Transvaal</td>
<td>Oct. 14, 1893</td>
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<td>272</td>
<td>Everard, J. B.</td>
<td>6, Millstone Lane, Leicester</td>
<td>March 6, 1869</td>
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<td>273</td>
<td>Fairley, James</td>
<td>Craghead and Holmside Colliery, Chester-le-Street</td>
<td>A.M. Aug. 7, 1880</td>
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<td>274</td>
<td>Fellows, Alfred</td>
<td>The Bede Metal and Chemical Company, limited, Hebburn, Newcastle-upon-Tyne</td>
<td>June 13, 1896</td>
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<td>275</td>
<td>Fenwick, Barnabas</td>
<td>37, Osborne Road, Newcastle-upon-Tyne</td>
<td>Aug. 2, 1866</td>
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<td>276</td>
<td>Fergie, Charles</td>
<td>Drummond Colliery, Westville, Nova Scotia</td>
<td>Dec. 9, 1893</td>
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Date of Election and Date of Transfer.
285 Fisher, Edward K., Blaina Lodge, Llandebie, R.S.O., Carmarthenshire  
A.M. Aug. 2 1884

286 Fletcher, James, Whickham and Bullock Island Coal Company, Limited,  
Carrington, New South Wales  
Dec. 9, 1893

287 Fletcher, Lancelot. Brigham Hill. Cockermouth  
A.M. April 14, 1888

288 Fletcher, Leonard Ralph, The Hindles, Atherton, near Manchester  
A.M. Aug. 5, 1899

289*Fletcher, Walter, The Hollins, Bolton, Lancashire  
Dec. 14 1895

290 Flint, John, Radcliffe House, Acklington, Northumberland  
Jan. 19, 1895

291 Ford, Make, Washington Colliery, Washington Station, Co. Durham  
Aug. 3, 1895

292 Ford, Stanley H., P.O. Box 2056, Johannesburg, Transvaal  
June 10, 1893

293 Forrest, J. C, Holly Bank Colliery, Essington. Wolverhampton  
April 12, 1884

294 Forster, Alfred Llewellyn, 5, Haldane Terrace, Newcastle-upon-Tyne  
June 8, 1901

295 Forster, John Henry Bacon, Cramlington Colliery, Northumberland  
S. Nov. 24, 1894

296 Forster. Richard Percival, Mount Pleasant. Spennymoor, R.S.O., Co. Durham  
M. Feb. 10, 1900

297 Forster. Thomas E., 3, Eldon Square, Newcastle-upon-Tyne (Vice-President,  
Member of Council)  
A.M. Aug. 1, 1885

298 Foster, Clement Le Neve, Royal College of Science, South Kensington,  
London, S.W.  
Feb. 14,1903

299 Foster, John Sutherland, Blaenau Festiniog, North Wales  
Dec. 9, 1899

300 Fox, George Charles, P.O. Box 1961, Johannesburg, Transvaal  
Feb. 14, 1903

301 Frecheville, William, North Breach Manor, Ewhurst. Surrey  
Feb. 15, 1896

302 Freeland, Francis Theodore, P.O. Box 1016, Aspen, Colorado, U.S.A  
June 14, 1902

303 Fryar, John William, Sherwood Colliery, Mansfield  
A. June 14, 1890

304 Fryar, Mark, Denby Colliery, Derby  
M. June 12, 1897

305 Fryar, William, Inspector of Mines, Brisbane, Queensland, Australia  
M. June 8, 1889

306 Fryer, George Kellett, Newfield Colliery, Willington, Durham  
Dec 14,1901

307 Galloway, T. Lindsay, 43, Mair Street, Plantation, Glasgow  
Sept. 2, 1876

308 Galloway William, Cardiff  
April 23, 1887

Bishopsgate Street Within, London,  
S. Oct. 2, 1880

310 Garcia, Telesforo, Jim., P.O. Box 463, City of Mexico, Mexico  
M. Oct. 10,1891

311 Gardiner, E. T., Hoppyland House, Albert Hill, Bishop Auckland  
Dec 13, 1902

312 Gascon y Miramon, Antonio, 36, Serrano, Madrid, Spain  
M. Aug. 2, 1902

313 Geddes, George H., 21, Young Street. Edinburgh  
Oct. 1, 1881

S. March 5, 1870

315 Gifford, Henry J., Minas de Passagem, Ouro Preto, Brazil  
M. Aug. 1,1874

316 Gilchrist. J. R., Garesfield Colliery. Lintz. Green, Newcastle-upon-Tyne  
Oct. 14, 1893

317 Gillman, F., Plattenstrasse, 68, Zurich (V.), Switzerland  
M. Dec. 8, 1894
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<td>Linares, Provincia de Jaen, Spain</td>
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<td>Reculvers, Claremont Road, Seaford, Sussex</td>
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<td>Goodwin, William Lawton</td>
<td>School of Mining, Kingston, Ontario, Canada</td>
<td>Feb. 11, 1899</td>
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<td>Gore, Henry</td>
<td>Victorian Gold Estates, Limited, Melbourne, Australia</td>
<td>Apr. 28, 1900</td>
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<td>Gough, George Henry</td>
<td>Umaria, B.N. Railway, Central Provinces, India</td>
<td>Aug. 4, 1900</td>
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<td>Gouldie, Joseph</td>
<td>The Gill, Bromheld, Brayton, S.O., Cumberland</td>
<td>Aug. 5, 1893</td>
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<td>Graham, Edward</td>
<td>Bedlington Colliery, Bedlington, R.S.O., Northumberland</td>
<td>Aug. 1, 1896</td>
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<td>Graham, F., West Hunwick Colliery</td>
<td>Hunwick, R.S.O., Co. Durham</td>
<td>Apr. 28, 1900</td>
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<td>Grave, Percy</td>
<td>Concepcion del Oro, Estado de Zacatecas, Mexico</td>
<td>Oct. 13, 1900</td>
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<td>Greaves, J. O.</td>
<td>Westgate, Wakefield</td>
<td>Aug. 7, 1862</td>
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<td>Green, Joseph</td>
<td>Crag House, Ferryhill, Co. Durham</td>
<td>Dec. 13, 1902</td>
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<td>332</td>
<td>Green, John Dampier</td>
<td>P.O. Box 340, Johannesburg, Transvaal M.</td>
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<td>Greener, T. V.</td>
<td>West Lodge, Crook, Darlington (Member of Council)</td>
<td>S. July 2, 1872</td>
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<td>49, Essex Street, Strand, London, W.C.</td>
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<td>Greenwell, G. O.</td>
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<td>S. March 6, 1869</td>
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<td>19, Pembroke Terrace, Cardiff</td>
<td>Oct. 9, 1897</td>
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<td>Gregson, G. Ernest</td>
<td>11, Chapel Street, Preston, Lancashire</td>
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<td>Gresley, W. S.</td>
<td>115, Radbourne Street, Derby</td>
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<td>Enniscorthy, Co. Wexford</td>
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<td>Griffith, N. Maurice</td>
<td>Westminster Chambers, Wrexham</td>
<td>S. Nov. 24, 1894</td>
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<td>Sept. 5, 1868</td>
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<td>Roseville, Hastings, Calcutta, India</td>
<td>June 13, 1896</td>
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<td>73, Cleveland Road, North Shields (Member of Council)</td>
<td>Aug. 3 1889</td>
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<td>Haddock, W. T.</td>
<td>4, Elmwood Street, Sunderland</td>
<td>S. Oct. 7, 1876</td>
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<td>348</td>
<td>Haggie, D. H.</td>
<td>Wearmouth Patent Rope Works, Sunderland</td>
<td>March 4, 1876</td>
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[xxxviii] Date of Election and Transfer.

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<th>No.</th>
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<td>Haggie, Peter Sinclair</td>
<td>Gateshead-upon-Tyne</td>
<td>A.M. Apr. 14, 1883</td>
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<td>Hair, Thomas Chicken</td>
<td>Bede House, Hebburn-upon-Tyne</td>
<td>Dec. 9, 1899</td>
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351. Halbaum, Henry Wallace Gregory, 19, Bute Terrace, Low Fell, Gateshead-upon-Tyne; April 8, 1899
352. Hall, Frederick, Fernleigh, Highfield, Workington; Oct 14, 1893
353. Hall, George William, Coolgardie, Western Australia; Dec. 12, 1896
355. Hall, M., 32, Louis Street, Leeds; M. Aug. 13, 1895
356. Hall, M. S., 8, Victoria Street, Bishop Auckland; Feb. 14, 1874
357. Hall, Tom, Ryhope Colliery, via Sunderland; June 8, 1899
358. Hall, William F., Haswell Colliery, Haswell, via Sunderland; S. Oct. 7, 1876
359. Hallas, G. H., Huyton, near Liverpool; A.M. Aug. 4, 1883
360. Hallimond, William Tasker, Jumpers Deep, Limited, P.O., Cleveland, near Johannesburg, Transvaal; Dec. 14, 1889
361. Halse, Edward, c/o Senores J. M. and E. Montoya, Puerto Berrio, Republic of Colombia, South America; A.M. June 13, 1885
363. Hancock, H. Lipson, Moonta Mines, South Australia; Dec. 14, 1895
364. Hancock, H. R., Ivymeade, Burnside, South Australia; A.M. Aug. 4, 1894
365. Hank, Robert, Jun., Clanton House, 3, Elizabeth Street, Newcastle Road, Sunderland; Oct. 14, 1895
366. Hannah, David, Brynderwen, Ferndale, South Wales; Feb. 9, 1895
367. Hark, Samuel, Murton Colliery, via Sunderland; S. Aug. 2, 1879
368. Harle, Peter, Page Bank Colliery, Co. Durham; Oct. 8, 1892
369. Harle, Richard, Browney Colliery, Durham; April 7, 1877
370. Harle, Robert Alfred, Wallsend Colliery, Wallsend-upon-Tyne; A. April 14, 1894
371. Harris, David, Elands Laagte Collieries, Limited, Elands Laagte, Natal, South Africa; A.M. June 12, 1897
372. Harris, G. E., Margherita, Debrugarh, Upper Assam; M. April 13, 1901
373. Harris, Howard, P.O. Box 311, Durban, Natal, South Africa; Aug. 7, 1897
374. Harris, W. S., Kibblesworth, Gateshead-upon-Tyne; A.M. Aug. 7, 1880
375. Harrison, Charles Augustus, North Eastern Railway, Newcastle-upon-Tyne; June 21, 1894
376. Harrison, G. B., Swinton, near Manchester; Aug. 6, 1892
377. Harrison, W. B., Brownhills Collieries, near Walsall; April 6, 1867
378. Haselden, Arthur, Linares, Provincia de Jaen, Spain; A.M. Dec. 11, 1897
379. Haselden, Eugene Kinnaird, Jardines No. 3, La Carolina, Provincia de Jaen, Spain; M. April 2, 1898
380. Hassall, Joseph, Abbey Villa, Kenilworth, near Cape Town, South Africa; A.M. Dec. 11, 1897
381. Hawker, Edward William, 8, Alma Chambers, Adelaide, South Australia; M. June 11, 1898
382. Hay, J., Jun., Widdrington Colliery, Acklington; S. Sept. 4, 1874
383. Heads, Robert William, Greenbushes, Western Australia; M. Aug. 4, 1902
384. Hedley, Robert Bertram, c/o W. Zimpel, Hay Street, Perth, Western Australia; June 14, 1902
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<td>Langholme, Roker, Sunderland</td>
<td>S. Feb. 15, 1879</td>
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<td>M. Aug. 3, 1889</td>
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<td>386</td>
<td>Hedley, William</td>
<td>Eighton Lodge, Low Fell, Gateshead-upon-Tyne</td>
<td>Feb. 13, 1897</td>
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**Date of Election and Transfer:**

387 Heinze, F. Aug., Trail, British Columbia Dec. 11, 1897
388 Henderson, Charles, Cowpen Colliery, Blyth, Northumberland Dec. 9, 1899
389 Henderson, Joseph J. June 13, 1891
391 Henzell, Charles George, Catcleugh, Otterburn, R.S.O., Northumberland Feb. 14, 1903
392 Hepburn, Wheldon, Littleton Colliery, near Durham Aug. 3, 1895
394 Heslop, C. Woodside, Marske Mill Lane, Saltburn-by-the-Sea S. Feb. 1, 1868
     |                       |                                              | M. Aug. 2, 1873               |
395 Heslop, Grainger, North Moor House, Sunderland Oct. 5, 1872
396 Heslop, Michael, Rough Lea Colliery, Willington, Co. Durham A. Feb. 10, 1894
     |                       |                                              | M. June 21, 1894              |
397 Heslop, Septimus, New Beerbohm Coal Company Limited, Asansol, Bengal, India Oct. 12, 1895
     |                       |                                              | A. M. Aug. 4, 1888            |
     |                       |                                              | M. Aug. 3, 1889               |
399 Heslop, William Taylor, St. George's Coal and Estate Company, Limited, Manager's Office, Hatting Spruit, Natal, South Africa Aug. 3, 1895
400 Hewitson, Thomas, Ivanhoe Cold Corporation, Limited, Boulder, Western Australia Dec. 9, 1899
401 Hewitt, G. C, Serridge House, Coalpit Heath, near Bristol June 3, 1871
402 Hewlett, A., Haseley Manor. Warwick March 7, 1861
404 Higson, Jacob. 18, Booth Street. Manchester Aug. 7, 1862
405 Hill, Albert James, New Westminster, British Columbia A.M. Dec. 10, 1898
     |                       |                                              | M. Dec. 8, 1900               |
406 Hill, William, 40, Wellington Road, Edgbaston, Birmingham A.M. June 9, 1883
     |                       |                                              | M. Aug. 3, 1889               |
407 Hilton, J., Woodcock Hall, Newburgh, near Southport S. Dec. 7, 1867
     |                       |                                              | M. Aug. 6, 1870               |
408 Hilton, Robert Stuart, c/o The Clay Cross Company, Clay Cross, near Chesterfield April 28, 1900
411 Hobson, Moses, Hartley House, Coundon, Bishop Auckland A. Aug. 5, 1893
     |                       |                                              | M. Aug. 3, 1901               |
412 Hodge, Francis, c/o John Whitworth, Camborne, Cornwall April 14, 1894
413 Hodgkin, Jonathan Edward, Shelleys, Darlington Dec. 13, 1902
414 Hodgson, Jacob, Cornsay Colliery, Co. Durham June 8, 1895
415 Hogg, C. E., 34 and 36, Gresham Street, London E.C. Oct. 12, 1895
416 Holberton, Walter Twining, Copiapo, Chile June 9, 1900
417 Holliday, Martin F., Langley Grove, Durham May 1, 1875
<table>
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<th>No.</th>
<th>Name</th>
<th>Address</th>
<th>Date</th>
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<tr>
<td>418</td>
<td>Hollings, James Spencer</td>
<td>Brymbo, near Wrexham</td>
<td>Oct. 14, 1899</td>
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<td>420</td>
<td>Homersham, Thomas H. C.</td>
<td>Vulcan Iron Works, Thornton Road, Bradford</td>
<td>Aug. 6, 1898</td>
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<td></td>
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<td>M. April 14, 1894</td>
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<td>422</td>
<td>Hooper, Reginald Thomas</td>
<td>Derwent Villa, St. Agnes, Cornwall</td>
<td>Aug. 2, 1902</td>
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<tr>
<td>423</td>
<td>Hope, Edmund Louis</td>
<td>Dandot, Jhelum, Punjab, India</td>
<td>Oct. 9, 1897</td>
</tr>
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<td>426</td>
<td>Horswill, Frederick J.</td>
<td>1218, Chesnut Street, Oakland, California, U.S.A.</td>
<td>Oct. 14, 1899</td>
</tr>
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<td>427</td>
<td>Hosking, George Frederic</td>
<td>Charles, Helensville, New Zealand</td>
<td>Dec. 8, 1900</td>
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<th>No.</th>
<th>Name</th>
<th>Address</th>
<th>Date</th>
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<tbody>
<tr>
<td>428</td>
<td>Hoskold, Carlos A. Lynes</td>
<td>First Engineer, Inspector of the National Department of Mines and Geology, Calle Charcas, 1222, Buenos Aires, Argentine Republic</td>
<td>June 8, 1895</td>
</tr>
<tr>
<td>429</td>
<td>Hoskold, H. D.</td>
<td>Inspector General of Mines of the Argentine Republic, and Director of the National Department of Mines and Geology. Buenos Aires, Argentine Republic</td>
<td>April 1, 1871</td>
</tr>
<tr>
<td>431</td>
<td>Howes, Frank T.</td>
<td>Hyderabad (Deccan) Company, Limited, Secunderabad, India</td>
<td>A. Dec. 10, 1892</td>
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<td>M. Oct. 14, 1893</td>
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<td>432</td>
<td>Hudson, James O.</td>
<td>Malcolm, Mount Margaret Gold-field, Western Australia</td>
<td>April 2, 1898</td>
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<td>433</td>
<td>Humble, John</td>
<td>West Pelton House, Beamish, R.S.O., Co. Durham</td>
<td>Feb. 8, 1902</td>
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<td>435</td>
<td>Humphris, Henry</td>
<td>Blaenau Ffestiniog, North Wales</td>
<td>Oct. 13, 1900</td>
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<td>436</td>
<td>Hunter, Robert</td>
<td>Gympie, Queensland, Australia</td>
<td>June 14, 1902</td>
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<tr>
<td>437</td>
<td>Hurst, George</td>
<td>9, Framlington Place, Newcastle-upon-Tyne</td>
<td>S. April 14, 1883</td>
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<td>M. Aug. 1, 1891</td>
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<td>438</td>
<td>Hutchinson, John William</td>
<td>Llwynceilyn House, Forth, near Pontypridd, South Wales</td>
<td>Oct. 14, 1899</td>
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<td>439</td>
<td>Jackson, W. G.</td>
<td>Prestwick, Witley, Surrey</td>
<td>June 7, 1873</td>
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<td>440</td>
<td>Jaffrey, Thomas</td>
<td>Water Works, Bundaberg, Queensland, Australia</td>
<td>Dec. 10, 1898</td>
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<td>441</td>
<td>Jaffrey, William</td>
<td>3, Victoria Street, London, S.W.</td>
<td>Feb. 13, 1897</td>
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<td>442</td>
<td>James, Thomas</td>
<td>Cae Duke Colliery, Loughor, near Swansea</td>
<td>April 12, 1902</td>
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<td>444</td>
<td>Jamieson, John William</td>
<td>Medomsley, R.S.O., Co. Durham</td>
<td>Aug. 2, 1902</td>
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<td>445</td>
<td>Jefferson, Frederick</td>
<td>Whitburn Colliery, South Shields</td>
<td>Dec. 11, 1897</td>
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<td>446</td>
<td>Jenkins, Charles</td>
<td>Warren Bowen, Mines Development Syndicate, late Fraser's G.M., Southern Cross, Western Australia</td>
<td>Oct. 9, 1897</td>
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<td>447</td>
<td>Jenkins, W.</td>
<td>Ocean Collieries. Treorchy, Glamorganshire</td>
<td>Dec. 6, 1862</td>
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<td>448</td>
<td>Jepson, H.</td>
<td>39, North Bailey, Durham</td>
<td>S. July 2, 1872</td>
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<td>A. M. Aug. 2, 1879</td>
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<td></td>
<td>M. June 8, 1889</td>
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<td>449</td>
<td>Jobling, John William</td>
<td>Clifton Cottage, Burnley, Lancashire</td>
<td>June 13, 1896</td>
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<tr>
<td>450</td>
<td>*Jobling, Thomas E.</td>
<td>Bebside, Northumberland (Member of Council)</td>
<td>S. Oct. 7, 1876</td>
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<td>A.M. Aug. 4, 1883</td>
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<td></td>
<td>M. June 8, 1889</td>
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<td>451</td>
<td>Johns, J. Harry</td>
<td>P.O. Box 231, Johannesburg, Transvaal</td>
<td>June 21, 1894</td>
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452 Johnson, J., York Terrace, Doncaster Road, Stairfoot, near Barnsley  
March 7, 1874
453 Johnson, W., Hall Garth, Carnforth, Lancashire  
S. Feb. 14, 1874
454 Johnston, J. Howard Backus and Johnston. Lima, Peru. South America  
A. M. Aug. 2, 1879
455 Joicey, W.J, Sunningdale Park, Berkshire  
M. June 8, 1889
456 Jones, John Arthur, Gijon, Asturias, Spain  
April 8, 1893
457 Jones, Jacob Carlos. Wollongong, New South Wales  
Aug. 6, 1892
458 Jones, John Elias, 1, Holmes and Dun Chambers, Durban, Natal, South Africa  
June 14, 1902
459 Jones, Percy Howard, Snatchwood Park, Pontypool, Monmouthshire  
Oct. 11, 1902
460 Jones, Thomas, 1, Holmes and Dun Chambers, Durban, Natal, South Africa  
June 12, 1897
461 Judd, Henry Alexander, Lake View South Gold Mine, Kalgoorlie, Western Australia  
Oct. 8, 1898
462 Justyne, William Percy, 29, Princess Street, Albert Square, Manchester  
Dec. 8, 1900

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Date of Election and of Transfer.

463 Kay, Robert, South Tanfield Colliery, Stanley. R.S.O., Co. Durham  
Aug. 4, 1894
464 Kayll, A. C. Gosforth, Newcastle-upon-Tyne  
S. Oct. 7, 1876
465 Kayser, H. W. Ferdinand, Launceston, Tasmania  
M. Aug. 3, 1889
466 Kebler, Julian A., Boston Building, Denver, Colorado, U.S.A.  
Nov. 24, 1894
467 Keighley, Frederick Charles, Uniontown, Fayette County, Pennsylvania, U.S.A  
June 13, 1896
468 Kellett, Matthew 11., St. Helen's Colliery, Bishop Auckland  
Aug. 4, 1900
469 Kennedy, George Thomas, King's College, Windsor, Hants County, Nova Scotia  
S. April 11, 1891
470 Kerr, David Gillespie, Cordova, Ontario, Canada  
M. Aug. 3, 1895
471 Kidd, Thomas, Jun., Linares, Provincia de Jaen, Spain  
M. April 10, 1896
472 Kirkegaard, Peter, Canadian Goldfields, Limited, Deloro, Hastings County, Ontario, Canada  
A.M. April 25, 1896
473 Kirkup, Austin, Newbottle Colliery, Bunker Hill, Fence Houses  
M. April 2, 1903
474 Kirkup, Frederic Octavius, Langley Park, Durham  
S. March 2, 1878
475 Kirkup, J. P., Burnhope, Lanchester  
A. M Aug. 7, 1886
476 Kirkup, Philip, Leafield House, Birtley, R.S.O. Co. Durham  
M. Aug. 3, 1889
477 Kirsopp, John, Jun., Lamesley, Gateshead-upon-Tyne  
June 9, 1900
478 Kirton, Hugh, Kimblesworth Colliery, Chester-le-Street  
S. April 7, 1877
479 Klepetko, Frank, 1011, Maritime Building. New York City, U.S.A.  
A.M. Aug. 1, 1885
480 Knowles, Robert, Ednaston Lodge, near Derby  
M. June 8, 1889
481 Kondo, R., 7, Setomoncho, Nihonbashii, Tokio, Japan  
Oct. 13, 1900
482 Kwong, Kwong Yung, c/o M. T. Liang, Director, Imperial Chinese Railways, Head Office, Tientsin, North China  
June 10, 1886
483 Kondo, R., 7, Setomoncho, Nihonbashii, Tokio, Japan  
April 10, 1886
483 Lamb, R. O., Hayton, How Mill, Carlisle Aug. 2, 1866
484 Lancaster, John, Ashlawn, Rugby March 2, 1865
485 Lancaster, John, Auchenheath, R.S.O., N. B Sept. 7, 1878
486 Lancaster, Joseph, 16, Nelson Street, Dalton-in-Furness Oct. 13, 1900
487 Landero, Carlos F. de, c/o Real del Monte Company, P.O. Box 1, Pachuca, Mexico Feb. 15, 1896
488 Laporte, H. 55, Rue de la Concorde. Brussels May 5, 1877
489 Lathbury, Graham Campbell, East Indian Railway Collieries, Giridih, E.I.R., Bengal, India Feb. 14, 1903
490 Laverick, John Wales, Thornley House, Thornley, R.S.O., Co. Durham A.M. Dec. 9, 1882
491 Lawn, James Gunson, P.O. Box 231, Johannesburg, Transvaal July 14, 1896
492 Lawrence, H., 7 and 8, Post Office Chambers, Newcastle-upon-Tyne A.M. July 14, 1888
(Member of Council)
493 Kirton, Hugh, Kimblesworth Colliery, Chester-le-Street S. April 7, 1877
494 Lawrence, H. L., Southern Rand Proprietary, Limited, P.O., Vredefort, Orange River Colony, South Africa April 8, 1893
495 Leach, C. C, Seghill Colliery, Northumberland (Member of Council) S. March 6, 1875
497 Leck, William, H.M. Inspector of Mines, Cleator Moor, Cumberland Nov. 24, 1894

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499 Leech, Arthur Henry, 11, King Street, Wigan Feb. 9, 1901
500 Lewis, John Dyer, H.M. Inspector of Mines, Richmond Road, Roath, Cardiff Oct. 9, 1897
501 Lewis, Sir William Thomas, Bart., Manly. Aberdare Sept. 3, 1864
504 Lister, Ralph, Langley Park Colliery, Durham April 4, 1893
505 Lindsay, George June 10, 1893
506 Lindsay, Robert, Netherton Coal Company, Limited Netherton Collieries, Newcastle-upon-Tyne A. Dec. 8, 1894
507 Lindop, A. B., Westport Coal Company, Limited, Denniston, Westport, New Zealand M. Feb. 8, 1902
508 Lishman, R. R., Bretby Colliery, Burton-upon-Trent Dec.9, 1893
510 Lishman, Tom Alfred, Harton Colliery, Tyne Dock, South Shields S. Nov. 24, 1894
511 Lishman, William, Holly House. Witton-le-Wear April 1, 1858
512 Lishman, W. Ernest. Leasingthorne Colliery, Bishop Auckland

513 Lisle, J., El Bote Mine, Zacatecas, Mexico 
S. July 2, 1872
A.M. Aug. 3, 1878
M. June 8, 1889

514 Little, Gilbert, Transport Appliance Works, Smethwick, Birmingham
April 27, 1895

515 Littlejohn, Albert, c/o Scott, Henderson and Company, Loftus Street, Sydney, New South Wales
S. Nov. 24, 1894
A. Aug. 2, 1897
M. Feb. 10, 1900

516 Liveing, E. H., Langford, near Biggleswade, Bedfordshire
S. Sept. 1, 1877
A.M. Aug. 2, 1884
M. Aug. 3, 1889

517 Livesey, John, Rose Hill Colliery, Bolton, Lancashire
April 13, 1901

518 Llewellin, David Morgan, Glanwern Offices, Pontypool
May 14, 1881

519 Lockwood, Alfred Andrew, 46, Marmora Road, Honor Oak, London, S.E.
June 12, 1897

520 Logan, William, Langley Bark, Durham (Vice-President, Member of Council)
Oct. 5, 1867

521 Longridge, Jethro, Burradon and Hazelrigg Collieries, South Gosforth, Newcastle-upon-Tyne
Dec. 14, 1889

522 Lonsdale, Talbot Richard, 53, Low' Fell Crescent. Durham Road, Gateshead-upon-Tyne
June 14, 1902

April 8, 1893

524 Louis, Henry, 11, Windsor Terrace, Newcastle-upon-Tyne (Member of Council)
Feb. 15, 1896

525 Lowdon, Thomas, Hamsteels, near Durham
Dec. 14, 1889

526 Lupton, Arnold, 6, De Grey Road, Leeds
Nov. 6, 1869

527 MacArthur, John S., 45, Renfield Street, Glasgow
April 8, 1893

528 McCarthy, E T., c/o Colonel Pigott, Archer Lodge, Charles A.M. Oct. 8, 1887
M. Aug. 3, 1889

Road, St. Leonards-on-the-Sea

529 McCreath, J., 208, St. Vincent Street, Glasgow
March 5, 1870

530 McDaid, John Alexander, c/o James E. Macdonald, 4, Chapel Street,
Cripplegate, London, E.C.
June 9, 1900

531 McFarlane, James Alexander, 5, Warkworth Avenue, Whitley, R.S.O., Northumberland
April 12, 1902

532 McGeachie, Duncan, West Wallsend, New South Wales
Nov. 24, 1894

533 Mackintosh, James
Oct, 12,1895

534 Maclaren, James Malcolm, Office of the Geological Survey, Calcutta, India
April 28, 1900

535 McLellan, Neil, Idsley House, Spennymoor, Co. Durham
Dec. 13, 1902

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Date of Election and of Transfer.

536 McMurtrie, George Edwin James, Radstock, near Bath
S. Aug. 2, 1884
M. Dec. 12, 1891

537 McMurtrie, J., 5, Belvedere Road, Durdham Park, Bristol
Nov. 7, 1863

538 McNeill, Bedford, 25a, Old Broad Street, London, E.C.
Dec. 11, 1897

539 MacTaggart, John Pettie, c/o Siemens Brothers and Company, 21, Grainger Street West, Newcastle-upon-Tyne
Dec. 13, 1902

540 Maddison, Thomas R., Durkar House, near Wakefield A
S. March 3, 1877
A. M. Aug. 6,1881
M. June 8. 1889

541 Maddison, W. H. F., The Lindens, Darlington
June 14. 1890

542 Mammat. J. E., 1, Albion Place, Leeds Manning, Arthur Hope, P.O. Box 88, Heidelberg, Transvaal.
Aug. 3. 1865
543 Manning, Arthur Hope, P.O. Box 88, Heidelberg, Transvaal Dec. 11, 1897
544 Markham, G. E., Gloucester Villa, Darlington S. Dec. 4, 1875, A.M. Aug. 7, 1880, M. June 8, 1889
545 Marks, Herbert T., 8, Union Court, Old Broad Street, London, E.C. Oct. 12, 1901
546 Marriott, Hugh Frederick, c/o H. Eckstein and Company, P.O. Box 149, Johannesburg, Transvaal Dec. 12, 1896
547 Martin, Henry W., Trewern, Dowlais, Glamorganshire Oct. 9, 1897
548 Martin, Tom Pattinson, Cumberland Coal Owners' Association, Workington, Cumberland April 4, 1903
549 Mason, Francis Herbert, Queen Building, Hollis Street, Halifax, Nova Scotia June 8, 1895
550 Mathieson, Alexander, Hetton Colliery, Carrington, near Newcastle, New South Wales Nov. 5 1892
551 Matthews, D. H. F., H. M. Inspector of Mines, Hoole, Chester Nov. 24, 1894
552 Matthews, J., c/o R and W. Hawthorn, Newcastle-upon-Tyne A. M. April 11, 1885, M. Aug. 3, 1889
553 Matthews, R. F., Lartington Hall, Darlington March 5, 1857
554 Mawson. R, Bryham, Bickershaw House, Bickershaw, near Wigan June 11, 1892
555 May, George, The Harton Collieries, South Shields (Past-President, Member of Council) March 6 1862
556 Mein, Henry Johnson, Carterthorne Colliery, Toff Hill, Bishop Auckland Dec. 9, 1899
557 Meldrum, J. J., Atlantic Works, City Road, Manchester Nov. 24, 1894
558 Mellon, Henry, Brook Lea, Askam-in-Furness April 25, 1896
559 Merivale, J. H., Togston Hall, Acklington, Northumberland (Vice-President, Member of Council) May 5, 1877
560 Metcalfe, A. T., United Reefs (Sheba), Limited, Eureka City, De Kaap, South Africa June 21, 1894
562 Middleton, Robert, Sheep Scar Foundry, Leeds Aug. 1, 1891
563 Miller, George Appleby Bartram, Blackwell Colliery, near Alfreton, Derbyshire June 13, 1896
564 Miller, James, Minas de Sao Bento, Santa Barbara de Matto Dentro, Minas Geraes, Brazil Aug. 4, 1894
565 Miller, John Henry, South Hetton, Sunderland A. Dec. 8, 1894
567 Mitchinson, R., Pontop Colliery, Annfield Plain, R.S.O., Co. Durham Feb. 4, 1865
568 Molengraaff, Gustaaf Adolf Frederik, P.O. Box 149, Johannesburg, Transvaal Oct. 14, 1899
569 Montgomery, Alexander State Mining Engineer, Department of Mines, Perth, Western Australia Dec. 9, 1899
570 Moore, R. T., 142. St. Vincent Street, Glasgow Oct. 8, 1892
571 Moore, R. W., Somerset House, Whitehaven S. Nov. 5, 1870, M. Aug. 4, 1877

[xxxiv] Date of Election and Transfer.
574 Morison, John, Cramlington House, Northumberland (Member of Council) A.M. Dec. 4, 1880, M. Aug 3, 1889
575 Morland-Johnson, Edward Thomas, c/o H. T. Johnson, Railway Road, Urmston, near Manchester  
576 Morris, William, Waldridge Colliery, Chester-le-Street  
577 Morse, Willard S., Apartado A, Aguascalientes, Mexico  
578 Mort, Arthur, North Western State Railways Collieries, Sharigh, Baluchistan, India  
579* Morton, H. J., 2, Westbourne Villas, Scarborough  
580 Mountain, William C., Forth Banks, Newcastle-upon-Tyne  
581 Muir, John James, Mount Lyell Comstock Mine, North Lyell P.O., Tasmania  
582 Mundie, Arthur, Murton Chambers, 8, Grainger Street, Newcastle-upon-Tyne  
583 Mundie, Harry Arthur, Marley Hill House, Swalwell, R.S.O., Co. Durham  
584 Murray, William Cuthbert, Clifton House, Sherburn Colliery Station, near Durham  
585 Neave, Henry Edward, Victoria, British Columbia  
587 Nevin, John, Littlemoor, Mirfield, Normanton  
588 Newbiggin, H. Thornton, 2, Lovaine Place, Newcastle-upon-Tyne  
589 Nicholson, Arthur Darling, H.M. Inspector of Mines, 14, Chatsworth Square, Carlisle  
590 Nicholson, J. Cook, City Road Tool Works, Newcastle-upon-Tyne  
591 Nicholson, J. H., Cowpen Colliery Office, Blyth (Member of Council)  
592 Nicholson, Marshall, Middleton Hall, Leeds  
593 Noble, Thomas George, Sacriston Colliery, Durham  
594 Nomi, Aitaro, Namazuta Colliery, Province of Chikuzen, Japan  
595 North, F. W., 60, Cheapside, London, E.C.  
596 Northey, Arthur Ernest, Esqair Hir Mines, Talvbont. R.S.O., Cardiganshire  
597 Oakes, Francis James, Jan., 58, Pearl Street, Boston, Massachusetts, U.S.A.  
598 Oates, Robert J. W., Rewah State Collieries, Umaria, C. India, Bengal Nagpur Railway  
599 O'Donahue, Thomas Aloisius, 113, Dickson Street, Wigan  
600 Oldham, George, 25, Western Hill, Durham  
601 Ormsby, Howard Thomas, 3, St. James' Road, Benwell, Newcastle-upon-Tyne  
602 Ormsby, Robert Embleton, Seaton Delaval Colliery, Northumberland  
603 Osborne, Francis Dowlas, Gopeng, Perak, Federated Malay States  
604* Oshima, Rokuro, Hokkaido Colliery and Railway Company, Sapporo, Japan  
605 Oughton, William, 33, Westgate Road, Newcastle-upon-Tyne  

Date of Election and Transfer.
606 Paley, George, De Beers Mines, Kimberley, South Africa Oct. 12, 1901
607 Palmer, Claude B., Wardley Hall, Pelaw-upon-Tyne A.M. Nov. 5, 1892
M. June 8, 1895
608 Palmer, Henry, Medomsley, R.S.O. Co. Durham (Member of Council) S. Nov. 2, 1878
A.M. Aug. 4, 1883
M. Aug. 3, 1889
609 Pamely, G, York House, Chepstow M. Aug. 5, 1877
610 Panton, F. S., Sitio de Callea, Puerto Oratava, Tenerife S. Oct. 5, 1867
611 Parish, Charles Edward, 4, Park Road, Harlesden, London, N. W. M. Aug. 6, 1870
Feb. 10, 1900
612 Parker, Thomas, Wellington Pit, Whitehaven June 10, 1899
613 Parrington, Matthew William, Wearmouth Colliery, Sunderland (Member of Council) M. Aug. 6, 1870
S. Dec. 1, 1864
614 Parsons, Hon. Charles Algernon, Heaton Works, Newcastle-upon-Tyne A.M. June 12, 1886
M. Aug. 3, 1889
615 Pascoe, Thomas, New Options, Limited, Harrautville, Victoria, Australia A.M. April 10, 1897
M. June 12, 1897
616 Paterson, Andrew James, P.O. Box 20, Maryborough, Queensland, Australia June 11, 1898
617 Paterson, George Alexander, Ooregum Gold Mine, Oorgaum, Province of Mysore, India Oct. 12, 1901
618 Peake, R. C, Cumberland House, Redbourn, Herts. S. Feb. 7, 1880
A.M. Aug. 7, 1886
M. Aug. 3, 1889
619 Pearse, John Walter, 47 bis, Avenue de Clichy, Paris, France June 10, 1899
620 Peel, Robert, New Brancepeth Colliery, Durham Aug. 6, 1892
M. Aug. 6, 1870
Aug. 7, 1897
622 Pile, William, Cambrian Collieries, Limited, Castle Buildings, Durban, Natal, South Africa
623 Pingstone, George Arthur, P.O. Box 445, Bulawayo, Rhodesia, South Africa A.M. June 11, 1898
M. Dec. 10, 1898
624 Plummer, John. H.M. Inspector of Mines, Bishop Auckland June 8, 1889
625 Pollitzer, Samuel Joseph, Temple Court, 146, King Street, Sydney, New South Wales April 12, 1902
626 Poore, G. Bentley, c/o H. Eckstein and Company, P.O. Box 149, Johannesburg, Transvaal A.M. Dec. 10, 1898
M. April 8, 1899
627 Porter, John Bonsall, McGill University, Montreal, Quebec, Canada Dec. 8, 1900
628 Potter, C. J., Heaton Hall, Newcastle-upon-Tyne Oct. 3, 1874
629 Powell, Charles Henry, c/o Walter Lupton and Company, Limited, Albert Street, Brisbane, Queensland June 14, 1902
630 Prest, John Joseph, Hardwick Hall, Castle Eden, Durham Feb. 9, 1901
631 Price, Francis Holborrow Glyn, Longlands Place, Swansea June 10, 1899
632 Price, S. R., c/o A. W. Price, Drury Lane Chambers, Mosley Street, Newcastle-upon-Tyne S. Nov. 3, 1877
A.M. Aug. 1, 1885
M. Aug. 3, 1889
634 Pringle, John Archibald, P.O. Box 155, Johannesburg, Transvaal Dec. 10, 1898
636 Rae, J. L. C., Sydney Harbour Collieries, Balmain, Sydney, New South Wales Oct. 14, 1899
637 Ramsay, J. A., Harperley Hall, Tantobie, R S.O., Co. Durham March 6, 1869
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<th>No.</th>
<th>Name</th>
<th>Address and Details</th>
<th>Date of Election and of Transfer</th>
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<tr>
<td>638</td>
<td>Ramsay, William</td>
<td>Tursdale, Co. Durham</td>
<td>Sept. 11, 1875</td>
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<td>639</td>
<td>Randolph, Beverley S.</td>
<td>Frostburg, Maryland, U.S.A.</td>
<td>Aug. 4, 1894</td>
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<td>640</td>
<td>Rateau, Auguste</td>
<td>105, Quai d'Orsay, Paris, France</td>
<td>Aug. 2, 1902</td>
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<td>642</td>
<td>Redmayne, R. A. S.</td>
<td>The University, Birmingham</td>
<td>S. Dec. 13, 1884</td>
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<td>643</td>
<td>Redwood, Boverton</td>
<td>Wadham Lodge, Wadham Gardens, London, N.W.</td>
<td>June 21, 1894</td>
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<td>644</td>
<td>Rees, D. J. Arthur</td>
<td>co F. Napier White, H.M. Inspector of Mines, 9, Mirador Crescent, Swansea</td>
<td>Aug. 4, 1900</td>
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<tr>
<td>645</td>
<td>Rees, Ithel Treharne</td>
<td>Guildhall Chambers, Cardiff</td>
<td>April 4, 1903</td>
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<td>646</td>
<td>Rees, Robert Thomas</td>
<td>Glandare, Aberdare, South Wales</td>
<td>Aug. 7, 1897</td>
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<td>647</td>
<td>Rees, William Thomas</td>
<td>Maesyffynon, Aberdare, South Wales</td>
<td>A.M. Oct. 9, 1897</td>
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<td>648</td>
<td>Reid, A. H.</td>
<td>20. South African Chambers, St. George's Street. Cape Town, South Africa</td>
<td>June 21, 1894</td>
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<td>649</td>
<td>Reid, Francis</td>
<td>Riverside, Black Boys, Sussex</td>
<td>April 9, 1892</td>
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<td>Renwick, T. C.</td>
<td>Lumley Thicks, Fence Houses</td>
<td>April 14, 1894</td>
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<td>Reynolds, Henry Baker</td>
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<td>April 12, 1902</td>
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<td>652</td>
<td>Rhodes, C. F.</td>
<td>Car House, Rotherham</td>
<td>Aug. 4, 1883</td>
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<td>654</td>
<td>Rhodes, Samuel Hulme</td>
<td>50, Zimmerstrasse, Berlin, Germany</td>
<td>April 12, 1902</td>
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<td>655</td>
<td>Rich, Francis Arthur</td>
<td>Karangahake, Auckland, New Zealand</td>
<td>Aug. 5, 1899</td>
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<td>656</td>
<td>Rich, William</td>
<td>Trevu, Camborne, Cornwall</td>
<td>A.M. June 9, 1888</td>
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<td>657</td>
<td>Richard, George Anderson</td>
<td>Mount Morgan, Queensland, Australia</td>
<td>June 11, 1898</td>
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<td>658</td>
<td>Richards, T. J. Manod House</td>
<td>Bridge Street, Aberystwyth, South Wales</td>
<td>Oct. 10, 1896</td>
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<td>659</td>
<td>Richardson, H., 89</td>
<td>Ashley Gardens, Westminster, London, S.W.</td>
<td>March 2, 186</td>
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<td>660</td>
<td>Richardson, Nicholas</td>
<td>Holywell House, Backworth, Northumberland</td>
<td>S. Dec. 12, 1896</td>
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<td>661</td>
<td>Richardson, Robert</td>
<td>Blaydon Main Colliery, Blaydon-upon-Tyne</td>
<td>A. Feb. 8, 1890</td>
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<td>662</td>
<td>Ridley, N. B.</td>
<td>2, Collingwood Street, Newcastle-upon-Tyne</td>
<td>June 8, 1895</td>
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<td>663</td>
<td>Ridyard, J.</td>
<td>Hilton Bank, Little Hulton, Bolton-le-Moors, Lancashire</td>
<td>Nov. 7, 1874</td>
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<td>664</td>
<td>Ritson, John Ridley</td>
<td>Burnhope Colliers, Lanchester</td>
<td>S. April 11, 1891</td>
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<td>665</td>
<td>Ritson, U. A.</td>
<td>15, Queen Street, Newcastle-upon-Tyne</td>
<td>A.M. Aug. 3, 1895</td>
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<td>667</td>
<td>Robert, Philip Rhinelander</td>
<td>618, Orchard Lake Avenue, Pontiac, Michigan, U.S.A.</td>
<td>Feb. 10, 1900</td>
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<td>669</td>
<td>Roberts, Robert</td>
<td>Oakley Slate Quarries Company, Limited, Blaenau Festiniog, North Wales</td>
<td>Oct. 12, 1895</td>
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<td>670</td>
<td>Roberts, Stephen</td>
<td>Luipaards Vlei Estate and Gold Mining Company, P.O. Box 53, Krugersdorp, Transvaal</td>
<td>April 28, 1900</td>
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<td>671</td>
<td>Robertson, Andrew</td>
<td>49, Mining Exchange, Ballarat, Victoria, Australia</td>
<td>Aug. 7, 1897</td>
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</tbody>
</table>
Robinson, D. A. W., Metropolitan Colliery, Helensburgh, near Sydney, New South Wales
Aug. 6, 1892

*Robinson, J. R. M., Linton, Milson's Point, Sydney, New South Wales
Aug. 2, 1890

Robeson, Anthony Maurice, c/o H. Eckstein and Company, P.O. Box 149, Johannesburg, Transvaal
June 13, 1896

Date of Election and of Transfer.

Robins, Samuel M., Nanaimo, British Columbia
Oct. 12, 1895

Robinson, George, Boldon Colliery, R.S.O., Co. Durham.
June 10, 1899

Robinson, G. C., Breerton and Hayes Colliery, Rugeley, Staffordshire
Nov. 5, 1870

Robinson, John, The Grange, Haydock, near St. Helen's, Lancashire
Aug. 1, 1896

Robinson, John, High Hedgefield, Blaydon-upon-Tyne
Feb. 10, 1900

Robinson, J. P., Colliery Offices, Tow Law, R.S.O., Co. Durham
Aug. 5, 1893

Robinson, John Thomas, South Medomsley Colliery, Dipton, R.S.O
Feb. 13, 1892

Robinson, Robert Dobson, Tamworth Colliery Company, Tamworth, Warwickshire
Feb. 9, 1901

Robinson, Timothy, Ryhope Colliery, via Sunderland
Feb. 8, 1902

Robinson, J. S., Butterknowle Colliery, via Darlington
May 15, 1862

Ronaldson, J. H., c/o British African Gold Dredging Company, Limited, P.O. Box 5224, Johannesburg, Transvaal
Aug. 6, 1892

Ross, Hugh, Croxdale Colliery Office, Durham
Aug. 6, 1892

Ross, J. A. G., 11, Royal Arcade, Newcastle-upon-Tyne
July 2, 1872

Rothwell, Samuel, 21, Chorley New Road, Bolton, Lancashire
Dec. 9, 1899

Routledge, W. H., Woodfield Park, Blackwood, Monmouthshire
S. Oct. 7, 1876

Rowe, William Henry, 9, Earl Terrace, Douglas, Isle of Man
June 13, 1896

Rowlands, William Edward, 16, Penmaier-Glas Road, Aberystwyth, South Wales
June 9, 1900

Rowley, Walter, 20, Park Row, Leeds
Aug. 5, 1893

Rumbold, William Richard, Mill House, Holmwood, Surrey
June 14, 1902

Russell, Robert, Colness Iron Works, Newmains, N.B.
Aug. 3, 1878

Rutherford, Robert, Axwell Park Colliery, Swalwell, R.S.O., Co. Durham
Oct. II, 1902

Rutherford, W., Lindum House, Gateshead-upon-Tyne
Oct. 3, 1874

Rutherford, William, Jun., South Derwent Colliery, Annfield Plain, R.S.O., Co. Durham
Feb. 9, 1901

Saint, William, H.M. Inspector of Mines, Kersal Bank, Higher Broughton, Manchester
Oct. 10, 1896

Saise, Walter, Gujiadih, Giridih, E.I.R., Bengal, India
A.M. Nov. 3, 1877

Sam, T. B. F., c/o F. and A. Swanzy, Cape Coast Castle, West Africa
Aug. 5, 1893

Samborne, John Stukely Palmer, Timsbury House, Bath
Aug. 1, 1891

April 13, 1901

Saunders, David William Alban, Worcester Chambers, Swansea
A.M. Feb 12, 1898

Saunders, William Thomas, The Pahang Corporation, Limited, Sungei Lembing, Kuantan, via Singapore
June 11, 1898

Sawyer, A. R., P.O. Box 5456, Johannesburg, Transvaal; and 26, Budge Row, Cannon Street, London, E.C.
S. Dec. 6, 1873

A. M. Aug. 2, 1879

M. June 8, 1889
706 Scott, C. F., Newbell, Leadgate, R.S.O., Co. Durham  
S. April 11, 1874  
M. Aug. 4, 1877

707 Scott, Elgin, Ropienka Oil Wells, Ropienka, Galicia, Austria  
Aug. 4, 1894

708 Scott, Ernest, Close Works, Newcastle-upon-Tyne  
April 9, 1892

709 Scott, Edward Charlton, Woodside Cottage, Totley Rise, near Sheffield  
A. Oct, 8, 1892  
M. Feb. 11, 1899

709 Scott, Edward Charlton, Woodside Cottage, Totley Rise, near Sheffield  
Dec. 14, 1895

710 Scott, F. Bowes, Broadway Chambers, Westminster, London, S. W.  
Oct 11, 1902

Date of Election and  
of Transfer.

712 Scott, Joseph, Ngahiro, via Greymouth, New Zealand  
Aug. 5, 1893

713 Scott, Joseph S., Trindmon Hall, Trindmon Grange, R S O., Co. Durham  
S. Nov. 19, 1881  
M. Apr. 9, 1892

714 Scoular, G., St. Bees, Cumberland  
July 2, 1872

715 Selby, John Baseley, Leigh, Lancashire  
April 25, 1896

716 Settle, Joseph Burton  
Dec. 11, 1897

717 Severs, Joseph, North Walbottle, Newburn, R.S.O., Northumberland  
June 8, 1901  
A. Nov. 5, 1892  
M. Dec. 8, 1900

719 Sharp, Jacob, Lampton House, Fence Houses  
Dec. 14, 1901  
June 10, 1893

720 Shaw, F. George  
Dec. 12, 1896

721 Shaw, James, The Terraces, Avenue Road, North Adelaide, South Australia  
Oct. 8, 1892

722 Shaw, J. Leslie. Somerset House, Whitehaven  
Aug. 4, 1894

723 Shear, A. Whitcomb, Pottsville, Pennsylvania. U.S.A.  
May 6, 1871  
A.M. Aug. 2 1884  
M. Aug 3 1889

725 Shipley, T. B., 18, Green's Buildings, Johannesburg, Transvaal,  
Transactions sent to c/o Andrew Reid and Company, Limited, Newcastle-upon-Tyne  
A.M. Dec. 13, 1884  
M. Aug. 3, 1889

726 Shute, C. A., 7, Dixon Terrace, Darlington  
April 11, 1874

727 Simon, Frank, P.O. Box 2986, Johannesburg, Transvaal  
Dec. 14, 1895

April 8, 1893

729 Simpson, F. L. G., Mohpani Coal Mines, Gadawarra, C.P., India  
A.M. Dec. 13, 1884  
M. Aug. 3, 1889

730 Simpson, F. R., Hedgefield House, Blaydon-upon-Tyne (Member of Council)  
S. Aug. 4, 1883  
M. Aug. 1, 1891

731 Simpson, Gilbert Pitcairn, 3, Cornwall Terrace, Regent's Park, London, N.W.  
Oct. 10, 1896

732 Simpson, J., Heworth Colliery, Felling, R.S.O., Co. Durham (Member of Council)  
S. Dec. 6, 1866  
M. Aug. 1, 1868

733 Simpson, John Bell, Bradley Hall, Wylam-upon-Tyne (Past-President,  
Member of Council)  
Oct. 4,1860

734 Simpson, Robert Rowell, Office of the Geological Survey, Calcutta, India  
S. Aug. 3, 1895  
A. Aug. 2, 1902  
M. Oct. 11, 1902

735 Simpson, Thomas Ventress. Throckley Colliery, Newburn, R.S.O.,  
Northumberland  
S. Dec. 14, 1895  
A. Aug. 2, 1902  
M. Dec. 13, 1902

736 Skertchley, Sydney A. R., Burlington Drive, Beltinge, Heme Bay, Kent  
April 13, 1901  
Nov. 24. 1894

737 Sladden, Harry, P.O. Box 2844, 6, Barnato Buildings, Johannesburg,  
Transvaal
738 Slinn, T., 40, Park Avenue, Whitley, R.S.O., Northumberland  July 2, 1872
739 Smart, A., c/o Frazer and Chalmers, Limited, Frith, Kent  Feb. 10, 1894
740*Smith, R. Clifford, Ashford Hall, Bakewell  Dec. 5, 1874
741 Smith, William, P.O. Box653, Johannesburg, Transvaal  Oct. 11, 1902
742 Sopwith, A., Cannock Chase Collieries, near Walsall  Aug. 6, 1863
743 Southern, F. (), Ashington Colliery, near Morpeth  S. Dec. 5, 1874
744 Southern, John, Heworth Colliery, Felling, R.S.O., Co. Durham  A. Dec.14, 1889
745 Southern, R. W. A., 33, The Parade, Cardiff  M. April 8, 1899
746 Sparkes, J. S., 55, Richmond Road, Cardiff  Aug. 3, 1865
747 Spence, R. F., Backworth, R.S.O., Northumberland (Member of Council)  April 9,. 1892
748 Spencer, Francis H., Bonanza Gold Mining Company, P.O. Box 149, Johannesburg, Transvaal  S. Nov. 2, 1878
749 Spencer, John, Westgate Road, Newcastle-upon-Tyne  A.M. Aug. 2, 1884
750 Spencer, John W., Newburn, near Newcastle-upon-Tyne  M. Aug. 4, 1889
752 Stanley, George Hardy, Durham College of Science, Newcastle-upon-Tyne  May 4, 1878
753 Stansfeld, Harold Sinclair, Rainford Colliery, near St. Helen's, Lancashire  June 8, 1895
754 Stanton, John, 11 and 13, William Street, New York, U.S. A.  Dec. 6, 1855
755 Steavenson, Addison Langhorse, Durham (Past-President, Member of Council)  S. April 14, 1883
757 Stevens, A. J., Uskside Iron Works, Newport, Monmouthshire  M. Aug. 3, 1895
758 Stevens, James, 9, Fenchurch Avenue, London, E.C.  April 8, 1893
759 Stewart, William, Tillery Collieries, Abertillery, Monmouthshire  Feb. 14, 1885
760 Stobart, F., Biddick Hall, Fence Houses  May 4, 1878
761 Stobart, H. T., Wearmouth Colliery, Sunderland  June 8, 1895
762 Stobart, W., Pepper Aden, Northallerton  April 12, 1902
763 Stobart, William Ryder, Etherley Lodge, Darlington  July 2, 1872
764 Stoiber, Edward G., c/o Prof. Regis Channenet, President, State School of Mines, Golden, Colorado, U.S.A.  Oct. 11, 1890
765 Stoker, Arthur P., Ouston House, near Chester-le-Street  A.M. Oct. 12, 1895
767 Storey, William, Urpeth Villas, Beamish, R.S.O., Co. Durham  S. Oct. 6, 1877
768 Straker, J. H., Howden Dene, Corbridge-upon-Tyne  A.M. Aug. 1, 1885
769 Streatfield, Hugh S., Rvhope, near Sunderland  M. Aug. 3, 1889
770 Stuart, Donald M D., Redland, Bristol  June 8, 1895
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<th>Date of Election and Transfer</th>
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<td>Sutcliffe, Richard</td>
<td>Horbury, near Wakefield, Yorkshire</td>
<td>June 14, 1902</td>
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<td>Sutton, William</td>
<td>Baltic House, Balham Hill, London, S. W.</td>
<td>April 28, 1900</td>
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<td>Swallow, Frederick Charles</td>
<td>Glenroy, Nuneaton</td>
<td>A. April 14, 1894</td>
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<td>Swallow, J.</td>
<td>East Pontop Colliery, Annfield Plain, R.S.O. Co. Durham</td>
<td>May 2, 1874</td>
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<td>Swallow, Wardle Asquith</td>
<td>Tantfield Lea, Tantobie, R.S.O., Co. Durham</td>
<td>S. Dec. 9, 1893</td>
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<td>Swan, Henry Frederick</td>
<td>Walker Shipyard, Newcastle-upon-Tyne</td>
<td>A. Dec. 8, 1900</td>
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<td>Swinburne, Richard</td>
<td>Horbury, near Wakefield, Yorkshire</td>
<td>June 11, 1898 F</td>
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<td>Symons, Francis</td>
<td>Ulverston, Lancashire</td>
<td>Feb. 11, 1899</td>
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<td>Tate, Simon</td>
<td>Trimmend Grange Colliery, Co. Durham</td>
<td>Sept. 11, 1875</td>
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<td>Tattley, William</td>
<td>Crammer Road, Newton, Auckland, New Zealand</td>
<td>Aug. 3, 1895</td>
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<td>Taylor, Alfred Henry</td>
<td>Ngunguru Coal Mines, Kiripaka, via Auckland, New Zealand</td>
<td>Dec. 14, 1901</td>
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<td>Taylor, T.</td>
<td>Quay, Newcastle</td>
<td>July 2, 1872</td>
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[xi] Date of Election and Transfer.

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<td>Tennent, Robert</td>
<td>H. M. Inspector of Mines, Westport, new Zealand</td>
<td>A. M. Aug. 6, 1881</td>
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<td>Thomas, Arthur</td>
<td>Zalamea la Real, Huelva, Spain</td>
<td>M. June 8, 1889</td>
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<td>Thomas, Ernest Henry</td>
<td>Oakhill, Gadlys, Aberdare, South Wales</td>
<td>Oct. 8, 1898</td>
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<td>Thomas, Iltyd Edward</td>
<td>Glanymor, Swansea</td>
<td>Aug. 7, 1897</td>
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<td>Thomas, J. J.</td>
<td>Hawthorn Villa, Kendal</td>
<td>Feb. 10, 1890</td>
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<td>Thomas, Richard</td>
<td>c/o Henry J. Thomas, 100, Mariaw Street, Clydach Vale, Llwynypia, Pontypridd</td>
<td>Feb. 11, 1899</td>
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<td>Thomas, Trevor Falconer</td>
<td>9, Mount Stuart Square, Butt Docks, Cardiff</td>
<td>A.M. Feb. 12, 1898</td>
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<td>Thomlinson, William</td>
<td>Seaton Carew, R.S.O</td>
<td>M. Aug. 6, 1898</td>
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<td>Thompson, Alfred</td>
<td>Talbot House, Birtley, R.S.O.. Co. Durham</td>
<td>April 25, 1896</td>
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<td>Thompson, Charles Lacy</td>
<td>Farlam Hall, Brampton Junction, Cumberland</td>
<td>Dec. 13, 1902</td>
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<td>Thompson, Francis William</td>
<td>15, Wood Street, Bolton, Lancashire</td>
<td>A. M. Feb. 10, 1883</td>
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<td>Thompson, John G.</td>
<td>Bank House, Collins Green, Earlstown, Lancashire</td>
<td>M. Aug. 3, 1889</td>
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<td>Thompson, John William</td>
<td>Greenfield House, Crook, R.S.O., Co. Durham</td>
<td>June 8, 1895</td>
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<td>Thompson, John Whitfield</td>
<td>c/o Isaac Thomson, Law Junction, Carluke, Lanarkshire</td>
<td>June 8, 1895</td>
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<td>Thompson, VV.</td>
<td>1 and 2, Great Winchester Street, London, E.C</td>
<td>A.June 10, 1893</td>
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<td>Thomson, John</td>
<td>Bolton Mines, by Middlesbrough</td>
<td>M. Feb. 10, 1900</td>
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<td>Thomson, Joseph F.</td>
<td>Manvers Main Colliery, Rotherham</td>
<td>Aug. 4, 1888</td>
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<td>Thomson, Joseph</td>
<td>424, New York Life Building, Chicago, Illinois, U.S.A</td>
<td>April 7, 1877</td>
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806 Thornton, Norman M., South Pelaw Colliery, Chester de-Street  
S. Apr. 27, 1895  
A. Aug. 2, 1902  
M. June 10, 1903

807 Todd, John T., Blackwell Collieries, Alfreton  
S. Nov. 4, 1876  
A.M. Aug. 1, 1885  
M. June 8, 1889

808 Tonkin, J. J., Linares, Provincia de Jaen, Spain  
Oct. 14, 1893

809 Townsend, Harry Poyser, The Penhalonga Proprietary Mines, Limited, Umtali, Rhodesia, South Africa  
April 12, 1902

810 Trelease, W. Henwood, Ceppomorelli per Macugnaya, Vall' Anzasca, Prov. di Novara, Italy  
April 8, 1893

811 Trevaille-Williams, T., Johannesburg Consolidated Investment Company, Limited, P.O. Box 590, Johannesburg, Transvaal  
Dec. 10, 1898

812 Trevor, Earle Wellington Jenks, 78, Palace Chambers, 9, Bridge Street, Westminster, London, S. W.  
Aug. 2, 1902

813 Tulip, Samuel, Bunker Hill, Fence Houses  
June 12, 1897

814 Turnbull, John James, East Indian Coal Company, Limited, Jherria P.O., District Manbhum, Bengal, India  
Feb. 12, 1898

815 Turnbull, Robert, Usworth Colliery, Washington, R.S.O., Co. Durham  
Aug. 2, 1902

816 Tyers, John E., c/o The Hyderabad Deccan Company, Limited, Secunderabad, East India  
A.M. Dec. 10, 1877  
M. Aug. 3, 1889

817 Tyrrell, Joseph Burr, Dawson, Yukon Territory, Canada  
Feb. 10, 1900

818 TyzacK, David, Bellingham, Northumberland  
Feb. 14, 1874

819 Upton, Prescott, P.O. Box 1026, Johannesburg, Transvaal  
June 12, 1897

820 Varty, Thomas, Skelton Park Mines, Skelton, R.S.O., Cleveland  
Feb. 12, 188/

821 Vaughan, Cedric, Hodbarrow Iron Ore Mines, Millom, Cumberland  
Dec. 10, 1892

822 Vaughan, John, Balaclava House, Dowlais, Glamorganshire  
Feb. 12, 1898

823 Veasey, Harvey O, c/o H. W. Veasey, 1, Bedford Park, Chiswick, London  
June 21, 1894

Oct. 12, 1895

825 Verney, George, Doubovais, Balka Krivoi, Russia  
Oct. 8, 1898

826 Verschoyle, William Denham, P.O. Box 1074, Seattle, Washington, U.S.A.  
Dec. 11, 1897

827 Vitanoff, George N., 1, Tynemouth Place, Tynemouth, Northumberland  
A.M. April 22, 1882  
M. Aug. 3, 1889

828 Vivian, John, Vivian's Boring and Exploration Company, Limited, 42, Lowther Street, Whitehaven  
March 3, 1877

829 Waddle, Hugh, Llanmore Iron Works, Llanelly, South Wales  
Dec. 13, 1890

830 Wadham, E., Millwood, Dalton-in-Furness  
Dec. 7, 1867

831 Wadham, Walter Francis Ainslie, Millwood, Dalton-in-Furness  
Dec. 10, 1898

832 Wales, H. T., Western Mail Chambers, Cardiff  
Feb. 11, 1893

833 Walker, Henry Blair, Cassell Coal Company, Springs, Transvaal  
Oct. 9, 1897

834 Walker, James Howard, Bank Chambers, Wigan  
Dec. 9, 1899

835 Walker, J. S., Pagefield Iron Works, Wigan, Lancashire  
Dec. 4, 1869

836 Walker, Sydney Ferris, Bloomfield Crescent, Bath  
June 11, 1898

837 Walker, Thomas A., Pagefield Iron Works, Wigan, Lancashire  
June 8, 1895

Aug. 3, 1889

839 Walker, William Edward, Lowther Street, Whitehaven  
Nov. 19, 1881

840 Wall, Henry, Rowbottom Square, Wallgate, Wigan  
June 8, 1895

841 Wall, William Henry, 46, Haliburton Street, Nanaimo, British Columbia  
June 14, 1902
<table>
<thead>
<tr>
<th>Name</th>
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<th>Date of Election and Transfer</th>
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<tbody>
<tr>
<td>Wallwork, Jesse</td>
<td>Bolton Road, Atherton, Lancashire</td>
<td>Feb. 9, 1895</td>
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<td>Walsh, G. Paton</td>
<td>Heinegracht, Amsterdam, Holland</td>
<td>Nov. 24, 1894</td>
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<tr>
<td>Walton, J. Coulthard</td>
<td>Whithlington Colliery, Radstock, via Bath</td>
<td>S. Nov. 7, 1874</td>
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<tr>
<td>Walton, Thomas</td>
<td>Executive of Col. Hargreaves, Colliery Offices, Bank Parade</td>
<td>A.M. Aug. 6, 1881</td>
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<tr>
<td>Ward, H. Rodbaston Hall</td>
<td>near Penkriddle, Stafford</td>
<td>Aug. 3, 1895</td>
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<td>Ward, T. H., Giridih</td>
<td>Bengal, East India</td>
<td>April 14, 1894</td>
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<td>Waters, Stephen</td>
<td>Apartado No. 96, Pachuca, Mexico</td>
<td>March 6, 1862</td>
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<tr>
<td>Watson, Claude Leslie</td>
<td>Elliot Colliery, New Tredegar, via Cardiff</td>
<td>Oct. 11, 1890</td>
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<td>Watson, Michael</td>
<td>St. Nicholas' Buildings, Newcastle-upon-Tyne</td>
<td>Dec. 12, 1896</td>
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<td>Watson, Thomas</td>
<td>Trimdon Colliery, Trimdon Grange</td>
<td>June 13, 1896</td>
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<tr>
<td>Watts, J. Whidbourne</td>
<td>P.O. Box 179, Barberton, Transvaal</td>
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<td>Watts, William</td>
<td>Sheffield Corporation Water Department, Little Don Valley</td>
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<td>Webster, Alfred Edward</td>
<td>Manton, Worksop, Notts</td>
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<td>Weeks, J. G.</td>
<td>Bedlington, R.S.O., Northumberland (Past-President,</td>
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<td>Watson, Frederick Napier</td>
<td>H.M. Inspector of Mines, 9, Mirador Crescent, Swansea</td>
<td></td>
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<tr>
<td>White, C. E.</td>
<td>Wellington Terrace, South Shields</td>
<td>S. Nov. 4, 1876</td>
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<tr>
<td>White, John</td>
<td>Albany Street, Edinburgh</td>
<td>June 10, 1893</td>
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<tr>
<td>Whitelaw, C. N.</td>
<td>North Bitchburn Colliery, Howden, Darlington</td>
<td>June 6, 1866</td>
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<tr>
<td>Wight, Edward</td>
<td>Taupiri Coal Mines, Limited, Mine Manager's Office,</td>
<td>A.M. Dec. 12, 1885</td>
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<td></td>
<td>Hunlty, near Auckland, New Zealand</td>
<td>M. Aug. 3, 1889</td>
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873 Wight, Robert Tennant, Hallbankgate, Milton, Carlisle  
Oct. 13, 1900
874 Wight, W. H., Cowpen Colliery, Blyth  
Feb. 3, 1877
875 Wilbraham, Arthur George Bootle, Mina de San Domingos, Mertola, Portugal  
S. Dec. 11, 1897
876 Wilkins, William Glyde, Westinghouse Building, Pittsburg, Pennsylvania, U.S.A.  
Dec. 11, 1897
877 Wilkinson, John Thomas, East Howie Colliery, via Ferryhill, Co. Durham  
Dec. 8, 1900
Oct. 10, 1896
879 Williams, Alpheus Fuller, De Beers Consolidated Mines, Limited, Kimberley, South Africa  
Oct. 12, 1901
880 Williams, Gardner F., De Beers Consolidated Mines, Limited, Kimberley, South Africa  
Oct. 12, 1895
881 Williams, Griffith John, H.M. Inspector of Mines, Bangor, Wales  
Aug. 2, 1902
882 Williams, H. J. Carnegie, The Voel Mines (Merioneth), Limited, Dolgelley, North Wales  
Oct. 12, 1895
883 Williams, James Wilson, 15, Valley Drive. Harrogate  
April 4, 1903
884 Williams, Luke, Mount Reid Mining Company, Limited, Mount Read, Tasmania. All Transactions and Correspondence to be addressed to Parkside, Park Street, Hobart, Tasmania  
April 10, 1897
885 Williams, Richard, The Johnsons Reef Gold Mines Company, California Gulley, Bendigo, Victoria, Australia. M,  
A.M. June 13, 1896
886 Williams, Robert, 30, Clements Lane, Lombard Street, London, E.C.  
June 13, 1896
887 Wilson, Anthony, Thornthwaite, Keswick, Cumberland A  
A.M. Feb. 10, 1900
888 Wilson, Archibald Laurence, The New Ravenswood, Limited, Ravenswood, Queensland, Australia  
A.M. June 12, 1897
889 Wilson, Arthur P., Mansion House Chambers, Queen Victoria Street, London, E.C.  
A.M. Aug. 3, 1889
890 Wilson, James, Wellington House, Edmondsley, Chester-le-Street, Co. Durham  
April 13, 1901
891 Wilson, Joseph R., 705, Drexel Building, Philadelphia, Pennsylvania, U.S.A.  
Oct. 12, 1895
892 Wilson, Lloyd, Flimby Colliery, Maryport  
Jan. 19, 1895
893 Wilson, Nathaniel  
Dec. 9, 1899
894 Wilson, P. O  
Dec. 9, 1893
895 Wilson, W. B., Horden Dene, Easington, Castle Eden, R.S.O., Co. Durham  
S. Feb. 6, 1869
896*Wilson, William Brumwell, Jun., Hedley Hill Colliery, Waterhouses, Co. Durham  
Feb. 9, 1901

Date of Election and of Transfer.
897 Wilson-Moore, Aubrey Percy, Sheba Queen Gold and Exploration, Limited, Barberton, Transvaal  
Oct. 14, 1899
Feb. 10, 1900
899 Winchell, Horace V, Butte, Montana, U.S.A.  
Nov. 24, 1894
900 Winstanley, Robert, 42, Deansgate, Manchester  
Sept. 7, 1878
901 Wood, C. L., Freeland, Forgangdenny, Perthshire  
Aug. 3, 1854
902 Wood, Ernest Seymour, c/o The Bengal Coal Company, Limited, 5 Fairlie Place, Calcutta, India
Oct 10, 1891

903 Wood, John, Coxhoe Hall, Coxhoe, R.S.O., Co. Durham
S. June 8, 1899
A. Aug. 4, 1894
M. Aug. 3, 1895

904*Wood, Sir Lindsay, Bart., The Hermitage, Chester-le-Street (Past-President, Member of Council)
Oct 1, 1857

905 Wood, Richard, P.O. Box 5550, Johannesburg, Transvaal
June 14, 1902

April 10, 1897

907 Wood, Thomas, North Hetton Colliery Office, Moorsley, Hetton-le-Hole, R.S.O., Co. Durham
S. Sept 3, 1870
M. Aug. 5, 1871

908 Wood, Thomas Outterson, Bunker Hill, Fence Houses
Feb. 14, 1903

909 Wood, W. H, Coxhoe Hall, Coxhoe, R.S.O., Co. Durham
Aug. 6, 1857

910 Wood, W. O. South Hetton, Sunderland (President, Member of Council)
Nov. 7, 1863

911 Woodburne, T. J., Bultfontein Mine, De Beers Consolidated Mines, Limited, Kimberley, South Africa
Feb. 10, 1894

912 Woolcock, J. H., 49, Lowther Street, Whitehaven
June 10, 1893

913 Wormald, C. F., Mayfeld Villa, Saltwell, Gateshead-upon-Tyne
A.M. Dec. 8, 1883
M. Aug. 3, 1889

914 Worsdell, Wilson, North Eastern Railway Company, Gateshead-upon-Tyne
Oct. 14, 1899

915 Wrightson, Sir Thomas, Bart., Stockton-upon-Tees
Sept 13, 1873

916 Young, Henry William, Greymouth, New Zealand
Dec. 13, 1902

917 Young, John A., 3, Fountain Avenue, Gateshead-upon-Tyne
A.M. Dec. 10, 1887
M. Aug. 3, 1889

920 Young, John Huntley, Wearmouth Colliery, Sunderland
June 21, 1894

921 Younger, John Wishart, The Poplars, North Biddick, Washington Station, Co. Durham

ASSOCIATE MEMBERS.
Marked have paid life composition.

Date of Election and of Transfer.

1 Ahier, Philippe Davidson, 3, Alder Street, Seaforth, Liverpool
Oct. 14, 1899

2 Alder, William, 3, Beech Avenue, Whitley, R.S.O., Northumberland
Oct. 12, 1901

3 Armstrong, J. H., St. Nicholas' Chambers, Newcastle-upon-Tyne
Aug. 1, 1885

4 Armstrong, T. J., Hawthorn Terrace, Newcastle-upon-Tyne
Feb. 10, 1883

5 Atkinson, Alfred, 12, Pape Buildings, Newcastle-upon-Tyne
April 13, 1901

6 Atkinson, G. B., Prudential Assurance Buildings, Mosley Street, Newcastle-upon-Tyne
Nov. 5, 1892

7 Banks, Charles John, Chelsea Lea, Orrell Lane, Aintree, Liverpool
Feb. 12, 1898

8 Barrett, William Scott, Abbotsgate, Blundellsands, Lancashire
Oct 14, 1899
<table>
<thead>
<tr>
<th>Name</th>
<th>Address</th>
<th>Date</th>
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<tr>
<td>Broadbent, Denis Ripley</td>
<td>Royal Societies Club St. James Street, London, S.W.</td>
<td>Oct. 14, 1899</td>
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<td>Brutton, P. M.</td>
<td>17, Sandhill, Newcastle-upon-Tyne</td>
<td>Oct. 13, 1900</td>
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<tr>
<td>Burdon, A. E.</td>
<td>Hartington, R.S.O., Northumberland</td>
<td>Feb. 10, 1883</td>
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<tr>
<td>Burn. Charles William</td>
<td>28, Fawcett Street, Sunderland</td>
<td>June 11, 1898</td>
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<tr>
<td>Capell, Rev. G. M.</td>
<td>Passenham Rectory, Stony Stratford</td>
<td>Oct. 8, 1892</td>
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<tr>
<td>Carr, William Cochran</td>
<td>Benwell Colliery, Newcastle-upon-Tyne</td>
<td>Oct. 11, 1890</td>
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<tr>
<td>Chewings, Charles</td>
<td>85, Edward Street, Norwood, South Australia</td>
<td>April 25, 1896</td>
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<tr>
<td>Cochrane, Ralph D.</td>
<td>Hetton Colliery Offices, Fence Houses. Transactions sent to W. Cochrane</td>
<td>June 1, 1878</td>
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<td>Collopy, Charles J.</td>
<td>P.O. Box 1212, Johannesburg, Transvaal</td>
<td>Dec. 10, 1898</td>
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<tr>
<td>Cooper, R. W.</td>
<td>Newcastle-upon-Tyne</td>
<td>Sept. 4, 1880</td>
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<td>Cory, Clifford J.</td>
<td>c/o Cory Brothers and Company, Limited, Cardiff</td>
<td>Dec. 11, 1897</td>
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<td>Davison, Louis</td>
<td>8, Burdon Terrace, Newcastle-upon-Tyne</td>
<td>Oct. 14, 1899</td>
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<tr>
<td>Douglas, Benjamin</td>
<td>Rhodesia Exploration and Development Company, Limited, Main Street, Bulawayo, Rhodesia, South Africa</td>
<td>Aug. 6, 1898</td>
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<tr>
<td>Eccles, Edward</td>
<td>King Street, Newcastle-upon-Tyne</td>
<td>Oct. 13, 1894</td>
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<td>Edwards, F. H.</td>
<td>Forth House, Bewick Street, Newcastle-upon-Tyne</td>
<td>June 11, 1887</td>
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<td>Edwards, George Maitland</td>
<td>Kuliebinski Mines, Kotchkar, Ourenburg Government, Russia</td>
<td>Oct. 11, 1902</td>
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<tr>
<td>Ellam, Albert Spencer</td>
<td>Devonshire Club, St. James' Street, London, S.W.</td>
<td>April 25, 1896</td>
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<td>Elliot, Sir George</td>
<td>Bart</td>
<td>April 2, 1898</td>
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<td>Ellis, Oswald William</td>
<td>31, Grosvenor Place, Newcastle-upon-Tyne</td>
<td>Oct. 11, 1902</td>
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<td>Fairless, Joseph</td>
<td>Mineral Traffic Manager, North Eastern Railway Company, Newcastle-upon-Tyne</td>
<td>June 10, 1899</td>
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<td>Ferguson, C. A.</td>
<td>P.O. Box 1301, Johannesburg, Transvaal</td>
<td>July 14, 1896</td>
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<td>Foster, T. J.</td>
<td>Coal Exchange, Scranton, Pennsylvania, U. S. A.</td>
<td>Dec. 12, 1891</td>
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<td>Gibson, James</td>
<td>c/o W. E. Robarts, Acuts Arcade, Durban, Natal, South Africa</td>
<td>Dec. 9, 1899</td>
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<td>Gibson, Thomas William</td>
<td>Bureau of Mines, Toronto, Ontario, Canada</td>
<td>June 8, 1901</td>
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<tr>
<td>Graham, John</td>
<td>Findon Cottage, Sacriston, Durham</td>
<td>Oct. 9, 1897</td>
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<tr>
<td>Gregson, Jesse</td>
<td>Australian Agricultural Company, Newcastle, New South Wales</td>
<td>Aug. 6, 1898</td>
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<tr>
<td>Gummerson, James M.</td>
<td>35, Birkbeck Road, Acton, London, W.</td>
<td>June 10, 1899</td>
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<tr>
<td>Guthrie, Reginald</td>
<td>Neville Hall, Newcastle-upon-Tyne (Treasurer, Member of Council)</td>
<td>Aug. 4, 1888</td>
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<td>Harris-Edge, H. P.</td>
<td>Coalport Works, Shifnal, Salop</td>
<td>June 8, 1901</td>
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<td>Haswell, William Spence</td>
<td>47, Esplanade, Whitley, R.S.O., Northumberland</td>
<td>April 13, 1901</td>
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<td>Hedley, J. Hunt</td>
<td>John Street, Sunderland</td>
<td>June 13, 1891</td>
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<td>Heeley, George</td>
<td>East Avenue, Benton, Newcastle-upon-Tyne</td>
<td>Dec. 14, 1895</td>
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[xlv] Date of Election and of Transfer.

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<tr>
<th>Name</th>
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<tr>
<td>Henderson, C. V. C.</td>
<td>co J. G. Weeks, Bedlington, R.S.O., Northumberland</td>
<td>Dec. 9, 1882</td>
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<td>Henzell, Robert</td>
<td>Northern Oil Works, Newcastle-upon-Tyne</td>
<td>April 11, 1891</td>
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<td>Hildred, Willows</td>
<td>7, Voltaire Street, Clapham, London, S.W.</td>
<td>June 9, 1900</td>
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<td>Hodgetts, Arthur</td>
<td>c/o A. H. Thornton, 116, Church Hill Road, Handsworth, Birmingham</td>
<td>Oct. 9, 1897</td>
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<td>Holland, Williamson</td>
<td>36, Orchard Terrace, Rochdale Road, Heywood, Lancashire</td>
<td>Feb. 13, 1897</td>
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<tr>
<td>Holliday, Henry</td>
<td>Consett Iron Company, Limited, Blackhill, Co. Durham</td>
<td>Feb. 12, 1898</td>
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<tr>
<td>No.</td>
<td>Name (if available)</td>
<td>Address</td>
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<td>50</td>
<td>Hopper, J. I.</td>
<td>Wire Rope Works, Thornaby-upon-Tees</td>
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<td>51</td>
<td>Humphreys-Davies, G.</td>
<td>8, Laurence Pountney Hill, Cannon Street. London, E.C.</td>
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<td>Hunter, C. E.</td>
<td>Selaby Park, Darlington</td>
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<td>53</td>
<td>Innes, Thomas Snowball</td>
<td>Crown Chambers, Side, Newcastle-upon-Tyne</td>
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<td>54</td>
<td>Jack, Frederic Barrie</td>
<td>32, Grainger Street West, Newcastle-upon-Tyne</td>
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<td>James, Henry M.</td>
<td>Colliery Office, Whitehaven</td>
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<td>Jarvis, Horace William</td>
<td>West Dyke, Coatham, Redcar</td>
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<td>59</td>
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<td>Kidson, Arthur</td>
<td>c/o Glaholm and Robson. Limited, Rope Manufacturers, Sunderland</td>
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<td>Kirkby, William</td>
<td>c/o H. C. Embleton, Central Bank Chambers, Leeds</td>
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<td>Lamb, Edmund George</td>
<td>Borden Wood, Liphook, Hants.</td>
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<td>65</td>
<td>Lishman, George Percy</td>
<td>Bunker Hill, Fence Houses, Co. Durham</td>
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<td>66</td>
<td>Lumsden, John Alder</td>
<td>Rewah State Collieries, Umaria, C.P., India</td>
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<td>67</td>
<td>Macleod, Peter Joseph</td>
<td>Technical School, Hobart, Tasmania</td>
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<td>68</td>
<td>Marshall, P.</td>
<td>University School of Mines, Dunedin, New Zealand</td>
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<td>70</td>
<td>Newbery, Frederick</td>
<td>230, Camden Road, London, N.W.</td>
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<td>O'Connor, Arthur, K.C.</td>
<td>The Tower, Neville's Cross, Durham</td>
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<td>72</td>
<td>Palmer, A. M.</td>
<td>Newbrough Lodge, Fourstones, Northumberland</td>
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<td>73</td>
<td>Proctor, John H.</td>
<td>29, Side, Newcastle-upon-Tyne</td>
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<td>74</td>
<td>Pringle, John</td>
<td>c/o Russo-Chinese Bank, Newchwang, China</td>
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<tr>
<td>75</td>
<td>Pringle, John</td>
<td>c/o Russo-Chinese Bank, Newchwang, China</td>
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<td>77</td>
<td>Proctor, John H.</td>
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<td>Pringle, John</td>
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<td>79</td>
<td>Rogerson, John E.</td>
<td>Oswald House, Durham</td>
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<td>Rosen, John</td>
<td>P.O. Box 1647, Johannesburg, Transvaal</td>
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<td>81</td>
<td>Saunders, G. B.</td>
<td>Saunders, Todd and Company, Maritime Buildings, King Street, Newcastle-upon-Tyne</td>
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<td>82</td>
<td>Scholer, Peter</td>
<td>14, Tremadoc Road, Clapham, London, S.W.</td>
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<td>83</td>
<td>Scott, John Oliver</td>
<td>The Glebe, Riding Mill-upon-Tyne</td>
</tr>
<tr>
<td>Associate</td>
<td>Address</td>
<td>Date</td>
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<tr>
<td>Smith, C. A.</td>
<td>92 Smith, C. A., 23, Rectory Terrace, Gosforth, Newcastle-upon-Tyne</td>
<td>Dec. 8, 1894</td>
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<tr>
<td>Stewart, Samuel</td>
<td>93 Steuart, Douglas Stuart-Spens</td>
<td>June 10, 1899</td>
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<tr>
<td>Parkhurst, Park Road, Wallington, Surrey</td>
<td>94 Stewart, Samuel, 16, Great George Street, Westminster, London, S. W.; and Parkhurst, Park Road, Wallington, Surrey</td>
<td>Feb. 12, 1898</td>
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<tr>
<td>Stokes, H. G.</td>
<td>95 Stokes, H. G., Silver Spur Silver Mines, Texas, via Stanthorp, Queensland, Australia</td>
<td>Dec. 11, 1897</td>
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<td>Stowell, William</td>
<td>96 Stowell, William, 11, Queen Street, Newcastle-upon-Tyne</td>
<td>June 11, 1898</td>
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<td>Strange, Harold Fairbrother</td>
<td>97 Strange, Harold Fairbrother, Johannesburg Consolidated Investment Company, Limited, P.O. Box 590, Johannesburg, Transvaal</td>
<td>Dec. 11, 1897</td>
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<td>Thompson, Oswald</td>
<td>98 Thompson, Oswald, Hendon Lodge, Sunderland</td>
<td>June 10, 1899</td>
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<td>Telling, Samuel</td>
<td>99 Todd, James, West View House, Durham</td>
<td>Aug. 6, 1892</td>
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<tr>
<td>Armstrong</td>
<td>100 Tonge, James, Jun., 149, Church Street, Westhoughton, Lancashire</td>
<td>Dec. 14, 1901</td>
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<td>Tunnington, Albert</td>
<td>101 Toovey, Alfred Francis 33, Westgate Road, Newcastle-upon-Tyne</td>
<td>Dec. 13, 1902</td>
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<td>Strange</td>
<td>102 Tunnington, Albert, Colonia, Limited, Moodie's Creek, near Barberton, Vaal River Colony, South Africa</td>
<td>Oct. 9, 1897</td>
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<tr>
<td>Toovey, Alfred Francis</td>
<td>103 Turner, Charles Edward, Minas Herrerias, Puebla de Guerman, Provincia de Huelva, Spain</td>
<td>Aug. 6, 1898</td>
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<td>Valentine, James</td>
<td>104 Valentine, James, 1, West View, Horwich, Lancashire</td>
<td>June 14, 1902</td>
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<tr>
<td>Wall, G. Young</td>
<td>105 Wall, G. Young, Halmote Court Office, New Exchequer Building, Durham</td>
<td>Nov. 24, 1894</td>
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<tr>
<td>Walmsley</td>
<td>106 Walmsley, Oswald, 2, Stone Buildings, Lincoln's Inn, London, W.C</td>
<td>June 8, 1895</td>
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<td>Weatherburn</td>
<td>107 Weatherburn, John, Meynell House, Rowlands Gill, Newcastle-upon-Tyne</td>
<td>Oct. 13, 1894</td>
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<td>Whitehead, Thomas</td>
<td>108 Whitehead, Thomas, Brindled Lodge, near Preston, Lancashire</td>
<td>June 12, 1897</td>
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<tr>
<td>Williams, Thomas J.</td>
<td>109 Williams, Thomas J.</td>
<td>April 2, 1898</td>
</tr>
<tr>
<td>Wood, Arthur Nicholas Lindsay</td>
<td>110* Wood, Arthur Nicholas Lindsay, The Hermitage, Chester-le-Street</td>
<td>July 14, 1896</td>
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<tr>
<td>Wrightson, Wilfrid Ingram</td>
<td>111 Wrightson, Wilfrid Ingram, Neasham Hall, Darlington</td>
<td>April 4, 1903</td>
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<td>112 Wrightson, Wilfrid Ingram, Neasham Hall, Darlington</td>
<td>Dec. 9, 1899</td>
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</table>

ASSOCIATES.
Marked * have paid life composition.

<table>
<thead>
<tr>
<th>Date of Election and Transfer.</th>
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<td>Allport, E. A., Round House, Haxey, via Doncaster</td>
<td>S. April 14, 1894</td>
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<td>Archdale, Hewan, Church Street, Quebec, near Durham</td>
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<td>Archer, M. W., High Priestfield, Lintz Green, Co. Durham</td>
<td>S. June 8, 1895</td>
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<td>Armstrong, William P., Bewicke Main, Birtley, R.S.O., Co. Durham</td>
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<td>Barker, John Dunn, 23, Cobden Terrace, Brandon Colliery, R.S.O., Durham</td>
<td>Dec. 14, 1901</td>
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<td>Battey, Thomas, Station Road, Shiremoor, Northumberland</td>
<td>Aug. 5, 1899</td>
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<td>Bayldon, Harold Cresswell, c/o Bechuanaland Exploration Company, Limited, Bulawayo, Rhodesia, South Africa</td>
<td>Oct. 13, 1894</td>
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<td>Bell, John, Wardley Colliery, Newcastle-upon-Tyne</td>
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<td>Berkley, Robert, Durban Colliery, Dannhauser, Natal, South Africa</td>
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<td>Bowes, Thomas, Pontop House, Annfield Plain, R.S.O.</td>
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<td>Bowman, Frank, Ouston Colliery Office, Chester-le-Street, Co. Durham</td>
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16 Carroll, John. Newfield House, Newfield, Willington, Co. Durham  
Feb. 12, 1898
17 Charlton, William John, Jun., 17, First Row. Ashington, Morpeth, 
Northumberland  
April 12, 1902
18 Chipchase, John, 23, St. Helen's Terrace, Coxhoe, R.S.O., Co. Durham  
Dec. 13, 1902
19 Clark, Nathaniel J., 1, Hawthorn Terrace, Pelton Fell, Chester-le-Street, 
Co. Durham  
S. April 13, 1901
20 Clark, Thomas, Dipton Colliery, Lintz Green Station  
Oct. 11, 1890
21 Clifford, Edward Herbert, Rand Club, Johannesburg, Transvaal  
S. Oct. 13, 1894
22 Clive, Robert, Loftus Mines, Skinningrove, Carlin How, R.S.O., Cleveland  
S. Feb. 10, 1900
A. Aug. 1, 1903
23 Clough, Edward Stokoe, Bomarsund House, Bomarsund, Bedlington, 
R.S.O., Northumberland  
Feb. 14, 1903
24 Clough, John, 1, Melton Terrace, Seaton Delaval Colliery, R.S.O., 
Northumberland  
Feb. 13, 1897
25 Cockburn, Edmund, 27, Bolckow Street, North Skelton, Skelton-in- 
Cleveland, Yorkshire  
Dec. 11, 1897
26 Cockburn, Evan, Waldridge Colliery, Chester-le-Street, Co. Durham  
Aug. 5, 1893
27 Corbett, Vincent. Blackett Colliery, Haltwhistle  
June 11, 1898
28 Cowx, H. F., Thornley Collieries, via Trimdon Grange, R.S.O  
April 14, 1894
29 Coxon, S. G., 13, Station View, Waterhouses, Co. Durham  
Feb. 9, 1901
30 Coxon, William B., South View, Crook, Co. Durham  
S. Feb. 12, 1898
A. Aug. 2, 1902
31 Crofton, Charles Arthur, Netherton Collieries, near Newcastle-upon-Tyne  
S. Dec. 10, 1898
A. Aug. 1, 1903
32 Cummings, Jno., Moor House, Littleton Colliery, near Durham  
Aug. 2, 1902
33 Daknes, John, 32, South Street, Brandon Colliery, Durham  
Aug. 5, 1899
34 Danskin, Thomas, Springwell Colliery, Gateshead-upon-Tyne  
Dec 10, 1898
35 Davis, James E., South Medomsley Colliery, Dipton, R.S.O., Co. Durham  
Feb. 12, 1898
36 Davison, Francis, 37, Hedley Hill Terrace, Waterhouses, Co. Durham  
Feb 12, 1898
37 Dickinson, Archibald, 199, Brunshaw Road, Burnley, Lancashire  
S. Dec 14, 1901
A. Aug. 1, 1903
38 Dodds, William, Bewieke Main Colliery, Birtley, R.S.O., Co. Durham  
Dec. 14, 1901
39 Draper, William, Silksworth Colliery, Sunderland  
Dec. 14, 1889
40 Dunnett, Samuel, 20, Hambledon Street, Blyth, Northumberland  
June 8, 1895
41 Eddowes, Hugh M., c/o Robinson Deep Gold Mining Company, P.O. Box  
1488, Johannesburg, Transvaal  
S. Oct. 8, 1698
A. Aug. 1, 1903
42 Elves, Edward, Midridge Colliery, Heighington, R.S.O., Co. Durham  
June 13, 1896
43 Emmerson, George, Brandon Colliery, near Durham  
Oct. 8, 1898
44 Eskdale, John, Ashington Colliery, Morpeth, Northumberland  
Oct. 11, 1902
45 Falcon, Michael, 33, Butte Street, Treorchy, South Wales  
S. Oct. 13, 1894
A. Aug. 4, 1900
46 Fawcett, Edward, Middle Street, Walker-upon-Tyne  
June 11, 1892
47 Fewster, John, 4, Belgrave Terrace, Felling, R.S.O., Co. Durham  
Feb. 13, 1897
48 Finney, Joseph, Elswick Collieries, Newcastle-upon-Tyne  
Aug. 6, 1898
49 Ford, Thomas, Blaydon Burn Colliery, Blaydon-upon-Tyne  
Aug. 2, 1902
50 Forster, Frank, 22, Gowland Terrace, Wheatley Hill Colliery, Thornley, R.S. O., Co. Durham  
   Feb. 8, 1902

51 Gallagher, Patrick, 15, James Street, Newfield, Chester-le-Street, Co. Durham  
   Dec. 13, 1902

52 Glass, Robert William, Craigielea, Whickham, R.S.O., Co. Durham  
   S. June 10, 1899  
   A. Aug. 1, 1903

53 Gordon, George Stoker, Louisa Terrace, West Stanley  
   Feb. 15, 1896

54 Graham, Cecil, Sunniside, Tow Law, R. S.O., Co. Durham  
   S. April 4, 1903  
   A. Aug. 1, 1903

55 Greene, Charles C, Eston Mines, near Middlesbrough-upon-Tees  
   S. Feb. 15, 1896  
   A. Aug. 3, 1901

56 Hall, Joseph Percival, Edmondsley Colliery, Chester-le-Street  
   S. Oct. 9, 1897  
   A. Aug. 2, 1902

57 Hall, Robert William, 1, Railway Street, Murton Colliery, Sunderland  
   Dec. 13, 1902

58 Hampson, Alexander, St. Helen's Colliery, Bishop Auckland  
   Feb. 12, 1898

59 Handyside, William, Jun., 4, Brandling Terrace, Felling-upon-Tyne  
   June 12, 1897

60 Hare, George, Seghill Colliery, Northumberland  
   Feb. 12, 1898

61 Hedley, A. M., Medomsley, R.S.O., Co. Durham  
   Nov. 24, 1894

62 Hedley, George William, Deathall Colliery, Trimdon Grange, R.S.O., Co. Durham  
   Dec. 13, 1902

63 Henderson, William, 12, Success Cottages, Bunker Hill, Fence Houses  
   Oct. 12, 1901

64 Herriotts, Joseph George, 7, Granville Terrace, Blyth, Northumberland  
   April 28, 1900

65 Herron, Edward, Holly Terrace, Stanley, R.S.O.  
   Feb. 15, 1896

66 Heslop, William, Hunwick, Willington, Co. Durham  
   Oct. 8, 1898

67 Hodgson, Joseph, West Thornley Colliery, Tow Law, R.S.O., Co. Durham  
   Feb. 14, 1903

68 Hornsby, Demster, Choppington Colliery, Scotland Gate, R.S.O., Northumberland  
   Feb. 12, 1898

69 Howe, James, Jun., East Cross Street, Langley Park, Durham  
   Feb. 11, 1899

70 Hughes, James Nicholson, Hedley Hill Colliery, Waterhouses, Co. Durham  
   Feb. 12, 1898

71 Hunter, A., 2, Abbotsford Terrace, South Shields  
   Feb. 13, 1897

72 Hunter, Christopher, Cowpen Colliery Office, Blyth, Northumberland  
   Dec. 10, 1892

73 Imrie, Henry Marshall, Western Hill, Durham  
   Feb. 14, 1903

74 Jaeger, Bernard, 10, Crozier Terrace, Shildon, via Darlington  
   S. June 12, 1897  
   A. Aug. 1, 1903

75 James, Alexander A., Croxdale, near Durham  
   June 10, 1893

76 Jeffery, Albert J., 6, Bowby Street, Houghton-le-Spring, R.S.O., Co. Durham  
   April 28, 1900

77 Johnson, James, Hawthorn Lodge, East Boldon, R.S.O., Co. Durham  
   Aug. 6, 1898

78 Johnson, William, Framwellgate Moor. Durham 79 Jones, William  
   Aug. 6, 1892

80 Kellett, Robert, Sherburn Colliery Station, Durham  
   S. Aug. 4, 1894  
   A. Aug. 1, 1903

81 King, Fred., 1, Shankhouse Row, Shankhouse, near Cramlington, Northumberland  
   Feb. 12, 1898

82 Kirby, Matthew Robson, c/o A. L. Steavenson, Holywell Hall, Durham  
   S. Oct. 8, 1892  
   A. Aug. 4, 1900

83 Knight, William James, 2, Front Street, Easington Colliery, Castle Eden,  
   R.S.O., Co. Durham  
   S. June 9, 1900  
   A. Aug. 1, 1903

84 Latimer, Hugh, South Durham Colliery, Eidy, Bishop Auckland  
   Oct. 11, 1902
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<th>Date of Transfer</th>
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<td>85</td>
<td>Lightley, John.</td>
<td>9, Hawthorn Grove, Wallsend-upon-Tyne</td>
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<td>86</td>
<td>Logan, Reginald</td>
<td>Samuel Moncrieff, Royal Grammar School, Newcastle-upon-Tyne</td>
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<td>87</td>
<td>McCarthy, Michael</td>
<td>Dodds, Fourth Street, Urpeth, Ouston, Chester-le-Street, Co. Durham</td>
<td>S. Feb. 9, 1901</td>
<td>A. Aug. 1, 1903</td>
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<td>87</td>
<td>McCarthy, Michael</td>
<td>Dodds, Fourth Street, Urpeth, Ouston, Chester-le-Street, Co. Durham</td>
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<td>88</td>
<td>McGregor, John</td>
<td>Edward, 2, Murray Street, Stanley, R.S.O., Co. Durham</td>
<td>S. Apr. 4, 1903</td>
<td>A. Aug. 1, 1903</td>
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<td>89</td>
<td>Marr, Joseph</td>
<td>Chopwell, Lintz Green, R.S.O., Co. Durham</td>
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<td>90</td>
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<td>91</td>
<td>Mason, Benjamin</td>
<td>Burnopfield Colliery, Burnopfield, R.S.O., Co. Durham</td>
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<td>Melville, John</td>
<td>Thomas, 12, Oakfield Terrace, Gosforth, Newcastle-upon-Tyne</td>
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<td>93</td>
<td>Middleton, H. W.</td>
<td>Trimdon Colliery, R.S.O., Co. Durham</td>
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<td>A. Aug. 1, 1903</td>
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<td>94</td>
<td>Milburn, William</td>
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<td>June 8, 1895</td>
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<td>Minns, Thomas</td>
<td>Tate, Jun., 13, Balfour Street, Houghton-le-Spring, R.S.O., Co. Durham</td>
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<td>97</td>
<td>Mitchell-Withers,</td>
<td>William Charles, 4, Ashgate Road, Broomhill, Sheffield</td>
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<td>Morland, Thomas</td>
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<td>Bailey, 7, Lloyd Street, Lemington-upon-Tyne</td>
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<td>William, Glenholm, Crook, R.S.O., Co. Durham</td>
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<td>102</td>
<td>Murray, Frank</td>
<td>Douglas, Jumpers Deep, Limited, P.O. Box 1056, Cleveland Station, Johannesburg, Transvaal</td>
<td>S. Aug. 7, 1897</td>
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<td>103</td>
<td>Musgrove, William</td>
<td>Throckley Colliery Office, Throckley Colliery, near Newcastle-upon-Tyne</td>
<td>S. June 8, 1895</td>
<td>A. Aug. 1, 1903</td>
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<td>Naisbit, John</td>
<td>No. 48, Tudhoe Colliery, Spennymoor</td>
<td>April 27, 1895</td>
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<td>105</td>
<td>Nelson, George</td>
<td>Catron, Garesfield Colliery, near Lintz Green, R.S.O., Co. Durham</td>
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<td>106</td>
<td>Nisbet, Norman</td>
<td>Harraton Colliery, Chester-le-Street, Co. Durham</td>
<td>S. Nov. 24, 1894</td>
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<td>O'Keefe, J. E.</td>
<td>10, Newburgh Street, Amble, Acklington, Northumberland</td>
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<td>108</td>
<td>Owen, William</td>
<td>Rowland, 24, Market Street, Milom, Cumberland</td>
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<td>Parkin, Thomas</td>
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<td>Parkinson, W.</td>
<td>6, Ivy Terrace, South Moor, Chester-le-Street</td>
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<td>Parrington, T. E.</td>
<td>Hill House, Monkwearmouth</td>
<td>S. Aug. 3 1895</td>
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<td>Patterson, Thomas</td>
<td>East Hetton, Coxhoe, R.S.O., Co. Durham</td>
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<td>113</td>
<td>Pattison, William</td>
<td>18, East Street, High Spen, Lintz Green, R.S.O., Co. Durham</td>
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<td>Pearson, John</td>
<td>Charlton, Swiss Cottage, Westerhope, Kenton, Newcastle-upon-Tyne</td>
<td>Feb. 14, 1903</td>
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<td>115</td>
<td>Pedelty, Simon</td>
<td>Littletown Colliery, Durham</td>
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116 Peel, George, Jun., 27, Langley Street, Langley Park, Durham April 4, 1903
117 Peel, J. W., Thornhill Collieries, near Dewsbury, Yorkshire S. Aug. 4, 1894
118 Phelps, Charles, Kimblesworth Colliery, Chester-le-Street, Co. Durham A. Aug. 4, 1900
119 Potts, Laurence, Wylam, The Leam, Felling, R.S.O., Co. Durham April 4, 1903
120 Pratt, G. Ross, Springwell Colliery, Gateshead-upon-Tyne June 8, 1895
121 Proctor, Thomas, Woodhorn Colliery, Morpeth Oct. 13, 1894
122 Ramsay, John, Tursdale Colliery, Ferryhill April 27, 1895
124 Raw, John, Hunwick, Willington, Co. Durham Aug. 5, 1899
125 Ridley, George D., Tudhoe Colliery, Spennymoor Feb. 8, 1890
126 Rivers, John, Bow Street, Thornley Colliery, Durham Feb. 9, 1895
127 Roberton, Edward Heton, The University, Birmingham S. April 13, 1901
128 Robinson, John, Hunwick, Willington, Co. Durham Aug. 5, 1899
129 Robinson, John William, Callerton, Kenton, Newcastle-upon-Tyne 2 Dec. 13, 1902
130 Robson, William, Jun., Byers Green House, Byers Green, Spennymoor, Co. Durham S. June 11, 1892
131 Rochester, William, Ryton Barmoor, Ryton-upon-Tyne A. Aug. 3, 1895
133 Sampf, J. B., Harraton Colliery, Chester-le-Street, Co. Durham Aug. 2, 1902
134 Saner, Charles B., Nourse Deep, Limited, Mine Office, P.O. Box 1050, Johannesburg, Transvaal April 10, 1897
135 Seed, Alexander, 1, College Terrace, Brandon Colliery, R.S.O., Co. Durham Apr. 4, 1903
136 Severs, Jonathan, Stanley, R.S.O., Newcastle-upon-Tyne S. June 8, 1890
137 Smallwood, Percy Edmund, Chopwell Colliery, Lintz Green, R.S.O., Co. Durham Oct. 11, 1902
138 Snowdon, Thomas, Jun., Oakwood, Cockfield, R.S.O., Co. Durham S. June 12, 1897
139 Southern, Stephen, Heworth Colliery, Felling, R.S.O., Co. Durham A. Aug. 3, 1901
140 Stobart, Thomas Carlton, Ushaw Moor Colliery, Durham Aug. 2, 1902
141 Stokoe, James, 53, Railway Terrace, New Herrington, Fence Houses, Co. Durham Nov. 24, 1894
142 Stokoe, John George, 5, Killowen Terrace, Low Fell, Gateshead-upon-Tyne Dec. 9, 1899
143 Stratton, H. S., Park View, Forest Hall, Newcastle-upon-Tyne S. Feb. 9, 1895
144 Swallow, Ralph Storey, Langley Park Colliery, Durham A. Aug. 1, 1903
145 Tarbuck, Harold, Ryhope Colliery, near Sunderland Dec. 9, 1899
146 Tate, W.O., Office Street, Shotton Colliery, Castle Eden, R.S.O., Co. Durham Feb. 15, 1896
147 Taylor, Herbert William, c/o George Spittal, 58, Caroline Place, Hull S. Oct. 12, 1895
148 Thompson, Joseph, North Biddick Colliery, Washington Station, Co. Durham A. Aug. 1, 1903
149 Thompson, Robert, Butcher, Co. Durham April 8, 1893

Date of Election and of Transfer.

[il]
149 Turner, George, Tindale Terrace, Roachburn Colliery, Brampton Junction, Carlisle  
June 8, 1895

150 Tweddell, John Smith, Seaton Delaval Colliery, Northumberland  
S. Feb. 13, 1897  
A. Aug. 1, 1903

151 Urwin, John, Inkerman House, Usworth Colliery  
Feb. 15, 1896

152 Urwin, Thomas, Dipton Colliery, Lintz Green, R.S.O., Co. Durham  
Feb. 14, 1903

153 Wainwright, William, Heworth Colliery, Felling, R.S.O., Co. Durham  
April 2, 1898

154 Walker, Joseph Henry, 1, Elms North, Sunderland  
S Oct. 13, 1900  
A. Aug. 2, 1902

155 Wallace, James, c o Wild's Temperance Hotel, Ludgate Hill, London, E.C.  
Oct. 11, 1902

156 Walton, Arthur John, Sherwood Colliery, Mansfield  
S. Feb. 12, 1898  
A. Aug. 1, 1903

157 Welsh, Arthur, 16, Charles Street, New Silksworth, Sunderland  
S. Aug. 1, 1896  
A. Aug. 1, 1903

158 Widdas, Frank, Shiremoor, Northumberland  
Dec. 8, 1900

159 Wilkinson, John William, 43, Double Row, South Durham Colliery, Bishop Auckland  
Dec. 13, 1902

160 Willis, Henry Stevenson, Medomsley, R.S.O., Co. Durham  
S. Feb. 13, 1892  
A. Aug. 4, 1900

161 Wilson, R. G. Whitehill Terrace, Pelton Colliery, Chester-le-Street  
Aug. 6, 1892

STUDENTS.

1 Armstrong, William, Jun., Wingate, R.S.O., Co. Durham  
June 11, 1898

2 Bell, Harold Percy, Clyvedon, Cleadon, Sunderland  
Aug. 2, 1902

3 Bell, William, 59, Rothwell Road, Gosforth, Newcastle-upon-Tyne  
Feb. 13, 1897

4 Borrow, Frank Kendall, 38, Nevem Square, London, S.W.  
Oct. 8, 1898

5 Brandon, Geoffroy, Eastfield, Earsdon, Northumberland  
Dec. 8, 1900

6 Brown, Edward Otto Forster, Springfort, Stoke Bishop, Bristol  
Dec. 14, 1901

7 Cheesman, Matthew Forster, Throckley Colliery, Newburn, R.S.O., Northumberland  
Dec. 13, 1902

8 Cook, George, Binchester Hall, Bishop Auckland  
Aug. 2, 1902

[lii]

9 Dixon, George, Dunston Colliery Office, Gateshead-upon-Tyne  
June 13 1896

10 Dixon, George, Seghill Colliery, Seghill, Northumberland  
Feb. 9, 1901

11 Elliot, Arthur, 13, Eldon Place, Newcastle-upon-Tyne  
Dec. 13, 1902

12 Felton, John R., West Stanley Colliery, Stanley, R.S.O., Co. Durham  
June 8, 1901

13 Field, Benjamin Starrs, 8, Esplanade, Whitley, R.S.O. Northumberland  
Aug. 2 1902

14 Foggo, John Frederick, Netherton Colliery, near Newcastle-upon-Tyne  
June 14, 1902

Aug. 2, 1902

16 Galloway, John, Hebburn Colliery, Hebburn-upon-Tyne  
Dec. 13, 1902

17 Gidney, William H., 9, Ravensbourne Terrace, South Shields  
April 13, 1901

18 Gilchrist, George Atkinson, 17, Eldon Place, Newcastle-upon-Tyne  
Dec. 14, 1901

19 Greenwell, Alax Leonard Stapylton, South Durham Colliery, Eldon, Bishop Auckland  
Oct. 8, 1898

20 Harbit, William Denham, 32, High Street, Wallsend-upon-Tyne  
Dec 10, 1898
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<td>21</td>
<td>Harper, George Octavious</td>
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<td>Dec. 13, 1902</td>
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<td>23</td>
<td>Heaps, Christopher</td>
<td>12, Richmond Terrace, Gateshead-upon-Tyne</td>
<td>Feb. 10, 1900</td>
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<td>24</td>
<td>Hedley, Rowland Frank Hutton</td>
<td>Langholme, Roker, Sunderland</td>
<td>Apr. 4, 1903</td>
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<td>25</td>
<td>Herisson, John Edward Ralph</td>
<td>Ottawa, via Durban, Natal, South Africa</td>
<td>Oct. 11, 1902</td>
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<td>26</td>
<td>Holliday, Norman Stanley</td>
<td>Langley Grove, Durham</td>
<td>Apr. 10, 1897</td>
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<td>27</td>
<td>Howson, Charles</td>
<td>c/o Miss Harland, 38, Edwin Street, Houghton-le-Spring, Co. Durham</td>
<td>Dec. 14, 1901</td>
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<td>28</td>
<td>Humble, Ernest</td>
<td>Shotton Colliery, Castle Eden, R.S.O., Co. Durham</td>
<td>Feb. 14, 1903</td>
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<td>29</td>
<td>Humble, John Norman</td>
<td>West Pelton House, Beamish, R.S.O., Co. Durham</td>
<td>Aug. 2, 1902</td>
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<td>30</td>
<td>Jacobs, Lionel Asher</td>
<td>3, Thornhill Park, Sunderland</td>
<td>Aug. 4, 1900</td>
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<td>31</td>
<td>Jones, Walter</td>
<td>Thornley Colliery Office, Thornley, R.S.O., Co. Durham</td>
<td>Feb. 9, 1901</td>
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<td>32</td>
<td>Junor, Patrick Bruce</td>
<td>Jun., Thornley Colliery, Thornley, R.S.O., Co. Durham</td>
<td>Apr. 12, 1902</td>
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<td>33</td>
<td>Liddell, Christopher</td>
<td>Woodhorn Colliery, Northumberland</td>
<td>Dec. 14, 1901</td>
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<td>34</td>
<td>MacGregor, Donald</td>
<td>Seghill Colliery, Seghill, Northumberland</td>
<td>Feb. 9, 1901</td>
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<td>35</td>
<td>MacGregor, James</td>
<td>Malcolm, Cowpen Colliery Office, Blyth</td>
<td>Oct. 14, 1899</td>
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<td>36</td>
<td>Marley, Frederick</td>
<td>Thomas, 83, Victoria Road, Hebburn-upon-Tyne</td>
<td>Oct. 8, 1898</td>
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<tr>
<td>37</td>
<td>Maynard, Francis</td>
<td>George, Russel House, Newbottle, Fence Houses, Co. Durham</td>
<td>June 14, 1902</td>
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<tr>
<td>38</td>
<td>Merivale, Charles</td>
<td>Herman, Togston Hall, Acklington, Northumberland</td>
<td>June 9, 1900</td>
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<td>39</td>
<td>Milburne, Edwin Walter</td>
<td>18, Lindum Terrace, Rotherham</td>
<td>Feb. 10, 1900</td>
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<td>40</td>
<td>Milburne, John</td>
<td>Etherington, St. John's Road, New Shildon, Darlington</td>
<td>Oct. 14, 1899</td>
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<td>41</td>
<td>Nesbit, John Straker</td>
<td>Cramlington Collieries, Northumberland</td>
<td>Oct. 9, 1897</td>
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<td>42</td>
<td>Oliver, Ernest Hunter</td>
<td>Cornsay Colliery, Co. Durham</td>
<td>Feb. 8, 1902</td>
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<td>43</td>
<td>Oswald, George Robert</td>
<td>c/o Mrs Curtice, Richmond House, Pontnewydd, near Newport, Monmouthshire</td>
<td>June 9, 1900</td>
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<th>Number</th>
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<tr>
<td>44</td>
<td>Palmer, Harry</td>
<td>The Manor House, Medomsley, R.S.O., Co. Durham</td>
<td>June 14, 1902</td>
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<td>45</td>
<td>Palmer, Meyrick</td>
<td>The Manor House, Medomsley, R.S.O., Co. Durham</td>
<td>June 8, 1901</td>
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<td>46</td>
<td>Pattison, Charles Arthur</td>
<td>10, Stanhope Road North, Darlington</td>
<td>Apr. 13, 1901</td>
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<tr>
<td>47</td>
<td>Paine, Fred. J.</td>
<td>Station Road, Birtley, R.S.O., Co. Durham</td>
<td>Feb. 15, 1896</td>
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<td>48</td>
<td>Richardson, Frank</td>
<td>Orchard House, Gateshead-upon-Tyne</td>
<td>Oct. 12, 1901</td>
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<td>49</td>
<td>Richardson, Sydney</td>
<td>Charlton Villa, Ovingham-upon-Tyne, Northumberland</td>
<td>Oct. 9, 1897</td>
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<td>50</td>
<td>Ridpath, Tom R.</td>
<td>Medomsley, R.S.O., Co. Durham</td>
<td>June 8, 1901</td>
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<td>51</td>
<td>Robinson, George Henry</td>
<td>Jun., Asturiana Mines, Limited, Covadonga, Asturias, Spain</td>
<td>Dec. 9, 1899</td>
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<td>52</td>
<td>Robinson, John William</td>
<td>Boldon Colliery Office, Boldon Colliery, R.S.O., Co. Durham</td>
<td>Apr. 12, 1902</td>
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<td>53</td>
<td>Robinson, Stanley</td>
<td>Bunker Hill, Fence Houses</td>
<td>Oct. 12, 1901</td>
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<td>54</td>
<td>Rogers, John</td>
<td>2, Pilgrim Street, Murton Colliery, Sunderland</td>
<td>Apr. 8, 1899</td>
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<td>55</td>
<td>Roose, Hubert F. G.</td>
<td>Inglenook, Dormans Park, East Grinstead, Sussex</td>
<td>Dec. 9, 1899</td>
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<td>56</td>
<td>Rutherford, Thomas</td>
<td>Easton, South Derwent Colliery, Annfield Plain, Co. Durham</td>
<td>June 10, 1899</td>
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<td>57</td>
<td>Scott, George Henry Hall</td>
<td>c/o T. E. Forster, 3, Eldon Square, Newcastle-upon-Tyne</td>
<td>Apr. 12, 1902</td>
</tr>
<tr>
<td>58</td>
<td>Sharpiev, Harold</td>
<td>co Percival Hadkinson, Smyrna, Asia Minor</td>
<td>Dec. 8, 1900</td>
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<td>59</td>
<td>Stewart, William</td>
<td>Milnthorp House, Sandal, Wakefield</td>
<td>Oct. 8, 1898</td>
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<td>60</td>
<td>Strong, George Adamson</td>
<td>26, Gladstone Terrace, Birtley, Co. Durham</td>
<td>Aug. 2, 1902</td>
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<td>61</td>
<td>Swan, Joseph Todd</td>
<td>Throckley Colliery, Newburn, R.S.O., Northumberland</td>
<td>Dec. 13, 1902</td>
</tr>
<tr>
<td>62</td>
<td>Tate, Robert Simon</td>
<td>Trimdon Grange, R.S.O., Co. Durham</td>
<td>Aug. 3, 1901</td>
</tr>
</tbody>
</table>
63 Teasdale, George, Jun., Garden House, Pelton, Chester-le-Street, Co. Durham Dec. 13, 1902
64 Thirlwell, Thomas A., Wallsend Colliery, Newcastle-upon-Tyne Dec. 13, 1902
65 Thompson, George Heron, Dinsdale, Dinsdale Vale, Windsor Avenue, Waterford, Blyth Feb. 14, 1903
66 Thornton, Frank, Cornsay Colliery, Co. Durham Feb. 8, 1902
68 Wraith, Alfred Osborn, Moor House, Spennymoor, R.S.O., Co. Durham June 9, 1900
69 Young, George Ellis, Kimblesworth Colliery, Chester-le-Street, Co. Durham Aug. 3, 1901

SUBSCRIBERS.

1 Owners of Ashington Colliery, Newcastle-upon-Tyne.
2 Birtley Iron Company (3), Birtley.
3 Bridgewater Trustees (2), Bridgewater Offices, Walkden, Bolton-le-Moors, Lancashire.
4 Marquess of Bute, Bute Estate Offices, Aberdare, South Wales.
5 Butterknowle Colliery Company, Darlington.
6 Cowpen Coal Company, Limited (2), F, King Street, Newcastle-upon-Tyne.
7 Earl of Durham (2), Lamton Offices, Fence Houses.
8 Elswick Coal Company, Limited, Newcastle-upon-Tyne.
9 Harton Coal Company, Limited (3), Harton Collieries, South Shields.
10 Hetton Coal Company (5), Fence Houses.
11 Joicey, James, and Company, Limited (2), Newcastle-upon-Tyne.
12 Lambton Collieries, Limited (2), E, Queen Street, Newcastle-upon-Tyne.

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13 Marquis of Londonderry (5), c/o V. W. Corbett, Londonderry Offices, Seaham Harbour.
14 North Brancepeth Coal Company, Limited, Crown Street, Cramlington.
15 Owners of North Hetton Colliery (3), Fence Houses.
16 Ryhope Coal Company (2), Ryhope Colliery, near Sunderland.
17 Owners of Seghill Colliery, Seghill, Northumberland.
18 Owners of South Hetton and Murton Collieries (2), 50 John Street, Sunderland.
19 Owners of Stella Colliery, Hedgefield, Blaydon-upon-Tyne.
20 Owners of Throckley Colliery, Newcastle-upon-Tyne.
22 Owners of Wearmouth Colliery (2), Sunderland.
23 Westport Coal Company, Limited (2), Manager. Dunedin, New Zealand

ENUMERATION.

August 1, 1903.
Honorary Members
Members
Associate Members
Associates
Students
Subscribers

Total

Members are desired to communicate all changes of address, or any corrections or omissions in the list of names, to the Secretary.

BRIEF SYLLABUS
OF THE
THREE YEARS' COURSE OF LECTURES
FOR
COLLIERY ENGINEERS, ENGINEWRIGHTS, APPRENTICE MECHANICS AND OTHERS.

The Council of the North of England Institute of Mining and Mechanical Engineers, in collaboration with the Council of The Durham College of Science, have arranged a course of Lectures for Colliery Engineers, Enginewrights, Apprentice Mechanics and others, to be delivered at The Durham College of Science, Newcastle-upon-Tyne.

The course will extend over three winter sessions, and involves attendance for about 24 Saturday afternoons, from 3 p.m. to 5 p.m. during each session. Students can enter any of the courses, each series of Lectures being, as far as possible, entirely independent of the others, and constituting a complete course upon its own subject.

It is desirable that Students should not be less than 17 years of age.

The delivery of the next course of Lectures will commence on October 3rd, 1903. The fee for the series of four courses given during each session is £1 10s.

Examinations will be held at the end of each course in the respective subjects. Certificates will be granted to those Students who attend satisfactorily and pass the Examinations throughout the three years' course, and Prizes will be awarded annually to the two Students who do best in the aggregate Examinations of the year.

The Council recommend that colliery owners and others, who send Students to these classes, should insist upon home work being done regularly.

A number of colliery owners have agreed to pay the fees and (or) train fares of some of their employees whom they propose to send to the course of Lectures.

Any further information will be supplied on application to Mr. F. H. Pruen, Secretary, Durham College of Science, Newcastle-upon-Tyne, or Mr. M. Walton Brown, Secretary, North of England Institute of Mining and Mechanical Engineers, Neville Hall, Newcastle-upon-Tyne.

MICHAELMAS TERM, Commencing October 3rd, 1903.

Mensuration.—3.0 to 3.50 p.m.
Lecturer—Principal H. P. Gurney, M.A., D.C.L., F.G.S.
Lengths, triangles, similar figures, chords, arcs and circumferences of circles. Areas of plain figures; rectangles, parallelograms, triangles and rectilinear figures; circles, sectors and segments of circles; Simpson's rule; similar figures. Volumes of solid figures; parallelipiped, right prism, right circular cylinder, ring and pipe, right pyramid, right circular cone and sphere. Areas of surfaces of solids; plane surfaces, right circular cylinder, right circular cone and sphere.

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The Chemistry of Fuel. — 4.5 to 4.55 p.m.
Lecturer—Mr. F. C. Garrett, M.Sc, F.C.S.


EPIPHANY TERM, Commencing January 9th, 1904.

Strength of Materials (with Experimental Illustrations).— 3.0 to 3.50 p.m.
Lecturer—Mr. H. R. Cullen, M.A.

Materials used in construction:—Cast-iron, wrought-iron, steel, brass, brick stress and strain. Strength under tension, compression, shearing and bending. Breaking and working strengths; factors of safety; the effect of live loads; extension and compression under loads; behaviour of material under stress; effect of length of specimens.

The lectures will be illustrated by actual experiments on the 100 tons testing-machine in the Engineering Laboratory.

Experimental Mechanics.—4.5 to 4.55 p.m.
Lecturer—Mr. R. J. Patterson, M.Sc.

Introductory definitions, with illustrations; force and work, and their measurement; power; horsepower; principle of the conservation of energy. Machines for changing the magnitude and the direction of force; workshop appliances, lever, single and double purchase winches, pulleys, inclined plane and screw, screwjack; friction, efficiency of machines. Graphical representation of forces. Specific gravity and its determination by the hydrostatic balance. The atmosphere and the pressure it exerts; the barometer; lifting and forcing pumps.

1904-1905.—MICHAELMAS TERM.

Theoretical Electricity.
Lecturer—Mr. R. J. Patterson, M.Sc.

Magnetism; lines of magnetic force, magnetic field; distinctive magnetic properties of iron and steel. Electricity; production of an electric current; magnetic, chemical and heating effects of the current; measurement of current strength, electro motive-force and resistance; practical electrical units, the ampere, volt and ohm; Ohm's Law. The principle of the dynamo and the electric motor.

Electrical Engineering.
Lecturer—Mr. W. M. Thornton, D.Sc, M.I.E.E.

Systems of measurement, current, voltage, resistance, practical instruments, magnetic induction, continuous-current dynamos, details of construction, motors, methods of connecting and testing dynamos and motors, alternating currents, incandescent and arc lamps,
secondary cells, mains, cables, wiring of buildings and mines, applications of electric-motive power in mining.

1904-1905. — EPIPHANY TERM.

The Steam-engine.
Lecturer—Mr. H. R. Cullen, M.A.

Heat, its measurement and transfer; saturated steam; pressure and temperature of steam; expansion of steam; the indicator and indicator-diagrams; horsepower, indicated and effective; simple forms of the steam-engine, valves and the distribution of steam, governors; compound and triple-expansion engines; efficiency of the steam-engine; steam-boilers, combustion and draught; evaporative power of coal.

Haulage and Winding.
Lecturer—Professor Henry Louis, M.A., A.R.S.M.

Main haulage-roads, animal traction, self-acting inclines, engine-planes, main-and-tail-rope haulage, endless-rope or endless-chain haulage; haulage-engines, plant and appliances, underground haulage-engines; electric, hydraulic and pneumatic engines; secondary haulage. Onsetting and banking. Winding-engines, cages, ropes, safety appliances, pulley-frames, heapsteads, surface arrangements.

1905-1906.—MICHAELMAS TERM.

Transmission of Power.
Lecturer—Mr. H. R. Cullen, M.A.

Work and power; different forms of energy, its storage, transformation and transmission; simple machines, friction and lost work, efficiency of machinery; methods of transmitting power, shafting and bearings, spur-and-bevel wheels, rope gearing, hydraulic transmission, compressed-air transmission; the steam-engine and boiler: comparison of different methods.

Pumping and Ventilation.
Lecturer—Professor Henry Louis, M.A., A.R.S.M.

Elementary notions of drainage, dams, reservoirs; syphons; baling; arrangement of pumps, driving, starting and working pumps; pipes; bucket-pumps; plunger-pumps; details, balance-bobs, angle-bobs, spears, catches, etc.; pump-valves; direct-acting pumps; electric, pneumatic and hydraulic pumps.

Principles of ventilation; movement of air-currents; measurement of air-currents, anemometers, water-gauges; natural ventilation; ventilating appliances, fans, furnaces; distribution of air-currents, splitting currents, doors, stoppings, regulators; general considerations affecting ventilation.

1905-1906.—EPIPHANY TERM.

Metallurgy of Iron and Steel.
Lecturer—Mr. G. H. Stanley, A.R.S.M.

into wrought-iron and steel. The puddling process and the various methods of steel making. The structure and nature of steel; hardening and tempering.

Mining Machinery (mainly Machinery used Underground).

Lecturer—Professor Henry Louis, M.A., A.R.S.M.


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LIST OF TRANSACTIONS AND JOURNALS OF SOCIETIES, Etc., IN THE LIBRARY.


American Academy of Arts and Sciences, Boston. Memoirs, complete from vol. i, 1873. Proceedings, complete from vol. i., 1846.

American Engineer and Railroad Journal, New York City. Vol. lxvii., 1893 (incomplete) vol. lxx., 1894; vol. lxix., 1895 (incomplete); and complete from vol lxxv, 1901, part 12.

American Gas Light Journal, New York City, Complete from vol. lxxv., 1901  no. 22

American Institute of Electrical Engineers, New York City. Transactions, complete from vol. xviii., 1901.


American Philosophical Society, Philadelphia. Proceedings, complete from vol xi, 1901.

American Society of Civil Engineers, New York City. Proceedings, complete from vol. i., 1873. Transactions, complete from vol i., 1872.

American Society of Mechanical Engineers, New York City. Transactions complete from 1880.


Annales des Mines de Belgique, Brussels. Memoires, complete.


Anthracite Coal Operators' Association, New York City. Complete from August, 1897.

Arms and Explosives, London. Complete from vol. i., 1892.

Association de la Presse Technique, Brussels. Index, complete from 1903.

Association of Civil Engineers of Cornell University, Ithaca. Transactions, complete from vol. x., 1902.

Association of Engineering Societies, Philadelphia. Journal, complete from vol. i., 1882, except vols, i., nos. 1 to 5, and vol. vii., nos. 3 and 5 to 8 (out of print).


Australasian Association for the Advancement of Science, Sydney, New South Wales. Reports, complete.

Australasian Institute of Mining Engineers, Melbourne. Transactions, complete from vol. i.

Australian Mining Standard, Melbourne. Vol. vii., 1892, no. 187; vol. x., 1894, no. 275; and complete from vol. xi., no. 355.


Barometer Readings, taken in the Wood Memorial Hall of the North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne. Complete from 1873.

Barrow Naturalists' Field Club, Barrow-in-Furness. Annual Reports, Proceedings, etc., complete from vol. i., 1877.


Birmingham Natural History and Philosophical Society, Birmingham. Proceedings, complete from vol. i., 1876.

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British Association for the Advancement of Science, London. Complete from 1831.

British Association of Waterworks Engineers, London. Transactions, complete from vol. v., 1900.


British Columbia Mining Record, Victoria. Complete from vol. v., 1899.


British Society of Mining Students, Medomsley. Journal, complete from vol. i., 1876.

Brown's Export List, Newcastle-upon-Tyne. Complete from 1853.


California, University of, Berkeley. Bulletin of the Department of Geology, complete from vol. iii.

Cambridge University Library, Cambridge. Annual Reports of the Library Syndicate, 1886, and complete from 1893 (except 1898 and 1900).

Canada, Department of Colonization and Mines, Quebec. Reports on Mining Operations in the Province of Quebec, complete from 1898.


Canadian Engineer, Toronto. Complete from vol. viii., 1901, no. 20.

Canadian Institute, Toronto. Annual Reports, complete from 1887. Transactions, complete, with the exception of vol. i., series 1 (The Canadian Journal), parts 6, 7 and 10; vol. xv., series 2 (The Canadian Journal), parts 5 and 7; vol. i., series 3 (Proceedings of the Canadian Institute); and vol. iii., series 3 (Proceedings of the Canadian Institute), parts 1, 3, and all after 4.

Canadian Mining Institute (late Federated Canadian Mining Institute), Ottawa. Journal, complete from vol. i., 1896.

Canadian Mining Manual and Mining Companies Yearbook, Ottawa. Complete from 1890-91.

Canadian Mining Review, Ottawa. Vol. ix., 1890, nos. 4 and 5; vol. x., 1891, nos. 1, 4 to 6 and 8 to 12; and complete from vol. xi., 1892.

Canadian Society of Civil Engineers, Montreal. Transactions, complete from vol. xiv.

Cape Mail, London. Complete from vol. i., 1902.

Cape of Good Hope, Department of Agriculture, Cape Town. Reports of the Inspector of Mines, Kimberley, etc., for the years 1889, 1890 and 1892 to 1895.


Central Mining Institute of Western Pennsylvania. Journal, complete from vol. i.


Chemical and Metallurgical Society of South Africa, Johannesburg. Proceedings, complete from vol. i. Journal, complete from vol. i.

Chemical Trade Journal, Manchester. Complete from vol. xxix., 1901.

Chesterfield and Midland Counties Institution of Engineers, Chesterfield. Transactions, complete.

Civil and Mechanical Engineers' Society, London. Transactions, complete from vol. xliii., 1901.

Cleveland Institution of Engineers, Middlesbro'. Proceedings, complete from 1869.

Coal and Iron, London. Complete from vol. iii.

Colegio de Ingenieros de Venezuela, Caracas. El Ingeniero, complete from vol. i.

Colliery Guardian, London. Vol. ii., 1858, pages 1 to 384; and complete from vol. i., 1861, except vols. ix. to xiii.

Colliery Journal and Mining Engineer, Glasgow. Complete from vol. i., 1902.

Colliery Manager, London. Complete from vol. i., 1885.

Colliery Manager's Pocket-Book, Almanac and Diary, London. 1874, 1887, 1891, 1894, and 1896 to date.

Colonial Museum and Geological Survey of New Zealand, Wellington. Geological Reports, complete from 1870 to 1891, except for 1873-74. Palaeontology of New Zealand, part 4. Museum and Laboratory Reports, complete from 1868. Meteorological Returns and Reports, complete from 1868 to 1886, with the exception of those for 1873-74 and 1885-86.
Miscellaneous Publications, complete, with the exception of nos. 1, 2, 12, 13, 16, 17 and 19 to 28. Colonial Reports. Annual and Miscellaneous Series. Complete from commencement, 1891.

Compressed Air, New York City. Complete from vol. i., 1890, except vol. i., nos 1 and 12
Connecticut Academy of Arts and Science, New Haven. Transactions, complete.
Copper Handbook, Houghton, Michigan. Complete from vol. i., 1901
Cuerpo de Ingenieros de Minas del Peru, Lima. Boletin, complete from no. 1, 1902
De Ingenieur. See Koninklijk Instituut van Ingenieurs.
Digest of Physical Tests and Laboratory Practice, Philadelphia. Complete.
Dinglers Polytechnisches Journal, Berlin. Complete from vol. ccxlvii. 1883
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Electrical Investments, London. Complete from vol. iii., 1903.
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Geological Survey of Iowa, Des Moines. Annual Reports, complete from vol. i.
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Geologiska Forening, Stockholm. Forhandlingar, complete from 1872.
Hazell’s Annual, London. Complete from 1900.
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Institution of Mining Engineers, Newcastle-upon-Tyne. Transactions, complete from vol. I, 1889.


International Association for Testing Materials, Zurich. Reports, etc., from 1898.

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Italy, Rivista del Servizio Minerario, Roma. Complete from 1897.

Jaarboek van het Mijnwezen in Nederlandsch Oost-Indie, Amsterdam. Complete from 1878.


Kaiserlich Leopoldinisch-Carolinische Deutsche Akademie der Naturforscher, Halle. Complete from vol. XXXVI.

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Kansas, The University Geological Survey of. Annual Reports, complete from vol. II. Mineral Resources, complete from 1897. Bulletin (late Kansas, Lawrence, University Quarterly), complete from vol. VIII, no. 1.


Labour Gazette, Board of Trade, London. Complete.

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The Library comprises over 9,000 Volumes, etc., treating of Geology, and Mining, Mechanical, and Civil Engineering.
August 1st, 1903.

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CHARTER OF THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

FOUNDED 1852.
INCORPORATED NOVEMBER 28th, 1876.

VICTORIA, by the Grace of God, of the United Kingdom of Great Britain and Ireland, Queen, Defender of the Faith, to all to whom these Presents shall Come, Greeting:

Whereas it has been represented to us that Nicholas Wood, of Hetton, in the County of Durham, Esquire (since deceased); Thomas Emerson Forster, of Newcastle-upon-Tyne, Esquire (since deceased); Sir George Elliot, Baronet (then George Elliot, Esquire), of Houghton Hall, in the said County of Durham, and Edward Fenwick Boyd, of Moor House, in the said County of Durham, Esquire, and others of our loving subjects, did, in the year one thousand eight hundred and fifty-two, form themselves into a Society, which is known by the name of The North of England Institute of Mining and Mechanical Engineers, having for its objects the Prevention of Accidents in Mines and the Advancement of the Sciences of Mining and Engineering generally, of which Society Lindsay Wood, of Southill, Chester-le-Street, in the County of Durham, Esquire, is the present President. And whereas it has been further represented to us that the Society was not constituted for gain, and that neither its projectors nor Members derive nor have derived pecuniary profit from its prosperity; that it has during its existence of a period of nearly a quarter of a century steadily devoted itself to the preservation of human life and the safer development of mineral property; that it has contributed substantially and beneficially to the prosperity of the country and the welfare and happiness of the working members of the community; that the Society has since its establishment diligently pursued its aforesaid objects, and in so doing has made costly experiments and researches with a view to the saving of life by improvements in the ventilation of mines, by ascertaining the conditions under which the safety lamp may be relied on for security; that the experiments conducted by the Society have related to accidents in mines of every description, and have not been limited to those proceeding from explosions; that the various modes of getting coal, whether by mechanical appliances or otherwise, have received careful and continuous attention, while the improvements in the mode of working and hauling belowground, the machinery employed for preventing the disastrous falls of roof underground, and the prevention of spontaneous combustion in seams of coal as well as in cargoes, and the providing additional security for the miners in ascending and descending the pits, the improvements in the cages used for this purpose, and in the safeguards against what is technically known as "overwinding," have been most successful in lessening the dangers of mining, and in preserving human life; that the Society has held meetings at stated periods, at which the results of the said experiments and researches have been considered and discussed, and has published a series of Transactions, filling many volumes, and forming in itself a highly valuable Library of scientific reference, by which the same have been made known to the public, and has formed a Library of Scientific Works and Collections of Models and Apparatus, and that distinguished persons in foreign countries have availed themselves
of the facilities afforded by the Society for communicating important scientific and practical discoveries, and thus a useful interchange of valuable information has been effected; that in particular, with regard to ventilation, the experiments and researches of the Society, which have involved much pecuniary outlay and personal labour, and the details of which are recorded in the successive volumes of the Society's Transactions, have led to large and important advances in the practical knowledge of that subject, and that the Society's researches have tended largely to increase the security of life: that the Members of the Society exceed 800 in number, and include a large proportion of the leading Mining Engineers in the United Kingdom. And whereas in order to secure the property of the Society, and to extend its useful operations, and to give it a more permanent establishment among the Scientific Institutions of our Kingdom, we have been besought to grant to the said Lindsay Wood, and other the present Members of the Society, and to those who shall hereafter become Members thereof, our Royal Charter of Incorporation. Now know ye that we, being desirous of encouraging a design so laudable and salutary, of our especial grace, certain knowledge, and mere motion, have willed, granted, and declared, and do, by these presents, for us, our heirs, and successors, will, grant, and declare, that the said Lindsay Wood, and such others of our loving subjects as are now Members of the said Society, and such others as shall from time to time hereafter become Members thereof, according to such Bye-laws as shall be made as hereinafter mentioned, and their successors, shall for ever hereafter be, by virtue of these presents, one body, politic and corporate, by the name of "The North of England Institute of Mining and Mechanical Engineers," and by the name aforesaid shall have perpetual succession and a Common Seal, with full power and authority to alter, vary, break, and renew the same at their discretion, and by the same name to sue and be sued, implead and be impleaded, answer and be answered unto, in every Court of us, our heirs and successors, and be for ever able and capable in the law to purchase, acquire, receive, possess, hold, and enjoy to them and their successors any goods and chattels whatsoever, and also be able and capable in the law (notwithstanding the statutes of mortmain) to purchase, acquire, possess, hold and enjoy to them and their successors a hall or house, and any such other lands, tenements, or hereditaments whatsoever, as they may deem requisite for the purposes of the Society, the yearly value of which, including the site of the said hall or house, shall not exceed in the whole the sum of three thousand pounds, computing the same respectively at the rack rent which might have been had or gotten for the same respectively at the time of the purchase or acquisition thereof. And we do hereby grant our especial license and authority unto all and every person and persons and bodies politic and corporate, otherwise competent, to grant, sell, alien, convey or devise in mortmain unto and to the use of the said Society and their successors, any lands, tenements, or hereditaments not exceeding

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with the lands, tenements or hereditaments so purchased or previously acquired, such annual value as aforesaid, and also any moneys, stocks, securities, and other personal estate to be laid out and disposed of in the purchase of any lands, tenements or hereditaments not exceeding the like annual value. And we further will, grant, and declare, that the said Society shall have full power and authority, from time to time, to sell, grant, demise, exchange and dispose of absolutely, or by way of mortgage, or otherwise, any of the lands, tenements, hereditaments and possessions, wherein they have any estate or interest, or which they shall acquire as aforesaid, but that no sale, mortgage, or other disposition of any lands, tenements, or hereditaments of the Society shall be made, except with the approbation and concurrence of a General Meeting. And our will and pleasure is, and we further grant and declare that for the better rule and government of the Society, and the direction and management of the
concerns thereof, there shall be a Council of the Society, to be appointed from among the Members thereof, and to include the President and the Vice-Presidents, and such other office-bearers or past office-bearers as may be directed by such Bye-laws as hereinafter mentioned, but so that the Council, including all ex-officio Members thereof, shall consist of not more than forty or less than twelve Members, and that the Vice-Presidents shall be not more than six or less than two in number. And we do hereby further will and declare that, the said Lindsay Wood shall be the first President of the Society, and the persons now being the Vice-Presidents, and the Treasurer and Secretary, shall be the first Vice-Presidents, and the first Treasurer and Secretary, and the persons now being the Members of the Council shall lie the first Members of the Council of the Society, and that they respectively shall continue such until the first election shall be made at a General Meeting in pursuance of these presents. And we do hereby further will and declare that, subject to the powers by these presents vested in the General Meetings of the Society, the Council shall have the management of the Society, and of the income and property thereof, including the appointment of officers and servants, the definition of their duties, and the removal of any of such officers and servants, and generally may do all such acts and deeds as they shall deem necessary or fitting to be done, in order to carry into full operation and effect the objects and purposes of the Society, but so always that the same be not inconsistent with, or repugnant to, any of the provisions of this our Charter, or the Laws of our Realm, or any Bye-law of the Society in force for the time being. And we do further will and declare that at any General Meeting of the Society, it shall be lawful for the Society, subject as hereinafter mentioned, to make such Bye-laws as to them shall seem necessary or proper for the regulation and good government of the Society, and of the Members and affairs thereof, and generally for carrying the objects of the Society into full and complete effect, and particularly (and without its being intended hereby to prejudice the foregoing generality), to make Bye-laws for all or any of the purposes hereinafter mentioned, that is to say: for fixing the number of Vice-Presidents, and the number of Members of which the Council shall consist, and the manner of electing the President and Vice-Presidents, and other Members of the Council, and the period of their continuance in office, and the manner and time of supplying any vacancy therein; and for regulating the times at which General Meetings of the Society and Meetings of the Council shall be held,

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and for convening the same and regulating the proceedings thereat, and for regulating the manner of admitting persons to be Members of the Society, and of removing or expelling Members from the Society, and for imposing reasonable lines or penalties for non-performance of any such Bye-laws, or for disobedience thereto, and from time to time to annul, alter, or change any such Bye-laws, so always that all Bye-laws to be made as aforesaid be not repugnant to these presents, or to any of the laws of our Realm. And we do further will and declare that the present Rules and Regulations of the Society, so far as they are not inconsistent with these presents, shall continue in force, and be deemed the Bye-laws of the Society until the same shall be altered by a General Meeting, provided always that the present Rules and Regulations of the Society and any future Bye-laws of the Society so to be made as aforesaid shall have no force or effect whatsoever until the same shall have been approved in writing by our Secretary of State for the Home Department. In witness whereof we have caused these our Letters to be made Patent.

Witness Ourself at our Palace, at Westminster, the 28th day of November, in the fortieth year of our reign.

By Her Majesty's Command.

CARDEW.
BYE-LAWS.

I.—Constitution.
1.—The North of England Institute of Mining and Mechanical Engineers shall consist of Members, Associate Members and Honorary Members. The Institute shall in addition comprise Associates and Students.
2.—The Officers of the Institute, other than the Treasurer and the Secretary, shall be elected from the Members and Associate Members, and shall consist of a President, six Vice-Presidents, and eighteen Councillors, who, with the Treasurer and the Secretary (if Members of the Institute) shall constitute the Council.

All Past-Presidents shall be ex-officio Members of the Council, so long as they continue Members or Associate Members of the Institute; and Vice-Presidents who have not been re-elected or have become ineligible from having held office for three consecutive years, shall be ex-officio Members of the Council for the following year.

II.—Qualifications of Members, Associate Members, Honorary Members, Associates and Students.
3.—Members.—Every candidate for admission into the class of Members, or for transfer into that class, shall come within the following conditions:—He shall be more than twenty-three years of age, have been regularly educated as a Mining or Mechanical Engineer, or in some other branch of Engineering, according to the usual routine of pupilage, and have had subsequent employment for at least two years in some responsible situation as an Engineer, or if he has not undergone the usual routine of pupilage, he must have been employed or have practised as an Engineer for at least five years. This class shall also comprise every person who was an Ordinary Member, Life Member, or Student on the first of August, 1877.
4.—Associate Members shall be persons connected with or interested in Mining or Engineering, and not practising as Mining or Mechanical Engineers, or in some other branch of Engineering.
5.—Honorary Members shall be persons who have distinguished themselves by their literary or scientific attainments, or who have made important communications to the Society.
6.—Associates shall be persons acting as under-viewers, under-managers, or in other subordinate positions in mines, or employed in analogous positions in other branches of Engineering.
7.—Students shall be persons who are qualifying themselves for the profession of Mining or Mechanical Engineering, or other branch of Engineering, and such persons may continue Students until they attain the age of twenty-five years.

III.—Election and Expulsion of Members.
8.—Any person desirous of becoming a Member, an Associate Member, an Associate or a Student, shall be proposed according to the proper Form in the Appendix, in which Form the
name, usual residence, and qualifications of the candidate shall be distinctly specified. The Form must be signed by the proposer and at least two other Members or Associate Members, certifying a personal knowledge of the candidate, who shall himself sign the undertaking contained therein.

Any person qualified to become an Honorary Member shall be proposed according to the proper Form in the Appendix, in which Form the name, usual residence, and qualifications of the candidate shall be distinctly stated. This Form must be signed by the proposer and at least five other Members or Associate Members, certifying a personal knowledge of the candidate, who shall himself sign the undertaking contained therein, and the Council shall have the power of defining the time during which and the circumstances under which the candidate shall be an Honorary Member.

Any Associate or Student desirous of becoming a Member shall be proposed and recommended according to the proper Form in the Appendix, in which Form the name, usual residence, and qualifications of the candidate shall be distinctly specified. This Form must be signed by the proposer and at least two other Members or Associate Members, certifying a personal knowledge of the candidate, who shall himself sign the undertaking contained therein, and the proposal shall then be treated in the manner hereinafter described.

Every proposal shall be delivered to the Secretary, and by him submitted to the next meeting of the Council, who, on approving the qualifications, shall determine if the candidate is to be presented for ballot. And if it is so determined, the Chairman of the Council shall sign such proposal. The same shall be read at the next Ordinary General Meeting, and afterwards be exhibited in the Institute's Hall until the following Ordinary General Meeting, when the candidate shall be balloted for.

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A Student may become an Associate at any time after attaining the age of twenty-one years.

9.—The balloting shall be conducted in the following manner: — Each Member or Associate Member attending the meeting, at which a ballot is to take place, shall be supplied (on demand) with a list of the names of the persons to be balloted for, according to the proper Form in the Appendix, and shall strike out the names of such candidates as he desires shall not be elected, and return the list to the scrutineers appointed by the presiding Chairman for the purpose, and such scrutineers shall examine the lists so returned, and inform the meeting what elections have been made. No candidate shall be elected unless he secures the votes of two-thirds of the Members and Associate Members voting.

10.—Notice of election shall be sent to every person within one week after his election, according to the proper Form in the Appendix, and the person elected shall send the amount of his annual subscription, or life composition, within four months from the date of such election, which otherwise shall become void.

11.—Every Member having signed a declaration according to the proper Form in the Appendix, and having likewise made the proper payment, shall receive a certificate of his election, according to the proper Form in the Appendix.

12.—Any Member, Associate Member, Associate or Student elected at any meeting between the Annual Meetings shall be entitled to all Transactions issued in the Institute's year, so soon as he has signed and returned a declaration according to the proper Form in the Appendix, and paid his subscription.

13.—The Transactions of the Institute shall not be forwarded to those whose subscriptions are in arrear on the first of November in each year.
14.—Any person whose subscription is more than one year in arrear shall be reported to the Council, who shall direct application to be made for it, according to the proper Form in the Appendix, and in the event of its continuing one month in arrear after such application, the Council shall have the power, after remonstrance by letter to his last recorded address in the books of the Society, according to the proper Form in the Appendix, of declaring that the defaulter has ceased to be a Member.

15.—In case the expulsion of any person shall be judged expedient by ten or more Members or Associate Members, and they think fit to draw up and sign a proposal requiring such expulsion, the same being delivered to the Secretary, shall be by him laid before the next meeting of the Council for consideration. If the Council, after due inquiry, do not find reason to concur in the proposal, no entry thereof shall be made in any minutes, nor shall any public discussion thereon be permitted, unless by requisition signed by one-half of the Members or Associate Members of the Institute: but if the Council do find good reason for the proposed expulsion, they shall direct the Secretary to address a letter, according to the proper Form in the Appendix, to the person proposed to be expelled, advising him to withdraw from the Institute. If that advice be followed, no entry on the minutes nor any public discussion on the subject shall lie permitted: but if that advice be not followed, nor an explanation given which is satisfactory to the Council, they shall call a General Meeting for the purpose of deciding on the question of expulsion: and if a majority of the Members and Associate Members present at such meeting (provided the number so present be not less than forty) vote that such person be expelled, the Chairman of that meeting shall declare the same accordingly and the Secretary shall communicate the same to the person, according to the proper Form in the Appendix.

IV.—Subscriptions.

16. The annual subscription of each Member and Associate Member shall lie £2 2s., of each Associate and Student £1 5s., payable in advance, and shall be considered due on election, and afterwards on the first Saturday in August of each year.

17.—Any Member, Associate Member, Associate or Student, may, at any time, compound for all future subscriptions by a payment in accordance with the following scale:

<table>
<thead>
<tr>
<th>Age</th>
<th>Subscription</th>
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<tbody>
<tr>
<td>Under 30 years of age</td>
<td>£31</td>
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<tr>
<td>Over 30</td>
<td>£27</td>
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<tr>
<td>40</td>
<td>£24</td>
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<td>50</td>
<td>£21</td>
</tr>
<tr>
<td>60</td>
<td>£17</td>
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</tbody>
</table>

or on such other conditions as the Council may, in writing, accept. Every person so compounding shall be a Member, Associate Member, Associate or Student for life, as the case may be. Any Associate Member, Associate or Student so compounding who may afterwards be qualified to become a Member, may do so, by election in the manner described in Bye-law 8. All compositions shall be deemed capital money of the Institute.

18.—In case any Member, Associate Member or Associate, who has been long distinguished in his professional career, becomes unable, from ill-health, advanced age, or other sufficient cause, to carry on a lucrative practice, the Council may, on the report of a Sub-Committee appointed by them for that purpose, if they find good reason for the remission of the annual subscription, so remit it. They may also remit any arrears which are due from a Member, or
they may accept from him a collection of books, or drawings, or models, or other contributions, in lieu of the composition mentioned in Bye-law 17. and may thereupon release him from any or all future subscriptions, and permit him to resume his former rank in the Institute.

19.—Owners of Collieries, Engineers, Manufacturers, Railway Companies, and Employers of labour generally, may subscribe annually to the funds of the Institute, and each such subscriber of £2 2s. annually shall be entitled to tickets to admit two persons to the rooms, library, meetings, lectures, and public proceedings of the Society: and for every additional £2 2s., subscribed annually, two or other persons shall be admissible; and each such subscriber shall also be entitled for each £2 2s. subscription to have a copy of the Transactions of the Institute sent to him.

V.—Election of Officers.

20.—The President. Vice-Presidents, and Councillors shall be elected at the Annual Meeting in August (except in cases of vacancies) and shall be eligible for re-election to any office, with the exception of any President who may have held office for the two immediately preceding years, or Vice-President who may have held office for the three immediately preceding years, and such six Councillors as may have attended the fewest

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Council Meetings during the past year, and when any such attendances are equal, the Council shall decide between them; but any such Member or Associate Member shall be eligible for re-election after being one year out of office.

Any Retiring Vice-President or Councillor who may be ineligible for re-election shall nevertheless be eligible to any other office.

21.—Each Member and Associate Member shall be at liberty to nominate in writing, and send to the Secretary not less than eight days prior to the Ordinary General Meeting in June, a list, duly signed, of Members and Associate Members suitable to till the offices of President, Vice-Presidents, and Members of Council for the ensuing year. The Council shall prepare a list of the persons so nominated, together with the names of the Officers for the current year eligible for re-election, and of such, other Members and Associate Members as they deem suitable for the various offices. Such lists shall comprise the names of not less than thirty persons. The list so prepared by the Council shall be submitted to the Ordinary General Meeting in June, and shall be the balloting list for the annual election in August. (See proper Form in the Appendix.) A copy of this list shall be posted at least seven days previous to the Annual Meeting to every Member and Associate Member, who may erase any name or names from the list, and substitute the name or names of any other Member or Associate Member eligible for each respective office: but the number of names on the list, after such erasure or substitution, must not exceed the number to be elected to the respective offices. Papers which do not accord with these directions shall be rejected by the scrutineers. The votes for any Member who may not be elected President or Vice-Presidents shall count for them as Members of the Council, but in no case shall he receive more than one vote from each voter. The Chairman shall appoint four scrutineers, who shall receive the balloting papers, and, after making the necessary scrutiny, destroy the same, and sign and hand to the Chairman a list, of the elected Officers. The balloting papers may be returned through the post, addressed to the Secretary, or be handed to him, or to the Chairman of the meeting, so as to be received before the appointment of the scrutineers for the election of Officers.

22.—In case of the decease, expulsion, or resignation of any Officer or Officers, the Council, if they deem it requisite that the vacancy shall be filled up, shall present to the next Ordinary
General Meeting a List of persons whom they nominate as suitable for the vacant office or offices, and a new Officer or Officers shall be elected at the first succeeding Ordinary General Meeting.

23.—The Treasurer and the Secretary shall be appointed by the Council, and shall be removable by the Council, subject to appeal to a General Meeting. One and the same person may hold both these offices.

VI.—Duties of the Officers and Council.

21.—The President shall take the chair at all meetings of the Institute, the Council, and Committees, at which he is present (he being ex-officio a member of all), and shall regulate and keep order in the proceedings.

25.—In the absence of the President, it shall be the duty of the senior Vice-President present to preside at the meetings of the Institute, to keep order, and to regulate the proceedings. In case of the absence of

the President and of all the Vice-Presidents, the meeting may elect any Member of Council, or in case of their absence, any Member or Associate Member present, to take the chair at the Meeting.

26.—At Meetings of the Council, five shall be a quorum. The minutes of the Council's proceedings shall be at all times open to the inspection of the Members and Associate Members.

27.—The Treasurer and Secretary shall act under the direction and control of the Council, by which body their duties shall from time to time be defined.

28.—The Council may appoint Committees for the purpose of transacting any particular business, or of investigating any specific subject connected with the objects of the Institute; Such Committees shall make a report to the Council, who shall act thereon, and make use thereof as they see occasion.

VII.—Communications, and Memoirs.

29.—All papers shall be sent for the approval of the Council at least, twenty-one days before a. General Meeting, and after approval, shall be read before the Institute. The Council shall also direct whether any paper read before the Institute shall be printed in the Transactions, and immediate notice shall be given to the writer whether it is to be printed or not.

30.—The copyright of all papers, communicated to and accepted for printing by the Council, and printed within twelve months, shall become vested in the Institute, and such communications shall not be published for sale or otherwise, without the written permission of the Council.

31.—Twenty copies of each paper printed by the Institute shall be presented to the author for private use.

32.—All proofs of reports of discussions, forwarded to any person for correction, must be returned to the Secretary within, seven days from the date of their receipt, otherwise they will be considered correct and be printed off.

33.—The Institute is not, as a, body, responsible for the statements and opinions advanced in the papers which, may be read, nor in the discussions which may take place at the meetings of the Institute.
VIII.—Meetings of the Institute.

3-1.—An Ordinary General Meeting shall be held on the first Saturday of every month (except January and July) at two o'clock, unless otherwise determined by the Council; and the Ordinary General Meeting in the month of August shall be the Annual Meeting, at which a report of the proceedings, and an abstract of the accounts of the previous year, shall be presented by the Council.

35.—All donations to the Institute shall be acknowledged in the Annual Report of the Council.

36.—A Special General Meeting shall be called whenever the Council may think fit, and also on a requisition to the Council, signed by ten or more Members or Associate Members. The business of a Special Meeting shall be confined to that specified in the notice convening it.

37.—The Members, Associate Members, Honorary Members, Associates and Students, shall have notice of, and the privilege to attend, all Ordinary General Meetings and Special Meetings.

IX.—Property of the Institute.

40.—The Funds of the Society shall be deposited in the hands of the Treasurer, and shall be disbursed or invested by him according to the direction of the Council.

41. The Institute Hall and Reading Room shall be open to the Members, Associate Members, Honorary Members, Associates and Students on every week day, from 10 a.m. to 5 p.m., except on such special day or days when the Council shall think it expedient to close the rooms and suspend the circulation of Books. Books shall be issued according to regulations from time to time approved by the Council.

42.—No duplicate copies of any portion of the Transactions shall be issued to any Member, Associate Member, Associate or Student, unless by order from the Council.

X.—Alteration of Bye-laws.

43.—No alteration shall be made in the Bye-laws of the Institute, except at the Annual Meeting, or at a Special Meeting for that purpose, and the particulars of every such alteration shall be announced at a previous Ordinary Meeting, and inserted in its minutes, and shall be exhibited in the room of the Institute fourteen days previous to such Annual or Special Meeting, and such Meeting shall have power to adopt any modification of such proposed alteration of the Bye-laws.

I hereby approve the foregoing Bye-laws.

M. W. RIDLEY,

One of Her Majesty's Principal Secretaries of State.

Whitehall,
23rd September, 1898.

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APPENDIX TO THE BYE-LAWS.

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FORM A, Member or Honorary Member.

A. B. [Christian Name. Surname, Occupation, and Address in full], born on the day of 18, being desirous of belonging to The North of England Institute of Mining and Mechanical Engineers. I recommend him, from personal knowledge, as a person in every respect worthy of that distinction, because—

[Here specify distinctly the qualifications of the Candidate, according to the spirit of Bye-laws 3 or 5.]

On the above grounds, I propose him to the Council as a proper person to belong to the Institute.

Signed Member or Associate Member.

Dated this ..day of 190

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We, the undersigned, concur in the above recommendation, from personal knowledge, being convinced that A. B. is in every respect a proper person to belong to the Institute.

___________________Two Members or Associate
___________________Members, or by Five Members

or Associate Members in the
case of the nomination
of an Honorary Member.

[Undertaking to be signed by the Candidate.]

I, the undersigned, do hereby promise that, in the event of my election, I will be governed by the Royal Charter and Bye-laws of the Institute for the time being, or as they may hereafter be altered, amended, or enlarged under the powers of the said Royal Charter; and that I will promote the objects of the Institute as far as may be in my power, and will not aid in any unauthorised publication of the proceedings, and will attend the meetings thereof as often as I conveniently can; provided that whenever I shall signify in writing to the Secretary that I am desirous of withdrawing my name therefrom, I shall (after the payment of any arrears which may be due by me at that period) cease to belong to the Institute.

Signed

Dated this day of . .190

[To be filled up by the Council.]

The Council, having considered the above recommendation, present A. B. to be balloted for as a Member of The North of England Institute of Mining and Mechanical Engineers.

Signed Chairman.

Nominated at the Ordinary General Meeting 190

Passed by the Council 190

Elected at the Ordinary General Meeting 190 . Age years.

FORM B, Associate Member. Associate or Student.
A. B. [Christian Name, Surname, Occupation, and Address in full], born on the day of 18 , being desirous of belonging to The North of England Institute of Mining and Mechanical Engineers, I recommend him, from personal knowledge, as a person in every respect worthy of that distinction, and propose him to the Council as a proper person to belong to the Institute.

Signed ..Member or Associate Member.

Dated this : ..day of 190

We, the undersigned, concur in the above recommendation, from personal knowledge, being convinced that A. B. is in every respect a proper person to belong to the Institute.

____________________Two Members

____________________or Associate Members.

[Undertaking to be signed, by the Candidate.]

I, the undersigned, do hereby promise that, in the event of my election, T will be governed by the Royal Charter and Bye-laws of the Institute for the time being, or as they may hereafter be altered, amended, or enlarged under the powers of the said Royal Charter; and that I will promote the objects of the Institute as far as may be in my power, and will not aid in any unauthorised publication of the proceedings, and will attend the meetings thereof as often as I conveniently can; provided that whenever I shall signify in writing to the Secretary that I am desirous of withdrawing my name therefrom, I shall (after the payment of any arrears which may be due by me at that period) cease to belong to the Institute.

Signed

Dated this day of 190 ,

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[To be filled up by the Council.] The Council, having considered the above recommendation, present A B to be balloted for as a of The North of England Institute of Mining and Mechanical Engineers.

Signed Chairman

Nominated at the Ordinary General Meeting 190

Passed by the Council 190

Elected at the Ordinary General Meeting 190 . Ago years

FORM C, Transfer to Member or Associate Member.

A. B. [Christian Name, Surname, Occupation, and Address in full], born on the day of 18 , at present a of The North of England Institute of Mining and Mechanical Engineers, being desirous of becoming a Member of the said Institute, I recommend him, from personal knowledge, as a person in every respect worthy of that distinction, because—

[Here specify distinctly the qualifications of the Candidate, according to the spirit of Bye-laws 3 and 4.]

On the above grounds, I propose him to the Council as a proper person to be admitted a Member.

Signed Member or Associate Member.

Dated this day of 190

We, the undersigned, concur in the above recommendation, from personal knowledge, being convinced that A. B. is in every respect a proper person to be admitted a Member.

____________________Two Members
I, the undersigned, do hereby promise that, in the event of my election, I will be governed by the Royal Charter and Bye-laws of the Institute for the time being, or as they may hereafter be altered, amended, or enlarged under the powers of the said Royal Charter; and that I will promote the objects of the Institute as far as may be in my power, and will not aid in any unauthorised publication of the proceedings, and will attend the meetings thereof as often as I conveniently can; provided that whenever I shall signify in writing to the Secretary that I am desirous of withdrawing my name therefrom, I shall (after the payment of any arrears which may be due by me at that period) cease to belong to the Institute.

Signed.
Dated this day of 190.

[To be filled up by the Council.]

The Council, having considered the above recommendation, present A. B. to be balloted for as a Member of The North of England Institute of Mining and Mechanical Engineers.

Signed Chairman.

Nominated at the Ordinary General Meeting 190
Passed by the Council 190
Elected at the Ordinary General Meeting 190. Age years.

FORM D. List of the names of persons to be balloted for at the Ordinary General Meeting on the day of 190.

Members: —
Associate Members:
Honorary Members: —

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Associates:
Students:

Strike out the names of such persons as you desire should not be elected, and hand the list to the Chairman.

FORM E.

Sir,—I beg leave to inform you that on the day of you were elected a of The North of England Institute of Mining and Mechanical Engineers. In conformity with its Bye-laws your election cannot be confirmed until your first annual subscription be paid, the amount of which is £, or, at your option, a life-composition in accordance with the following scale:

Under 30 years of age £31
Over 30 £27
If the subscription is not received within four months from the present date, the election will become void under Bye-law 10.

All annual subscriptions are due on the first Saturday in August of each year.

I am, sir. yours faithfully.

Dated 190.

Secretary.

FORM F.

The North of England Institute of Mining and Mechanical Engineers.

Founded 1852. Incorporated by Royal Charter, A.D. 1876.

These are to certify that A. B. [Christian Name, Surname, Occupation, and Address in full] was elected a Member of The North of England Institute of Mining and Mechanical Engineers, at an Ordinary General Meeting held on the day of .190

Witness our hands and seal this day of 190

President.

Secretary.

FORM G.

Sir,—I am directed by the Council of The North of England Institute of Mining and Mechanical Engineers to draw your attention to Bye-law 14, and to remind you that the sum of £ of your annual subscriptions to the funds of the Institute remains unpaid, and that you are in consequence in arrear of subscription. I am also directed to request that you will cause the same to be paid without further delay, otherwise the Council will be under the necessity of exercising their discretion as to using the power vested in them by the Article above referred to.

I am, sir, yours faithfully.

Secretary.

Dated 190.

FORM H.

Sir,—I am directed by the Council of The North of England Institute of Mining and Mechanical Engineers to inform you that, in consequence of non-payment of your arrears of subscription, and in pursuance of Bye-law 14, the Council have determined that unless payment of the amount £ is made previous to the day of next, they will proceed to declare that you have ceased to be a Member of the Institute.

But, notwithstanding this declaration, you will remain liable for payment of the arrears due from you.

I am, sir, yours faithfully,

Secretary.

Dated 190.

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FORM I.
Sir,—I am directed by the Council of The North of England Institute of Mining and Mechanical Engineers to inform you that, upon mature consideration of a proposal which has been laid before them relative to you they feel it their duty to advise you to withdraw from the Institute, or otherwise they will be obliged to act in accordance with Bye-law 15.

I am, sir, yours faithfully,
_________________________ Secretary.

Dated 190

FORM J.
Sir,—It is my duty to inform you that, under a resolution passed at a Special General Meeting of The North of England Institute of Mining and Mechanical Engineers, held on the day of 190 according to the provisions of Bye-law 15, you have ceased to be a of the Institute.

I am, sir, yours faithfully,
_________________________ Secretary.

Dated ..190 .

FORM K, Balloting List.
Ballot to take place at the Annual Meeting on 19 at Two o'clock, p.m.
The names of persons for whom the voter does not vote must be erased, and the names of other persons eligible for re-election may be inserted in their place, provided the number remaining on the list does not exceed the number of persons to be elected.

President: Not more than One Name to be returned, or the vote will be lost.
__________________________ President for the current year eligible for re-election. *
--------------------------New Nominations.'

Vice-Presidents—Not more than Six Names to be returned, or the vote will be lost. The Votes for any Member who may not be elected President a or Vice-Presidents shall count for them as Members of the Council, but in no case shall he receive more than one vote from each voter.

__________________________ Vice-Presidents for the current year eligible for re-election.
__________________________ New Nominations.

Council —Not more than Eighteen Names to be returned, or the vote will be lost,
__________________________ Members of the Council for the current year eligible for re-election.
__________________________ New Nominations.
Ex-Officio Members of the Council for the ensuing year: —

__________Past-Presidents.

__________Retiring Vice-Presidents.

__________

Bye-law 21.
Each Member and Associate Member shall be at liberty to nominate in writing, and send to the Secretary not less than eight days prior to the Ordinary General Meeting in June, a list duly signed of Members and Associate Members suitable to fill the offices of President, Vice-Presidents, and Members of Council for the ensuing year. The Council shall prepare a list of the persons so nominated, together with the names of the Officers for the current year eligible for re-election, and of such other Members and Associate Members as they deem suitable for the various offices. Such list shall comprise the names of not less than thirty persons. The list so prepared by the Council shall be submitted to the Ordinary General Meeting in June, and shall be the balloting list for the annual election in August. (See proper Form in the Appendix.) A copy of this list shall be posted at least seven days previous to the Annual Meeting to every Member and Associate Member, who may erase any name or names from the list, and substitute the name or names of any other Member or Associate Member eligible for each respective office; but the number of names on the list, after such erasure or substitution, must not exceed the number to be elected to the respective offices. Papers which do not accord with these directions shall be rejected by the scrutineers. The votes for any member who may not be elected President or Vice-Presidents shall count for them as Members of the Council, but in no case shall he receive more than one vote from each voter. The Chairman shall appoint four scrutineers, who shall receive the balloting papers, and, after making the necessary scrutiny, destroy the same, and sign and hand to the Chairman a list of the elected Officers. The balloting papers may be returned through the post, addressed to the Secretary, or be handed to him, or to the Chairman of the meeting, so as to be received before the appointment of the scrutineers for the election of Officers.

Names substituted for any of the above are to be written in the blank spaces opposite those they are intended to supersede.

The following Members are ineligible from causes specified in Bye-law 20: —

As President
As Vice-Presidents
As Councillors

FORM L.

Admit of .

of .
to the Ordinary General Meeting on Saturday, the
(Signature of Member, Associate Member, Associate or Student)

The Chair to be taken at Two o'clock p.m.
I undertake to abide by the Bye-laws of The North of England Institute of Mining and Mechanical Engineers, and not to aid in any unauthorised publication of the Proceedings.

(Signature of Visitor)

Not transferable.

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