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Mr. Frederic Keffer, Engineer, B. C. Copper Co., Ltd. Greenwood, B. C.
President, Canadian Mining Institute, 1907.

THE LATE MR. JOHN BLUE.

For many years manager of the Eustis Mining Co., of Eustis, Que.,
and a charter member of the Canadian Mining Institute,
who died, from the effects of an accident
at the mine, in November, 1907.

The Late Dr. W. H. Drummond.

ANNUAL MEETING, 1907.

Proceedings of the Ninth Annual Meeting, Toronto, Ont., March, 1907.

The opening session was held on Wednesday morning, March 6th, 1907, in the Banquet Hall of the King Edward Hotel. The meeting was called to order by the President, Mr. George R. Smith, M.L.A., Manager of Bell's Asbestos Company, Thetford Mines, Que., who delivered the following address of welcome to the members and guests present:—

PRESIDENTIAL ADDRESS.

"Gentlemen, just a year ago, in opening the Eighth Annual Meeting of the Canadian Mining Institute, I was at that time afforded the exceptional pleasure of welcom ng you to the cradle of Canadian nationality, that ancient capital of an old French Province so justly renowned for its wealth of historical association and its picturesque environments.

"To-day it is my privilege to greet you in the magnificent 'Queen City' of the great and wealthy sister province of Ontario. Last year we peered together through mists of vanishing years into the early days in the history of New France, when the development of mineral wealth in North America by European settlers was aided by the fostering care of that great French Minister, Colbert. To-day we meet in a Province possessing, I believe, the youngest Bureau of Mines of any of the older Provinces of the Confederation, and wherein state encouragement and recognition of the mining industry can scarcely be traced back more than fifteen years, as compared with the two and a half centuries which have elapsed since the French Minister of State rendered his powerful patronage to the first practical mining essays in New France. It is said, nevertheless, that as early as 1660 the Jesuit missionaries reported the discovery of gold on St. Joseph's Island, in Lake Huron, and Mr. Merritt tells us that copper ore was actually worked in this Province in the vicinity of Point of Mines or Mica Bay as early as 1770 by an English company. For a great number of years the mining development of this Province was extremely intermittent, largely owing to the fact that no smelting was carried on here, and that the demand for ore came chiefly from the other side of the international boundary line. In recent years, the advance of mining operations in Ontario has been eminently gratifying. Metallic productions alone, in Ontario, increased from $2,565,286 in 1900 to $5,321,677 in 1904; and the annual increase since that time has been even more satisfactory. The output of silver, cobalt, iron ore, pig iron and steel was given as nil in the report of the Bureau of Mines for 1895, and in 1904 the output of silver was placed at $111,887; of cobalt, $36,620; iron ore, $108,068; pig iron, $1,811,664, and of steel, $1,888,349. The report of your Minister of Mines for 1905 shows that the Sudbury nickel-copper deposit constitutes the chief source of the world's supply of nickel. The output of nickel in that year was given as $3,344,409, while the copper contents of the matte amounted to $671,833, and if these products had been computed at the price of refined metals, as is done by many public statisticians, their total value would have been little short of $10,000,000, while employment was furnished in this industry to over 1,000 men.

"To all these facts and figures, illustrative of the rapid development of your mining industries in recent years, there is yet to be added the marvellous story of Cobalt, which has already proved itself to be a second Klondyke in the world-wide interest which it has aroused. The Province of Ontario is also to be congratulated in its Minister of Mines, the Hon. Mr. Cochrane, who has given such strong proof of how much he has the interests of the mining industry at heart. You must not, however, conclude that Ontario has a monopoly of mineral wealth. On your eastern boundary, we, in the Province of Quebec, have, only distant some ten or twenty miles from your Temiskaming area, a great mineral territory. But you are more fortunate in that you have railway facilities; yet it is only a question of time when we, too, shall have railway communication with the great northern mineral belt of our Province, and communication which, I hope shall prove valuable to both Provinces.

"Last year I remarked on the development in mineral resources that would follow the construction of the Transcontinental Railway. I am more than ever impressed with the assurance of this fact.

"We, in Quebec, without regard to political considerations, are anxious to co-operate with you in Ontario in securing the passage of legislation of a character most likely to serve the interests and promote the growth and welfare of the mining industry in general and of those practically engaged in it. The Institute has already justified its existence by the good service it has done in the past in this direction as well as in others, and the steady increase in membership testifies to its popularity. It is well, meanwhile, that outsiders should know that the Institute is not for the benefit of speculators or mining manipulators, but was established, and is maintained, for the advancement and protection of the genuine mining interests of the country; but to render this work effective, it is first of all essential that the Institute should have the loyal support of the membership as a whole. Then, while our individual operations, and even the industry, may have ups and downs, the Institute—like Tennyson's Brook—will flow on for ever; and, although Cobalt, contrary to every indication, may, as Port Arthur did some twenty years ago, cease to be productive, the Mining Institute will continue its useful career for future generations of mining men.

"I now declare this Ninth Annual Meeting of the Canadian Mining Institute open for the despatch of business. It only remains for me now to thank you for having honored me with the highest office in your gift, and to ask from you continued confidence and support through the sessions of the present convention.

"I believe, gentlemen, in conclusion, that the Ontario Government is now proposing to introduce certain legislation which, in the opinion of those engaged in mining in this Province, is inimical to their interests. An opportunity will be afforded these gentlemen to express their views on this question at this meeting, and I think I may add that it is the duty of the Institute to use its best endeavours to assist the mining industry in Ontario in opposing any measure which is likely to retard progress and penalize prosperity." (Applause.)

The Secretary, Mr. H. Mortimer-Lamb, then read the following:—

REPORT OF THE COUNCIL FOR THE YEAR 1906–1907.

MEETINGS.

The Eighth Annual General Meeting of the Institute was held at the Chateau Frontenac, in the City of Quebec, on March 7th, 8th, and 9th, 1906. The meeting was an unqualified success; and the Council again records its appreciation of the services rendered by Dr. J. Bonsall Porter, to whom, as Acting Secretary, fell the chief responsibility of organizing and carrying out the arrangements in connection with the proceedings.

During the year four meetings of Council were held at headquarters. As provided by Par. XXXII of the By-laws, typewritten copies of the minutes of these meetings have been regularly sent to individual members of the Council, affording those members residing at a distance and thus precluded from personally attending, an opportunity of presenting their views on all matters of business coming before the Council. It is hoped that in future full advantage will be taken of this provision, that the Institute may derive the benefit of the advice, and have the active interest of every member elected to serve on its Council.

PUBLICATIONS.

Thirty-four papers were presented at the Quebec Meeting, and these, with the discussions thereon, and a report of the Proceedings of the Meeting, now form Vol. IX of the Journal of the Institute, which has been issued to members in good standing.

MEMBERSHIP.

It is gratifying to be able to record an important increase, of approximately twenty per cent. in the membership during the year, which now, including Students, for the first time exceeds five hundred names. This may be regarded as indicative of appreciation and recognition on the part of those engaged in the development of our mineral resources, of the useful work this

Institute is endeavouring to perform in the interests of mining in the Dominion.

DEPUTATIONS.

Pursuant to a resolution unanimously passed at the Quebec Meeting, requesting the President to appoint a delegation to wait on the Dominion Government and urge the desirability of the early establishment of a Federal Department of Mines, under the direct supervision of a responsible Minister of the Crown, a deputation of which the following gentlemen were members, Messrs. Smith, Adams, Porter, Gwillim and Brown, proceeded to Ottawa on April 18th, and presented the views of the Institute to Sir Wilfrid Laurier and his colleagues, by whom they were most courteously received. Within a few weeks of this interview, the office of Director of the Geological Survey of Canada, which had remained vacant since the death of the late Dr. George Dawson, C.M.G., was filled by the appointment of Mr. A. P. Low, whose interest in that branch of geological science which deals more particularly with the solution of economic problems, is well known. The work of the Survey during the past year under Mr. Low's direction has been of an eminently useful and practical character; and the appointment of that gentleman to the head of the Survey is a matter for congratulation on the part of the Mining Industry in Canada. Following the appointment of Mr. Low to the Directorship, the Survey was disassociated from the Department of the Interior, and placed under the Ministerial charge of the Hon. Mr. Templeman. Although, as yet, the bill for the establishment of a Department of Mines has not been introduced into Parliament, it is understood that such a measure is now under contemplation, and it is hoped, therefore, that before another year shall have passed, the wishes of the Mining Industry in this important respect, will have been realized.

LIBRARY.

During the year an addition of some fifty volumes was made to the Library, and a number of exchanges, including transactions of technical societies, official report and periodicals, covering a period of three years, were bound and added to the shelves. A new catalogue, on the card index system, has also been prepared. The Librarian desires to thank, in particular, the Geological Survey of Canada, the British Columbia Bureau of Mines, the Mining Society of Nova Scotia, the Institution of Mining Engineers and the Mining Institute of Scotland for the donation of valuable early editions required to complete the Library sets.

STUDENTS' COMPETITION AND AWARDS.

After receiving the report of the judges. Messrs. Charles B. Going and Frederick Hobart, the Council awarded the President's Gold Medal, for the best paper submitted by a Student Member during the year, to Mr. Frank G. Wickware, of McGill University for his thesis entitled "The British Columbia Copper Company's Mine and Smelter." In commenting on this paper, the judges made the following remark:—"We would assign first place to Mr. Frank G. Wickware's paper, on account of the comprehensiveness, clearness and ability shown in his descriptive treatment, the good literary style and the judgment and care shown in arranging and preparing the paper. It is orderly and methodical, well illustrated, representing careful and painstaking work, and appears to us to be worthy of special commendation. A strong point is the inclusion of data in relation to costs of working, which are a critical point in all mining and beneficiating operations. It is also to be considered that the paper relates to a Canadian mining enterprise of importance." It may not be inappropriate to add, that in consequence of the general excellence of this paper, Mr. Wickware was offered, and has accepted, the post of Assistant Editor to so important a technical periodical as "The Engineering Magazine," of New York and London.

The Council also awarded three cash prizes of $25.00 each as follows:—To Mr. Frank G. Wickware for the paper mentioned above; to Mr. J. J. Robertson, School of Mining, Kingston, for his paper entitled "Cyanide Tests on Temiskaming Ores"; and to Mr. R. P. Cowen, McGill University, for his paper entitled "No. Four Pit, Brayton Domain Collieries, Cumberland, England."

The Council takes pleasure in congratulating the above gentlemen on the very creditable papers they have presented to the Institute.

NEW MEMBERS

The following gentlemen were admitted to membership during the year.

J. G. Harris, Port Arthur, Ont.
W. C. Fox, Toronto, Ont.
N. A. Timmins, Haileybury, Ont.
W. F. C. Parsons, M.E., Londonderry, N.S.
J. J. O'Conner, Port Arthur, Ont.
F. W. McCrady, Texada Island, B.C.
R. A. C. McNally, Montreal, P.Q.
D. J. McCuan, Eganville, Ont.
Robt. Jacobs, Cobalt, Ont.
J. A. Jacobs, Montreal, P.Q.
D. A. Dunlop, Haileybury, Ont.
J. B. O'Brien, Toronto, Ont.
E. E. Ling, New York, N.Y.
R. E. Kemerer, Toronto, Ont.
John S. McLean, Montreal, P.Q.
R. A. Stinson, Montreal, P.Q.
J. F. Forbes, Montreal, P.Q.
Hilder Daw, C.E., Montreal, P.Q.
C. N. Milne, Chemist, Bruce Mines, Ont.
J. J. Harpell, Toronto, Ont.
Howells Frechette Asst. Engineer, Fernie, B.C.
Robt. A. Bryce, M.E., Toronto, Ont.
W. J. Gillespie Dickson, Cobalt, Ont.
A. W. Davis, B.Sc., Moyie, B.C.
Dr. W. H. Drummond, Montreal, P.Q.
O. R. Smith, Sudbury, Ont.
L. Heber Cole, B.Sc., Phœnix, B.C.
O. N. Scott, B.Sc., Cobalt, Ont.
K. V. Gardner, (Superintendent), Cobalt, Ont.
J. C. Houston, (Superintendent), Cobalt, Ont.
J. G. MacMillan, (Superintendent), Cobalt, Ont.
H. G. V. Adler, A.R.S.M., Cobalt, Ont.
E. P. Kadeleck, Cobalt, Ont.
Rupert Simpson, C.E., Cobalt, Ont.

Oliver Hall, M.A., Victoria Mines, Ont.
M. Stackpole Coxon, M.E., Cobalt, Ont.
F. S. Parkhurst, Jr., B.Sc., Gold Rock, Ont.
Milton T. Hersey, M.Sc., Montreal, P.Q.
C. W. Knight, B.Sc., Kingston, Ont.
R. Anson Cartwright, B.Sc., Cobalt, Ont.
J. B. Woodsworth, M.E., Cobalt, Ont.
A. B. Munroe, Haileybury, Ont.
Wm. Earl Hidden, F.G.S., Newark, N.J.
G. O. McMurtry, B.Sc., Cobalt, Ont.
W. K. McNeil, Chemist, Cobalt, Ont.
Preston C. Coates, M.E., Toronto, Ont.
Carl Reinhardt, B.Sc., Montreal, Que.
W. S. Johnson, M.E., Lachine, Que.
C. M. Tilkie, Chemist, Cobalt, Ont.
C. A. O'Connell, (Superintendent), Cobalt, Ont.
W. M. Boultbee, Cobalt, Ont.
C. W. Jessop, Cobalt, Ont.
C. Carleton Sample, M.E., New York, N.Y.
W. G. Trethewey, Cobalt, Ont.
T. M. Paris, Chemist, Victoria Mines, Ont.
F. W. Pitts, Cobalt, Ont.
G. E. Silvester, Chief Engineer, Copper Cliff, Ont.
E. O. Taylor, Mattawa, Ont.
Frank C. Loring, M.E., Cobalt, Ont.
J. Cleveland Haas, M.E., Spokane, Wash.
A. C. Robertson, Dawson City, Yukon.
A. M. Campbell, Ottawa, Ont.
J. C. Murray, B.Sc., Toronto, Ont.
R. G. Dawe, C.E., Milverton, Ont.
Arthur P. Scott, Chief Chemist, Sydney, C.B.
W. F. Jennison, M.E., Sydney, C.B.
A. W. McDougald, Alexandria, Ont.
R. G. Hore, B.Sc., Toronto, Ont.
G. C. MacKenzie, B.Sc., Londonderry, N.S.
G. E. Corbitt, Annapolis Royal, N.S.
D. Stewart, Asst. Manager, Springhill, N.S.
M. R. Morrow, Halifax.
J. B. Morrow, B.Sc., Halifax, N.S.

Alex. McNeil, Halifax, N.S.
A. L. McCallum, B.Sc., Halifax, N.S.
Wm. Brown, Metallurgist, Londonderry, N.S.
R. H. Murray, Halifax, N.S.
James E. Day, Toronto, Ont.
Geo. W. Stuart, Truro, N.S.
John J. Robertson, B.Sc., Santa Barbara, Mex.
H. P. De Pencier, M.E., Roodepoort, South Africa.

STUDENT MEMBERS.

A. G. Morrison, Woodstock, Ont.
Submitted on behalf of the Council.

H. MORTIMER-LAMB,
Secretary.

The Report of the Council having been adopted, the Treasurer presented the Financial Statement for the year, duly audited and approved by the Council, as follows:—

TREASURER'S STATEMENT.
YEAR ENDING FEBRUARY 1ST, 1907.

RECEIPTS.

Balance from last year		1,191.84
SUBSCRIPTIONS—		
290 Ordinary Members at $10.00	2,900.00	
9 Student " 2.00	18.00	
60 University " 1.00	60.00	
Arrears collected	492.00	
		3,470.00
SALE OF PUBLICATION		46.00
DOMINION GOVERNMENT GRANT	3,000.00	
LOAN		250.00
INTEREST		26.75
SUNDRIES		21.44
		$8,006.03
LESS		
DISBURSEMENTS PER STATEMENT		6,651.83
Balance on hand		$1,354.20

J. STEVENSON BROWN,
Treasurer.

Audited and Certified Correct,

P. S. ROSS & SONS,
Chartered Accountants.

MONTREAL, Feb. 13th, 1907.

SUMMARY STATEMENT.

SHOWING DISTRIBUTION OF DISBURSEMENTS TO THE VARIOUS WORK AND BUSINESS OF THE INSTITUTE

PUBLICATION—		
Transactions, Vol. IX.	$3,089.28	
Postage and Express.	172.93	
Sundries	87.88	
		$3,350.09
LIBRARY—		
Rent.	$ 500.00	
Telephone.	40.00	
Binding.	45.88	
Sundries.	7.25	
		593.13
MEETINGS—		
Annual Meeting.	$ 344.75	
Council Meetings.	41.27	
		386.02
SECRETARY'S OFFICE—		
Secretary's Grant	$ 500.00	
Printing, Stationery, etc.	137.21	
Postage, Telegrams and Telephone.	65.40	
Travelling Expenses	280.95	
Sundries	85.31	
		1,068.87
TREASURER'S OFFICE—		
Treasurer's Grant	$ 500.00	
Printing, Stationery, etc.	59.95	
Postage and Telegrams.	60.70	
Bank Charges on Cheques and Drafts.	66.95	
Sundries	68.15	
		755.75
SUNDRIES—		
Deputation.	$ 60.60	
Prizes to Students.	75.00	
Advertising	37.50	
Subscriptions for this year included in last	42.00	
One Subscription paid in advance for 1907	10.00	
Loan Repaid	250.00	
Various.	22.87	
		497.97
		$6,651.83

J. STEVENSON BROWN,
Treasurer.

In presenting the Financial Statement for the year, it affords me pleasure to say that the Institute has no liabilities, all accounts having been paid.

The receipts from membership have increased by $638.00, and the expenditure has increased by $748.60.

The following statement will show the result of this year's business as compared with last year.

Received from membership for year ending 1st Feb., 1906	$2,832.00
Received from membership for year ending 1st Feb., 1907	3,470.00
Increase	$638.00

Total Receipts for year ending 1st Feb., 1906	$5,936.55
Total Receipts for year ending 1st Feb., 1907	6,564.19
Increase	$627.64

Expenditure for year ending 1st Feb., 1906	$5,653.23
Expenditure for year ending 1st Feb., 1907	6,401.83
Increase	$748.60

It is gratifying to note that during the year arrears to the amount of $492—much of which was of very old standing—has been collected, and that whereas at the close of last year there were 80 members in arrears, this year there were only 42 members who had not paid their subscriptions when the books were closed.

The net balance at the credit of the Institute at the close of each fiscal year, since 1900, is shown in the following table:—

1900	$ 484.87
1901	630.61
1902	957.40
1903	1,682.49
1904	1,909.58
1905	658.52
1906	1,191.84
1907	1,354.20

Respectfully submitted,

J. STEVENSON BROWN,

Treasurer.

MONTREAL, February 1st, 1907.

The Treasurer's Report was adopted.

APPOINTMENT OF SCRUTINEERS.

Messrs. F. Hobart, A. W. G. Wilson, and J. C. Murray were appointed scrutineers of the ballots for the election of Officers and Council for the year 1907-08.

MINERAL STATISTICS.

Mr. JOHN McLEISH, of the staff of the Mines Section of the Geological Survey of Canada, then presented a report embodying the annual preliminary statement of mineral production of Canada for the year 1906. The return placed the value of the total metallic and non-metallic production at $80,000,048, as compared with the return of $69,525,170 in 1905. The chief increase was in copper, 18.58 per cent.; in pig-iron (from Canadian ore) 53.50 per cent.; nickel, 13.85 per cent.; silver, 42.95 per cent.; asbestos and asbestic, 16.33 per cent.; corundum, 38.32 per cent.; feldspar, 35.66 per cent.; and Portland cement, 58.86 per cent. A decrease of 17.70 was shown in the production of gold; of 4.68 of lead; of 5.52 of gypsum, and of 10.14 of petroleum.

Mr. EUGENE COSTE (acting Chairman) in thanking Mr. McLeish for the report presented by him, added:—These figures strikingly indicate the enormous strides in the general development of the mining industry in Canada. An increase in the production of 15 per cent. in one year is surely a matter for congratulation. When I had the honour of being in charge of the Mines Branch of the Survey some twenty years ago, the total mineral production of the Dominion was at that time no more than $11,000,000, which represents the value of last year's increase. It is to be hoped, therefore, that this magnificent progress will not be retarded by ill-considered legislation such as is to be feared.

AMENDMENTS TO THE BY-LAWS.

The Council having recommended a number of amendments and additions to the By-laws, the meeting proceeded to consider them. The most important of the changes contemplated was the raising of the standard of membership and creating another class of membership, of persons not actually engaged in the direction or operation of mining and metallurgical works, mining engineers, geologists, metallurgists, or chemists, such persons to be known as Associate Members.

The Secretary pointed out that the object of the proposed change was to make membership in the Institute of greater value, and at the same time not to deprive such persons who are desirous of being associated with the work of the society, of that privilege. The time, he thought, had arrived when it was possible to secure a large membership of technical men, who would contribute papers of value, and take part in discussions on matters of general interest to the mining profession. Heretofore membership had been rather too general.

Another clause provided for the election of corresponding members.

Dr. J. B. Porter, the Chairman of the Committee on the Revision of the By-laws, stated that although the practice of providing for a class of corresponding members was not common in technical societies, it was usual in the learned societies. It was suggested by the Council as desirable in the case of the Institute, with a view to interesting a class of eminent persons residing abroad in the work of the Society.

A third important change provided for an increase in the number of Councillors from sixteen to twenty, while a new section was passed providing for a change in the procedure for the nomination of Officers and Council.

The Amendments as finally passed at this and a subsequent meeting are incorporated in the By-laws which are published in full on page 31 of this volume.

MINE TAXATION IN ONTARIO.

At the opening of the afternoon Session, Mr. J. M. Clark, K.C., read a paper on "Mining Royalties," which was productive of an interesting discussion in criticism of the bill introduced by the Ontario Government, proposing a tax on mines in that Province.

Mr. Clarke pointed out that the bill aimed at taxing mineral areas to which absolute title had previously been granted, and on which the province had pledged itself not to impose royalties.

Mr. Coste added that the incidence of the tax was unjust in many respects, while in the case of the proposed tax on natural gas, the provision for the measurement of gas at the mouth of the well was absurd and impracticable. A Mr. WHITE, representing American capital in Cobalt, having received permission to address the meeting, stated that, in view of the introduction of the measure by the Provincial Government, his principals, who were engaged in legitimate mining and were not company promoters, had decided to withdraw from the field.

It was then moved by Mr. CRAIG, seconded by Mr. HARDMAN, and carried, "That the Canadian Mining Institute, in annual meeting assembled, believe that the bill now before the Ontario Legislature, providing for the confiscating of mines, is opposed not only to the mining interests but also to the manufacturing and the agricultural interests of the province, and we as a body respectfully ask the Ontario Government to take time and carefully consider what have been the effects of mining legislation in other countries and in other provinces on such lines as now proposed, before allowing this bill to become law." On motion it was decided that a deputation of fifty gentlemen representing the Institute should wait on the Hon. F. Cochrane, Minister of Mines, to present the above resolution, and Messrs. Clarke, Leonard Hardman, Hay and the President were deputed to address the Minister on the subject of the resolution. The meeting, after some further discussion, adjourned to the Parliament Buildings, where the deputation waited on Mr. Cochrane and his colleagues. The Minister invited a full discussion of the bill, and asked that a committee from the Institute meet again with him on the following Friday afternoon to discuss suggested amendments. This invitation was accepted, and, after seeing Mr. Cochrane on Friday, the committee presented the following report:—

REPORT OF COMMITTEE ON MINING TAXATION.

The committee appointed by the Canadian Mining Institute to interview the Hon. the Minister of Mines concerning the bill for the taxation of mines in the Province of Ontario, met the honourable gentleman on Wednesday afternoon, accompanied by a delegation of fifty members of the Institute. On the invitation of Mr. Cochrane, the committee again met in the Minister of Mines' office on Friday at twelve o'clock. There were present at this interview the Premier, Mr. Whitney, the Provincial Secretary, Mr. Hanna, and the Minister of Mines, Mr. Cochrane.

Many paragraphs and features of the bill, together with the principle of the measure, were discussed, especially the objections which were submitted in a series of resolutions adopted by a full meeting of the Institute on Thursday afternoon and which were immediately transmitted to Mr. Cochrane. While the committee adhered firmly to the resolutions passed by the Institute, yet upon the personal assurance of the Minister that he would modify certain clauses to meet objections, which were stated, and upon his statement that some measure for revenue would have to be enacted at this session, and his further assurance that, as Minister of Mines, he would see to it that the execution of the law should be made as little onerous as possible, that he would be willing to support a new bill drafted to meet the views of the mining community of the province, if the same were prepared within a year, the committee decided to leave the matter in the hands of Mr. Cochrane for this year. They pledged themselves to submit to him within twelve months the draft of a new bill, which would be more acceptable to the mining interests of Ontario. This action was taken in consequence of the personal confidence which the representatives of the mining industry in Ontario have in Mr. Cochrane.

EVENING SESSION.

At 8.30 p.m. Mr. H. H. STOEK, editor of *Mines and Minerals*, of Scranton, Pa., delivered an interesting and instructive address, illustrated by lantern slides, on "Preparation and Mining of Anthracite in Pennsylvania." Mr. Stoek, was accorded a vote of thanks.

The following papers were then read and discussed.

THE STATUS OF THE MINING PROFESSION IN CANADA. By Mr. J. C. GWILLIM, Kingston, Ont.

THE NEW TILBURY OIL FIELDS. By Mr. EUGENE COSTE, Toronto, Ont.

MORNING SESSION—SECOND DAY.

The Session opened with a few remarks by Mr. W. G. MILLER, Provincial Geologist of Ontario, explanatory of some additions to the map of Cobalt district. Mr. Miller stated that on the occasion of the last annual meeting of the Institute in Toronto, three years ago, the Bureau of Mines displayed for the benefit of the members a fine exhibit of Cobalt ores, but that very little notice was taken of it, and it took the public eighteen months to awaken to the fact that the Cobalt district was worthy of attention. In the meanwhile the profits of mining in this small area had already made millionaires of eight or ten men, while some twenty or thirty others had, by legitimate means, amassed fortunes of from $25,000 to $300,000. Mr. Miller explained that his map of the district had been drawn to the scale of 400 feet to the inch, and all the known veins had been drawn to scale. He stated that there were roughly a hundred, probably, productive veins in the district, while others were being constantly uncovered.

The following papers were then read and discussed:—

THE GEOLOGY OF THE COBALT DISTRICT. By Dr. C. R. VAN HISE, of Wisconsin University, Wisconsin.

THE COBALT MINING DISTRICT. By Dr. ROBT. BELL, Ottawa, Ont.

At the afternoon Session papers were read as follows:—

THE SMELTING OF COBALT ORES. By Mr. HIRAM W. HIXON, Victoria Mines, Ont.

THE COALS AND COAL FIELDS OF ALBERTA, SASKATCHEWAN AND MANITOBA. By Mr. D. B. DOWLING, Ottawa, Ont.

THE GRÖNDAL PROCESSES OF CONCENTRATION. By Mr. P. McN. BENNIE.

ELECTRIC FURNACES. By Dr. A. E. STANSFIELD, McGill University, Montreal.

SIR WILLIAM LOGAN AND THE GEOLOGICAL SURVEY. By Dr. ROBT. BELL, Ottawa, Ont.

MAGMATIC WATERS. By Mr. HIRAM W. HIXON, Victoria Mines, Ont.

THE ANNUAL DINNER.

The Annual Dinner was held in the Banquet Hall of the King Edward Hotel, at 8.30 p.m, covers being laid for one hundred and thirty. The guests of the evening were His Honor the Lieutenant Governor of Ontario, the Hon. Frank Cochrane, Minister of Mines, the Hon. Mr. Hanna, Provincial Secretary, Dr. C. R. Van Hise, Wisconsin University, Dr. J. F. Kemp, Columbia University, Dr. Chamberlain, Dr. Baylie Willis, Dr. Wm. Campbell, the Mayor of Toronto and the President of the Toronto Board of Trade.

FRIDAY MORNING SESSION.

The Session opened at 10.30 a.m. when the President announced the result of the election of officers and council for the ensuing year, as follows:—

President—Mr. Frederic Keffer, Greenwood, B.C.

Vice-Presidents—Mr. W. G. Miller, Toronto, Ont.; Mr. W. Fleet Robertson, Victoria, B.C.; Dr. J. Bonsall Porter, Montreal.

Secretary—Mr. H. Mortimer-Lamb, Montreal.

Treasurer—Mr. J. Stevenson Brown, Montreal.

Council—Mr. E. W. Gilman, Montreal; Mr. Jas. McEvoy, Fernie, B.C.; Mr. Frank B. Smith, Edmonton, Alta.; Mr. R. W. Brock, Ottawa, Ont.; Mr. J. C. Gwillim, Kingston, Ont.; Dr. F. D. Adams, Montreal; Mr. H. E. T. Haultain, Craigmont, Ont.; Mr. D. H. Browne, Copper Cliff, Ont.

On motion of the secretary, Mr. John A. Dresser, M.A., of Montreal, was elected to fill the vacancy on the council occasioned by the election of Dr. Porter to a vice-presidency.

The following papers were then read:—

On the Microscopic Examination of Nickeliferous Pyrrhotite, by Dr. Wm. Campbell, of New York.

The Marble Bay Copper Deposit, Texada Island, B.C. by Mr. O. E. Leroy, of Ottawa.

On the Progress of British Columbia's Mineral Production, 1897–1906, by Mr. E. Jacobs, editor of the *British Columbia Mining Record*, Victoria, B.C.

The Geology of the Franklin District Ore Deposits, B.C., by Mr. R. W. Brock, of Kingston, Ont.

AFTERNOON SESSION.

The secretary, having read a letter from the Institution of Mining and Metallurgy, on the subject of standardization, the following committee, Dr. Porter, Mr. Haultain and Mr. Willmott, were appointed to convey the views of the Institute thereon to the Institution of Mining and Metallurgy.

Speaking on the work that is being undertaken by the Standardization Committee of the Institution of Mining and Metallurgy, of which he is corresponding member for Canada, Dr. J. BONSALL PORTER said that this effort is in line with that being done by the other great engineering societies in attempting to standardize—measurements, units, threads, rails, beams, screens, etc. Dr. Porter added that "this was an extremely important work and the societies all over the English-speaking world should, if possible, adopt uniform units. It would be very desirable if a committee of this Institute were to appoint to confer with the committee of the Institution of Mining and Metallurgy with a view if possible of adopting uniform standards. I am quite prepared to say that the home committee in London will go a considerable distance to meet any reasonable proposition we may make. As an illustration of the work that such a committee could do, I may instance sieve mesh unification. At present we have no certain standards of size—mesh numbers mean nothing, and we can not clearly understand one another's papers or reports on milling, ore dressing and cyaniding because we do not know just how our sieves compare with those used by others. That is one of many things in which standardization is desirable both for scientific and for professional and engineering ends, and there are many other matters of even greater importance. I should strongly recommend the appointment of a small committee to work with the Institution and possibly send out circulars through our Council trying to inform our members of the standardization work of the Institution."

The following telegram of regret at inability to be present at the meeting was read by the Secretary from Mr. John Hays Hammond:—

"Owing to illness of my family in Bermuda, whence I have only just returned, it is with extreme regret that I have been deprived of the pleasure of being present at your meeting. Please convey to your members my sincere regrets and best wishes for the prosperity of your Institute and my hope that I may have the opportunity of meeting them on some occasion in the near future."

The following papers were read:—

Some new Points in the Geology of Copper Ores. By Dr. J. F. Kemp, Columbia University, New York.

The Mineral Resources of the Province of Quebec. By Fritz Cirkel, Montreal.

The History of the Bruce Mines, Ontario. By Mr. H. J. Carnegie Williams, Bruce Mines, Ont.

A vote of thanks to the retiring President and Council was unanimously passed and the proceedings then terminated.

EXCURSION TO THE COBALT DISTRICT.

The Council having arranged—with the generous assistance and co-operation of the Grand Trunk Railway Co., who provided free haulage, and of the Ontario Government, who voted a special grant of money for the purpose—for an excursion of the Institute to the Cobalt district, some eighty members availed themselves of the opportunity so offered, and a special train of Pullman cars with the party on board left Toronto at 8 o'clock on Friday evening for the district. Cobalt was reached the next morning at 10 o'clock, and conveyances having been provided by the local Reception Committee, Messrs. Brigstock and Arthur A. Coles, visits were made to the Buffalo and Silver Queen mines in the morning, while in the afternoon the party viewed the Cobalt Lake, Nipissing and Trethewey properties, permission being courteously extended in the case of the two latter mines for an underground inspection. In the evening a largely attended meeting was held in the Imperial Hall, when a paper was read by Mr. T. M. Culbert, on "The Cobalt Ores", which provoked an interesting discussion.

Mr. B. A. C. Craig called attention to the provision of the Quebec Mining Act, which permitted large areas of mineral territory to be tied-up by speculative locators to the discouragement of exploration and development by prospectors.

Mr. J. Obalski, Inspector of Mines for the Province, defended the system on the grounds that many of the outlying districts were practically inaccessible to the ordinary prospector, and could only be exploited by capitalists. He also pointed out that the Quebec Government derived a considerable revenue from the lease and sale of mineral lands under the terms of the Act.

Mr. Linney, Mr. Brock, Mr. Coste, Mr. Mortimer-Lamb and Mr. W. S. Johnson spoke in agreement with Mr. Craig's contention. The following resolution was then moved by Mr. Craig, seconded by Mr. Johnson, and carried:—

"That the Council of the Canadian Mining Institute be requested to interview the Government of the Province of Quebec and urge the necessity for remedial legislation in respect to the provisions of the Mining Act whereby large tracts of mineral territory may be acquired under conditions not conducive to the development of the Province's resources; and the Provincial Government be invited to consider the advisability of repealing the exist ng Act and substituting therefor a mining law as nearly as possible similar to that in force in British Columbia regulating the acquisition of mineral lands."

The meeting closed at midnight and on the following morning the party were driven in sleighs to Kerr Lake, where after visiting th Jacobs and Drummond mines they were most hospitably entertained at luncheon by Mr. Robt. Jacobs and Mr. R. W. Brigstock, the managers of the respective companies.

At the station before leaving the district for the return journey three hearty cheers were given for the Cobalt mines and miners. The excursion was voted a great success and was most thoroughly enjoyed by every member of the party.

Excursion of the Canadian Mining Institute to Cobalt, March, 1907.

Examining the Dump on the Buffalo.

Excursion of the Canadian Mining Institute to Cobalt, March, 1907.

Mr. Brigstock and Mr. A. A. Cole, Members of the Local Reception Committee in discussion with Prof. Miller, at the Buffalo.

Excursion of the Canadian Mining Institute to Cobalt, March, 1907.

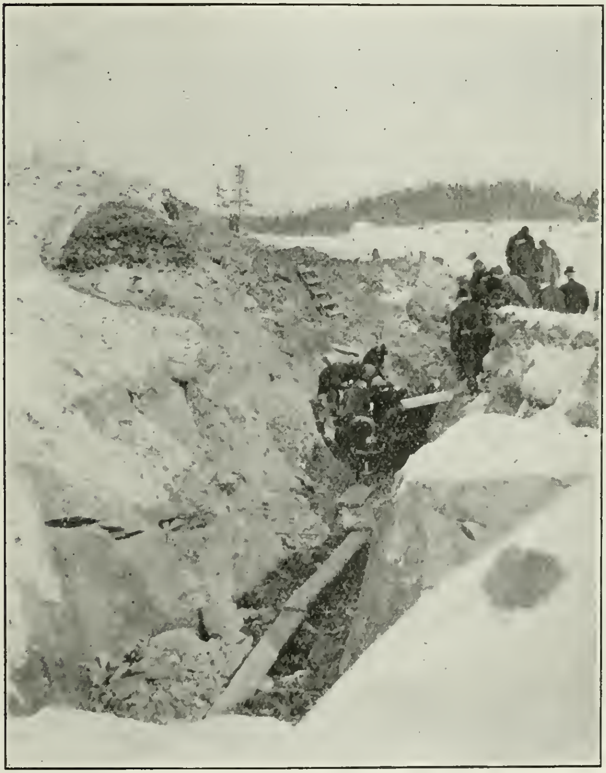
The Tretheway Mine Buildings.

A Group at the Cobalt Lake Mine.

Excursion of the Canadian Mining Institute to Cobalt, March, 1907.

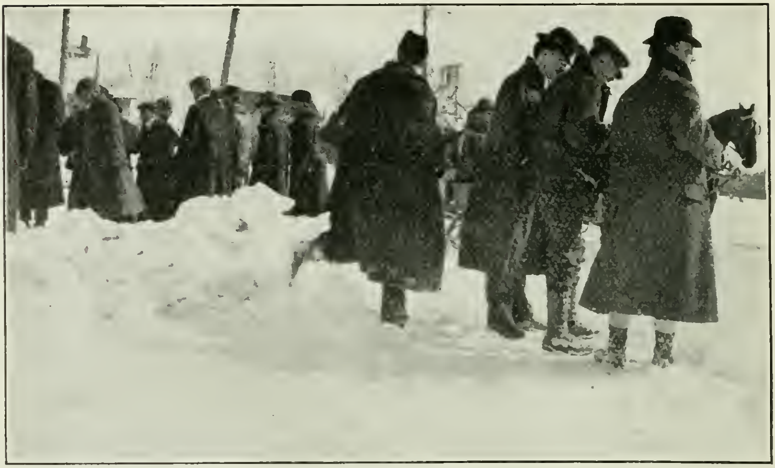
Descending the Shaft at the Nipissing.

Excursion of the Canadian Mining Institute to Cobalt, March, 1907.



The Open Cut on Vein 49 at the Nipissing.

Excursion of the Canadian Mining Institute to Cobalt, March, 1907.



Inspecting the Vein at the Lawson.

Shaft House and Buildings at the Foster.

Excursion of the Canadian Mining Institute to Cobalt, March, 1907

The Visit to the Foster Mine. The figures represented in the foreground are Mr. W. S. Lecky, Mr. W. S. Johnson and Mr. H. G. V. Adler, the Company's Manager, who is guiding the party over the property.

Excursion of the Canadian Mining Institute to Cobalt, March, 1907.

A Group at the Drummond Mine.

Excursion of the Canadian Mining Institute to Cobalt, March, 1907.

A Group of members at Cobalt Station. The Past President Mr. G. R. Smith is shown standing in the center of the picture. Prof. W. G. Miller, Vice.-President, is occupying a position in the tender of the locomotive.

Excursion of the Canadian Mining Institute to Cobalt, March, 1907.

Homeward Bound, saying good-bye to Cobalt at the station before the departure of the train.

The following are the By-Laws as amended at the Toronto Meeting, March, 1907.

BY-LAWS OF
THE CANADIAN MINING INSTITUTE

As adopted at the Annual General Meeting, Montreal, March, 1905, and amended at the Annual General Meeting, Toronto, 1907.

MEMBERSHIP.

1.—Members shall be persons actually engaged in the direction and operation of mining and metallurgical works, mining engineers, geologists, metallurgists, chemists, and such other persons as the Council may decide are eligible through connection with mining affairs.

2.—Associate Members shall be persons directly or indirectly associated with or interested in the business of mining, but not included under Sec. 1. Associate members shall not be entitled to vote or hold office.

3.—Student members shall include persons under the age of twenty-five years who are qualifying themselves for the profession of mining or metallurgical engineering, students in pure or applied science in any university or technical school in the Dominion, and such other persons, up to the age of twenty-five years, who shall be engaged as apprentices or assistants in mining, metallurgical or geological work, or who may desire to participate in the benefits of the meetings, library and publications of the Institute. Student members shall be eligible for election as members after graduation. Student members shall not be entitled to vote or to hold office.

4.—Corresponding members shall be eminent technical or scientific persons, not resident in Canada, who, from their position and experience in pursuits connected with the mining and metallurgical professions, are enabled to promote the interests of the Institute.

5.—Honorary members shall be persons who have distinguished themselves by their technical or scientific attainments, or persons eminent in the development of the mineral industry.

6.—The Director or Acting-Director of the Geological Survey of Canada, and the Director of Mines of the Dominion, are *ex-officio* honorary members of the Institute.

7.—The Technical Officers of the Geological Survey of Canada, who are in charge of Field Parties, are *ex-officio* members of the Institute.

ELECTION OF MEMBERS.

8.—Applicants for membership shall be proposed in writing by two members, and shall fill in and sign an application according to Form A in the appendix. This application shall be laid before the Council, which may cummunicate with the endorsers and shall have power to elect or reject by vote of the members present. When the proposed candidate is elected, the Secretary shall give him notice thereof, and on payment of his dues for the year he shall become a member.

9.—Applicants for student membership shall be proposed in writing by two members and shall fill in and sign an application in Form A, and, if elected by vote of the members present at a meeting of the Council, shall become student members upon payment of the dues specified in Section 14.

10.—Each person proposed as a corresponding member shall be recommended to the Council, which shall have power to elect or reject by a letter ballot returnable within one month from the date of the meeting at which the name was proposed.

11.—Each person proposed as an honorary member shall be recommended by the Council and elected by a two-thirds vote cast at a regular meeting of the Institute, his name having previously been sent out by letter to each member.

12.—Any member may be expelled from the Institute for cause on the recommendation of five members of Council, by a two-thirds vote, by letter ballot, of the whole Council. This expulsion shall be final, unless the member so expelled, shall successfully appeal from the ruling at the next Annual Meeting of the Institute.

SUBSCRIPTIONS.

13.—The annual subscription from members and associates shall be ten dollars, payable in advance on the first day of February, in each year. Subscriptions remaining unpaid on April first, in each year, may be subject to sight draft made by the Treasurer.

14.—Student members, except as provided in Sec. 15, shall pay two dollars per year in advance on the first day of February in each year.

15.—Any properly constituted society connected with a Canadian university, mining school or technical school may, with the approval of the Council, become affiliated with the Institute, and the students comprising such society shall then have all the privileges of student membership on payment by such society, annually in advance, on the first day of February in each year, of an amount equivalent to one dollar per head of its membership, and shall be known as affiliated members.

16.—Members in arrears for two years shall be considered as not in good standing and shall not be entitled to vote, and their names may be removed from the list of members by the Council at any regular meeting.

OFFICERS AND COUNCIL.

17.—The affairs and business of the Institute shall be managed and controlled by an elected Board, to be called "The Council," which shall comprise:—

(a) A President.

(b) Four Vice-Presidents.

(c) Councillors as specified in Sec. 24.

(d) Past Presidents of the Institute as specified in Sec. 20.

(e) A Secretary.

(f) A Treasurer.

18.—At each annual meeting there shall be elected a President, two Vice-Presidents, one-half of the Councillors, a Secretary and a Treasurer.

19.—The President shall be elected annually. He shall assume office at the close of the last session of the Annual Meeting at which he is elected.

20.—The three last past Presidents of the Institute shall be *ex-officio* members of the Council, provided they remain members of the Institute in good standing.

21.—The President shall take the chair at all meetings of the Institute and Council at which he may be present, and shall regulate and direct proceedings in accordance with the charter and by-laws of the Institute. In the absence of the President the chair shall be taken by the Senior Vice-President present at the meeting; in the absence of the President and all Vice-Presidents, the members present shall select the Chairman of the meeting.

22.—The Vice-Presidents shall hold office for two years, but two of them shall retire annually.

23.—The Council shall hold office as provided below, and members of it shall be eligible for immediate re-election. In case an officer whose term has not expired becomes a candidate for a higher office at the annual election and be elected, his election to such higher office shall automatically create a vacancy in the office formerly held by such member. The members in session at the annual meeting shall then proceed to elect a successor in the office thus vacated, and in the event of their failure to do so, the Council shall make the appointment.

24.—The Councillors of the Institute shall be twenty in number, ten of whom shall be elected annually for a term of two years. The retiring Councillors shall be eligible for immediate re-election.

25.—Should a vacancy in the Council arise from any cause during any year, the Council may select, by letter ballot of the whole Council, a member of the Institute to fill the unexpired term.

26.—The Treasurer shall receive all moneys payable to, or accruing to, the Institute, and deposit the same in a chartered bank to the credit of the Institute. He shall sign and issue all cheques for money to be paid, notes and drafts, endorse cheques and all other negotiable paper made payable to the order of the Canadian Mining Institute, and shall attend generally to the financial affairs of the Institute. The Treasurer, under the direction and management of the Council, shall pay accounts, shall keep, or cause to be kept, proper books of account, and shall enter all receipts and disbursements in a Cash Book. At the Council Meeting next preceding the Annual Meeting of the Institute he shall present a duly audited statement of the receipts and disbursements of the financial year, and at such other times as the Council may direct he shall submit to it, for its consideration, a balance sheet showing the financial position of the Institute. If in case of sickness, absence, or from any cause whatever, the Treasurer does not act for the period of one month, the Council may appoint a Treasurer *pro tempore*, who shall act with the powers of the Treasurer. The Council may remunerate the Treasurer at its discretion, but shall exact a guarantee company bond for such amount as they may deem necessary.

27.—The Secretary shall keep a true and correct record of all the proceedings of the Institute, the Council and all Committees, and also a correct list of the members and student members of the Institute and their addresses. He shall conduct the correspondence of the Institute and issue all notices of meetings, as set forth in the By-Laws. The Secretary shall have the custody of the seal of the Institute. If in case of sickness, absence, or from any cause whatever, the Secretary does not act for a period of one month, the Council may appoint a Secretary *pro tempore*, who shall act with the powers of the Secretary. The Council shall remunerate the Secretary at its discretion.

28.—The duties of all officers, unless otherwise specified herein, shall be such as usually pertain to the office or such as may be assigned to it by the Council or the Institute.

ELECTIONS.

29.—Not later than the 1st of November of each year the Secretary shall notify all members of offices falling vacant at the end of the next Annual Meeting and call for nominations to such offices. The list of such nominations shall close on January 1st following. All nominations for offices shall bear the signatures of not less than ten members in good standing. In the event of the Secretary failing to receive nominations for all vacant offices, the Council shall complete the list.

30.—The Secretary shall prepare a single ballot slip, containing all nominations made as above, and shall send it to all members not more than thirty-five nor less than thirty days prior to the Annual Meeting. This ballot shall be the sole ballot used in the elections. This ballot shall be so designed as to seal and to provide for the signature of the voter on a coupon, which shall be detached before opening the ballots. The ballot should be enclosed in an envelope addressed to the Secretary.

31.—The members assembled at the Annual Meeting shall appoint three scrutineers, who shall not be candidates for office. The scrutineers shall check the names on the sealed ballots with the Treasurer's list of members in good standing, and shall only accept the votes of members in good standing. All signatures of members voting shall be detached from the ballot slips before any of the ballots are opened. The scrutineers shall then open and count the ballots, and the candidates receiving the highest number of votes shall be declared elected. In case of a tie the scrutineers shall decide.

MEETINGS.

32.—The Annual Meeting of the Institute shall be held on the first Wednesday of March in each year at such place as the

Council may determine; the determination of the place of meeting shall be made at least two months prior to the date of the Annual Meeting.

33.—Special meetings o' the Institute may be called for such time and place as the Council shall determine, and notice of such special meeting shall state the business to be transacted thereat, and no other business shall be considered at such special meeting Upon a written requisition of twenty members of the Institute, specifying the nature and urgency of the business to be transacted, the Council shall be obliged to call a special meeting of the Institute not later than one month after the receipt of the requisition.

34.—Meetings of the Council shall be held at the headquarters of the Institute in the City of Montreal, but when an Annual Meeting shall take place elsewhere than at headquarters, Council meetings may be held at the place of the Annual Meeting, during and for two days immediately before and after such Annual Meeting Any notice calling an Annual Meeting shall be deemed to be sufficient notice of the meetings of Council specified in the above preceding sentence, whether such Annual Meeting be held at headquarters or elsewhere.

35.—Regular meetings of the Council shall be held at headquarters in the first week in October, December, January, February and April o each year, at such specific time and place as the Council shall determine. Special meetings of the Council may be called at headquarters at the written requisition of the President or of at least five members of the Council.

36.—In the event of it being advisable, in the opinion of the Council, to hold special meetings elsewhere than at headquarters, this may be done by a vote in person or by letter ballot of a majority of the Council. Two weeks' notice of such meeting must be given to all members of the Council.

37.—At all meetings of the Council five shall be a quorum for the transaction of business, and as soon as possible after each meeting copies of the minutes shall be sent to each member of the

Council. In the event of a majority of the whole Council signifying to the Secretary a wish to reconsider any act of a Council meeting, this shall be done at the next regular Council meeting, and letter ballots shall be accepted from such members as are unable to be present, and a majority of votes shall decide the point at issue.

38.—In its discretion the Council may appoint special committees, either from its own body or from the membership at large, for the purpose of transacting any particular business or of investigating any specific subject connected with the objects of the Institute, and shall request such committees to report either to the Council or to the Institute as it may see fit.

39.—The Council shall make an annual report to the Institute on the year's business, and in this, shall embody the financial statement of the Treasurer.

40.—All questions coming before any meeting of the Institute, Council or Committees, shall be decided by a majority of votes of the members present and voting, unless otherwise specified in the By-laws.

41.—Notice of all meetings of the Institute, whether regular or special, and of all meetings of the Council, except meetings authorized by Sec. 34 hereof, shall be sent by mail at least two weeks in advance. The business of special meetings shall be specificially stated. The business of regular meetings shall be stated, so far as is practicable.

LIBRARY.

42.—The Library of the Institute shall be kept at headquarters. The control and care of the Library shall be vested in the Council, which shall appoint a Committee of three members of the Institute, at least one member of which (chairman) shall be a member of the Council. This committee shall be known as the Library Committee, and shall have supervision of the Library. The Council may also appoint a Librarian, who shall have charge of the library, subject to the Library Committee. The Librarian may be remunerated for his services at the discretion of the Council, which may require a bond from him.

PUBLICATION.

43.—The Council shall appoint an Editorial Committee, of which the Chairman (at least) shall be a member of the Council. This Committee shall receive and consider each paper submitted to the Institute and shall advise the Council, which shall have power to publish or decline to publish any paper which may be communicated to the Institute at its meeting. So far as possible, papers and discussions shall be published first in pamphlet form "subject to revision," and distributed promptly to members.

44.—The Institute, as a body, shall not be responsible for the statements and opinions advanced in the papers which may be read, or in the discussions which may take place at its meetings.

45.—The copyright of all papers, plans, maps and drawings accepted by the Institute shall be vested in it, unless other agreements are specially entered into between the Council and the author. The author of each paper accepted and printed shall be entitled to fifty copies for his own use and additional copies at cost.

46.—Premiums and prizes, at the discretion of the Council, may be given annually for papers read by the students during the year. Any such award shall be made by the Council within three months after the Annual Meeting.

47.—Each member not in arrears shall be entitled to a bound copy of the Journal of the Institute for the year of which he has paid his subscription. Each student member not in arrears shall be entitled to an unbound copy of the said Journal, or to a bound copy thereof by the additional payment of one dollar in advance.

AUDIT.

48.—An auditor or auditors, one of whom shall be a chartered accountant, not a member of the Institute, shall be appointed yearly at the Annual Meeting. The duty of the auditors shall be to audit and examine the books and accounts of the Institute, and to certify to the correctness of the annual balance sheet submitted to the Council, prior to the Annual Meeting. The auditors may be remunerated at the discretion of the Council, and they shall also act for the Council during the year when requested to do so.

RESIGNATION.

49.—No resignation shall be recognized unless it is sent in writing to the Secretary, and also unless all accounts which may be due to the Institute by the resigning member shall have been paid.

BRANCHES.

50.—The Council may, from time to time, make such arrangements as it may deem best for the establishment and maintenance of local branches or sections of the Institute in mining camps, towns or districts which may have a considerable number, not less than ten, of members resident in such camp, town or district. These branches shall be governed by such regulations as may be made by the Council. In its discretion, the Council may grant such financial aid to such branches as it may deem necessary or desirable.

NOTICES.

51.—Any notices required to be given to any member or student member, under these By-laws, shall be sufficiently given by being mailed, postage prepaid, in any post office in Canada directed to the address of such member as recorded in the Secretary's book.

DISSOLUTION.

52.—The Institute shall not be broken up nor dissolved unless by the vote of two-thirds of the members present at a special general meeting convened for the purpose of considering such dissolution, and after confirmation by a similar vote at a subsequent meeting to be held not less than three nor more than six months after the first meeting, and notice of the last meeting shall be duly advertised, as the Council or the Institute may determine.

AMENDMENTS TO BY-LAWS.

53.—These By-laws may be amended at any Annual Meeting by a two-thirds vote of the members present and voting, provided that written notice of the proposed amendment shall have been sent to each member at least one month prior to the date of the meeting.

54.—The above By-laws shall come into force as soon as adopted by this Institute.

FORM A.

APPLICATION FOR MEMBERSHIP.

I, ...

....

approve of the Charter and By-laws of the CANADIAN MINING INSTITUTE, and hereby request enrollment as a

..................................member.

I HEREBY AGREE that I will be governed by the Charter, By laws and regulations of the said Institute as they are now or may hereafter become, and that I will advance the interests of the Institute as far as may be in my power, 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 amount which may be due by me at that time, be free from this obligation.

My connection (or experience) in mining affairs is as follows.—

....

....

Signed..

Profession..

P. O. Address...

Province or State...

Age (if student ....

Date ....

Proposed by..

Seconded by ....

PAPERS

THE ORE DEPOSITS OF THE COBALT DISTRICT, ONT.

By Dr. C. R. Van Hise, President University of Wisconsin, Madison, Wis.*

(Toronto Meeting, 1907.)

For many years I have been interested in the general principles concerning the deposition of ores, and it has been from that point of view that I have especially studied the Cobalt district. What does this district afford in confirmation or variation from the principles of ore deposition which have been the subject of study by so many geologists for so many years? For one thing it appears to me that it illustrates very well indeed the principles of two concentrations in ore deposits. In common with many other geologists in the States and other parts of the world, I have considered the question as to whether ore deposits are usually produced by one or by two or by several concentrations. As I view the matter, the ores of most of the districts which I have

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*Dr. Van Hise prefaced his address on the above subject with the following introductory remarks:—

"It has afforded me great pleasure, and I am greatly honoured at having been asked to attend this meeting of the Canadian Mining Institute. For many years I have had the pleasure of meeting many of the men engaged in mining in different parts of Canada, and always with the result of unfailing courtesy and wonderful resources in the way of refreshments. It does not make any difference whether one goes to a Cobalt mine, a corundum deposit, or to a cave, there always appear products which the district does not advertise.

"However, I have now the very great pleasure for the first time of meeting a large group of Canadian mining men together. The subject announced for me is not precisely the one upon which I shall speak. I shall not address you upon the geology of the Cobalt district, but rather on the ore deposits of that area. The foundation of everything I shall say has been laid by Professor W. G. Miller, Provincial Geologist of Ontario. The geology of the district has been worked out by him. He has also given an accurate description of the ore deposits. Others have added to the information concerning the district. Hence, what I may say will be merely a small contribution to that of the Canadian geologists for the Cobalt district. In my visits to the area I have learned to appreciate the accuracy and faithfulness of the geologic work that has been done by Canadians."

visited give evidence of more than one concentration. Usually an ore deposit has not so simple an origin as we should like to believe, but on the contrary has a long and complex history.

One geologist says that a certain ore deposit is produced altogether by magmatic segregation. Another says that it is deposited by circulating waters. This man may assert that the deposit is produced by magmatic waters, while another holds that the depositing waters were atmospheric. In each case of dispute of this kind, where I have been so fortunate as to see the deposit, it has seemed to me that it has a complex history; that each man has had part of the truth; for very frequently it is the case that an ore deposit in its first segregation is magmatic, while a further segregation is by magmatic vapors and waters and later segregation takes place through atmospheric waters. This is a very rough outline of the history of some deposits, and the full story of many is even more complex than that. Thus, frequently, the different points of view are all partial truths and they need merely to be fitted together to make the complete story.

I have been in the Cobalt district only about a month during each of two seasons, and could have done nothing except for the foundation work which I have mentioned. Very early in my study of the Cobalt deposits, I became convinced that this was a district in which there had been two periods of concentration. The first concentration occurred under deep-seated conditions when the waters were free from oxygen—I know nothing as to whether the waters were atmospheric or magmatic, or partly one and partly the other—during which arsenical, antimonial and sulphur compounds of cobalt, nickel and silver were deposited. Since this time there has been a second concentration through the influence of surface waters bearing oxygen and descending or traveling laterally. An adequate explanation of the ore deposits must combine the effects of the deep-seated and shallow circulations.

It appears clear that at least the major portion of the cobalt-bearing minerals, smaltite and cobaltite, are products of an early concentration. These minerals were doubtless deposited at a considerable depth below the surface. At this time the openings were largely or altogether filled with vein material, smaltite, cobaltite and gangue minerals.

After the main deposition of the cobalt minerals, there were movements which resulted in secondary fracturing of the veins. These openings permitted the entrance of silver-bearing solutions, and the contact of these solutions with the cobalt minerals resulted in the precipitation of the silver. It is a well known fact that if silver solutions be placed in contact with cobalt and nickel sulphides and arsenides under ordinary conditions, these minerals will precipitate the silver.

Thus I incline to the view that the cobalt minerals appeared comparatively early, and that later the silver-bearing solutions appeared which resulted in the silver minerals. In presenting this view I do not mean to say that the deposition of the cobalt minerals had ceased before the silver began to be deposited, for the two may have overlapped to a considerable extent.

The suggestion that the silver came in late and largely in connection with secondary fracturing explains many curious phenomena characteristic of the district. A vein may be very rich in silver in one place; followed along the strike a little way it may be very lean. Indeed, the variations of richness, both vertically and laterally, are rapid. If all the minerals came in at the same time and were deposited together, the silver should be somewhat evenly distributed through the cobalt minerals. On the contrary there is extraordinary irregularity in the distribution of the values. When the deposits are closely examined, it is found that the rich shoots are often at places where the veins were shattered, and the poor parts show comparatively little shattering. The openings produced by the secondary fractures have permitted silver-bearing solutions to enter when the silver would be thrown down by the cobalt minerals or other precipitating agents.

The question now arises as to the applicability of the principle of two concentrations. To what extent are the rich deposits the result of one segregation under comparatively deep-seated conditions and to what extent of two segregations, one under deep-seated and the other under shallow conditions? Did the shattering, which resulted in the entrance of the silver solutions, occur under deep-seated conditions so that the silver of the rich shoots was deposited as a closing episode of practically one continuous period of concentration? Or, after the first concentration was complete, did the shattering then occur and the later enrichment take place under comparatively shallow conditions, the two periods of concentration being separated by a long interval? At the present time I am unable to give a definite answer to this question for the main masses of the ore. This is one of the problems which the Canadian geologists will doubtless work out as the district develops and as their studies continue.

Whatever is the final answer to the above question, it appears certain that the extremely rich superficial deposits of a few feet in thickness, connected directly with the zone of weathering, are due to secondary concentration under surface conditions. I refer to the nugget horizon, which is so rich in silver and in which the smaltite and cobaltite have been largely altered into secondary minerals or have even been leached out altogether. It is practically certain that this extraordinary rich upper film in the Cobalt district has been produced by two concentrations, one under deep-seated conditions when atmospheric waters were not present, and the other under surface conditions when atmospheric waters were present.

We must remember that in the past the veins which now stop abruptly at the surface continued upward to an unknown height into what is now the atmosphere. Erosion has cut away this upper material. This process has been a very slow one. At any given time the silver salts at or near the surface were being oxidized to a soluble form and were being carried down in the openings of the veins. At or near the level of groundwater the silver in the solutions would be again precipitated by the cobalt minerals. These reactions would take place with the arsenical and antimonial silver-bearing minerals as well as with argentite, although the latter case is more simple. The argentite in the upper part of the belt is oxidized to silver sulphate which is readily soluble. As this salt is carried down and comes in contact with the cobalt minerals, native silver is precipitated, just as silver is precipitated from silver sulphate in a beaker when in contact with such minerals.

As the processes of erosion, solution and deposition go on, the material, once enriched, as the result of erosion reaches the surface and goes through the same process as before. In this manner a layer of rich material is accumulated at the surface. Thus the nugget zone is produced. During this process doubtless much more silver from the parts of the veins removed by erosion is lost and scattered abroad than accumulates in the veins below. I believe that the extremely rich upper silver belt, so characteristic of the district, is unquestionably the result of two concentrations, the latter of which is accomplished through the agency of atmospheric waters.

But the majority of the mines do not depend upon this very superficial rich film, but upon the main horizon below. To what extent is this deeper horizon the result of a single concentration under deep-seated conditions and of a later concentration under surface conditions? To this question I am unable to give a definite answer, but I believe that the later secondary concentration, even for this belt, has made important additions to the silver values. Whether the chief values of silver are thus explained or were produced under deep-seated conditions in the later stages of cobalt deposition is a point for the future to decide.

An important question comes up in this connection, that is, the relation of the ores to the diabase. What is the source of the ore-bearing solutions? On this matter my judgment coincides with that of Professor Miller, and other Canadian geologists, namely, that the diabase is probably the source of the ore. There are three possible sources for the ore in the district—the diabase, the Huronian and the Keewatin. However, the Huronian and the Keewatin rocks seem in all respects to be similar to the great masses of these formations which extend from the Lake of the Woods to and even east of the Cobalt district. In other words, Keewatin and Huronian rocks, similar to those of the Cobalt district, have an extent of hundreds of miles. If the source of the ore were either the Huronian conglomerate or the Keewatin schist, why have not other cobalt districts been found in this great area? With what formation then are the exceptional conditions associated which result in these deposits? The natural answer is the igneous rocks. But it may also be said that a diabase similar to that in the Cobalt district has as wide a distribution as the other formations. This is true, but it does not follow that some of the reservoirs from which they came did not contain the exceptional materials cobalt and silver.

If the diabase is the source of the silver, how does it happen that some of the veins are in the diabase? As is well known, the profitable veins are more abundant in the conglomerate than in any other formation, but they also occur in the Keewatin. Thus the veins occur in all three of the formations. How is this fact explained? A study of Professor Miller's excellent geological map shows that the main ore deposits which have been discovered are in the Huronian and Keewatin comparatively close to the diabase or else are along or near the borders of the diabase. This is not altogether true of the area directly about Cobalt, but if Professor Miller be correct in thinking the diabase to have been a sheet, it may have entirely overlain this area, and indeed this is rendered probable by the occurrence of a small area of diabase immediately northeast of Cobalt lake.

In this connection it should be remembered that Professor Miller regards the diabase as a laccolite. The igneous material entered from below, forced the layers apart and spread out between them, forming a sheet which has great lateral extent as compared with its vertical thickness. It is like a flat disk which has forced itself in between the sedimentary layers and spread them apart. Professor Miller gives much evidence in support of his view that the diabase is a laccolite rather than a great stock or batholith which increases in size as it extends down. It seems to me there is evidence on this point beyond that which Professor Miller has given If the diabase were a great mass extending down indefinitely, it would necessarily follow that the Keewatin and Huronian rocks, which occupied the area before the intrusion occurred, would have been forced aside in order to give place for the diabase. This would result in sharp or even very close folding of the sedimentary and Keewatin rocks. Northwest of Lake Superior, and at other places where large batholiths occur, such are the facts, but in the Cobalt district the conglomerate is in a series of very gentle rolls. No immense masses of material have been pushed aside. Therefore Professor Miller must be right in saying that the diabase is a flat sheet which is intercalated between the layers.

We now return to the concentration of the ores. Does a great diabase intrusion occur in a year or in a thousand years? We do not know how long a time is required for such an intrusion, but it is certain that it is very long, probably much longer than either of the times mentioned. When a thick sheet is intruded, it cools first along the contacts. Consequently, when the main mass is still molten, the exterior is solid. During cooling, contraction takes place, earth movements occur, and openings are formed not only in the conglomerate and Keewatin, but in the solidified diabase itself. Later, when these openings become filled by deposits from the circulating solutions, they form the veins of the district. Thus openings in the outer solid part of the diabase may be filled with silver-bearing solutions which are derived from the diabase itself. If this theory be correct, what would be expected as to the distribution of the ore-bearing veins? We should anticipate that the diabase would be most likely to bear productive veins in contact with or close to the older rocks, because these are the parts first cooled. As a matter of fact, the larger mines in the diabase are along the borders of that formation.

If the theory set forth be correct, where should the veins be found which are in the conglomerate and in the Keewatin? Plainly they should be in those parts of these formations close to the diabase and this is the position at which they are found for the larger part of the district, although, as already explained, the mines about Cobalt are some distance from the main mass of the diabase, but even these may have been immediately overlain by that formation.

The question now arises as to whether the Keewatin and the conglomerate played any important part other than as a recipient of the ores. As is well known, calcite is the most characteristic of the gangue minerals. Calcite could not be derived from the diabase since it contains no carbonates or so small a quantity that it is negligible. But one of the most characteristic features of the Keewatin rocks is the presence of carbonates, among which calcite is the most abundant. Also the conglomerate, being composed of debris from the Keewatin, contains much carbonate. Hence, I believe that the Keewatin and the conglomerate are the main sources of the calcite of the gangue minerals.

It may be that the solutions bearing calcium carbonate were a factor in the precipitation of the metalliferous minerals. This is a mere suggestion which some Canadian geologist should take up and investigate. It is a question whose answer will involve a close study of the chemistry of the ore deposits of the Cobalt district. The question is to what extent the precipitation of the ores was produced by the mingling of solutions, some of which came from the diabase bearing the ores and others of which came from the conglomerate and Keewatin, bringing precipitating agents. I think it probable it will be found that the precipitation was largely caused by the mingling of solutions from these different sources, although the mere cooling of the solutions may have been a factor in the process.

The foregoing suggestions have a bearing on exploration in the Cobalt district. If they are true, the exceptionally favorable places to explore are those in the conglomerate and Keewatin along the border of the diabase and the diabase comparatively near its border. It does not, however, follow that other areas should be excluded from consideration, for as already explained the diabase at an earlier date may have overlapped considerable areas and subsequently been removed by erosion. The mining men of the district already know empirically that the favorable places to explore are those already indicated, and thus their observations give confirmation to the theory outlined.

The theory, if correct, leads to further suggestions. There may be areas of conglomerate and Keewatin which have been covered by diabase from which the diabase has been barely removed by erosion with very little cutting of the formations beneath and these areas bear ore deposits. One further point is important, that is as to the conglomerate overlain by the diabase. If the diabase be a laccolite, the conglomerate underlying it is a legitimate horizon for exploration. Present knowledge warrants cautious attempts to follow the conglomerate horizon below the diabase. This is illustrated by the Kerr lake case. There, at the west end of the lake, the diabase may be seen resting upon the slate, the latter dipping under the diabase. The conglomerate has been very profitable on the south side of the lake. May it not be profitable when followed below the diabase? It is not asserted that such will be the fact, but merely that the chances are sufficiently good to warrant cautious exploration below its border.

If the conglomerate under the diabase proves to be profitable it will furnish information as to the relative importance of the primary and secondary concentrations; for the ores below the diabase will be largely those produced by the deeper circulation, with comparatively little effect of the secondary surface concentration.

In conclusion I may say that I believe the ore deposits of the Cobalt district to have been produced not by a single concentration but by two concentrations. The first of these was under deep-seated conditions in the absence of oxygen-bearing waters. The source of the ore was the diabase, the precipitating agents for the cobalt ores were probably in part from the conglomerate and Keewatin. Secondary enrichment has certainly been an important factor in producing the extremely rich superficial films of ores. It may have been an important factor throughout the entire horizon which is at present being mined. But how important, it is yet too early to say. The deductions already made from observation give a rational explanation of the distribution of the ores and give clues as to further exploration in the Cobalt district.

DISCUSSION.

THE PRESIDENT—I am sure that we cannot sufficiently thank Dr. Van Hise for his kindness in attending this meeting and giving us so interesting and valuable a paper as that just read. I desire to express to him the appreciation of the Institute.

MR. INGALL—Prof. Van Hise's very vivid description of the conditions in the Cobalt region certainly has a special interest to myself as having seen the working of that other silver region in the Thunder Bay district, with which my Canadian friends have been familiar for many years. A number of features were exhibited by that district similar to those of the Cobalt district. There you had the association of the deposits with a lot of flat-lying sedimentary rocks, and with a series of intrusive diabase sheets, as well as apparently secondary concentration, producing the enrichment which enabled the ores to be worked at a great profit as long as they lasted. You also apparently had, as the development of the district proved, the very same feature to which Prof. Van Hise alludes here—that the enrichment had occurred apparently from the surface down. It was clearer in that district perhaps than in this case, for you had a lot of permeable minerals, such as galena, blende, &c. These often exhibited films of argentite and native silver in the cleavages. When I went to Cobalt, about a year ago, it struck me that there were many points of similarity with the old Thunder Bay district, and again there were many points of great dissimilarity. The presence of highly complex ores in Cobalt certainly was not paralleled in the Thunder Bay district, except perhaps in Silver Islet mine in places. There might be some bearing on the future of Cobalt in what development proved in Thunder Bay. For instance, in the Silver Islet mine, where the conditions of deposition extended downward further than elsewhere, because a dyke of diabase was cut by the vein instead of a sheet, down to 600 feet they had enormously rich ores: Another feature that seemed to be almost associated with secondary concentration in the Thunder Bay district, was the large amount of carbonaceous matter in either the diabase dykes and sheets or in the sedimentary "country" rocks. In the Silver Islet Mine they went down to 1200 feet. The vein was persistent both in length and depth, but the really rich ores were concentrated near or at the point of intersection of the vein with the dyke of diabase. In the West End mines the silver went down to about 500 feet, and then the vein passed into a lower series of rocks which did not seem to be favorable to the deposition of silver minerals in the original vein-filling. The main features held in common by the Thunder Bay and Cobalt districts are:—The presence of diabase intrusions in a horizontal series of sedimentaries deposited on a denudation surface of Keewatin and Laurentian rocks; a distinctly primary vein-filling of quartz, calcite, barite, and fluorite accompanied by blende and galena and an enrichment by secondary deposition of silver minerals (native and argentite chiefly) wherever the permeability of the original vein-filling permitted.

MR. HIXON—Did you find much metallic silver in that region?

MR. INGALL—Yes, although it was not so prominent at most places as the argentite.

MR. HIXON—Associated with carbonaceous matter?

MR. INGALL—The carbonaceous matter was in the country rocks always.

MR. HIXON—Was it along the top more pronounced than anywhere else?

MR. INGALL—The district I particularly studied was that west of Port Arthur—the Silver Islet was shut down then—the carbonaceous matter was in the shales which lay under the sheets of diabase, but there was no very considerable carbonaceous matter in the vein-fillings. Those veins were quite large—four or five and eight feet in places.

PROF. PARKS—I would like to ask in regard to the original or first concentration of the ore. Is it your opinion, Prof. Van Hise, that the nickel and cobalt minerals appeared at one time in the original concentration, or at different times?

PROF. VAN HISE—So far as I have been able to get at the facts it looks to me as if the cobalt minerals came in comparatively early, and at a later stage were followed by the silver minerals. This is indicated not only by the phenomena of the secondary shattering in connection with the silver, but by the fact that a considerable number of the veins are altogether filled with the gangue and cobalt minerals, with only a small amount of silver. Certain veins are practically cobalt ores only for part of the distance, while some are thus for the entire distance they have been followed. It is believed that such veins were entirely filled during the chief period of the cobalt-nickel deposition. At this time the openings were cemented tight, and there was no chance for the later silver solutions to get in. But if after this period there was shattering, openings would be formed and the silver could enter and thus enrich the veins in their shattered portions.

MR. HIXON—Is it not possible that hydro-carbon, issuing with the other gases or with the magmatic waters, would reduce the silver to metallic silver at greater depth than it would be affected by surface concentration by secondary action.

PROF. VAN HISE—If hydro-carbons were there. I don't know that they were there.

MR. HIXON—Is it not a fact that along many of those veins you found evidence of hydro-carbon in the form of graphite deposits which can be rubbed off on the finger. Is not that a fact?

PROF. VAN HISE—I can't say.

MR. HIXON—In the Sudbury district you will find along the wall places where we can get a piece of rock associated with the ore from which you can rub off distinct evidence of graphite or of some kind of carbonaceous deposition, evidently due to the decomposition of hydro-carbons associated with solutions.

PROF. VAN HISE—In the Sudbury district there are carbonaceous slates. In the Cobalt district I do not know of any such slates.

MR. HIXON—I suggest that finding silver at great depth, shows the possibility that this silver might be reduced by hydrocarbons and not due to the secondary enrichment at the surface.

MR. COSTE—At Silver Islet it is very well known that they struck hydro-carbon gases in the mine a number of times, and that they had some trouble in the working.

MR. HIXON—I think it is quite possible that you will find this metallic silver in the Cobalt district extending to much greater depth than can possibly be affected by any secondary enrichment from the surface. In fact I think it has been already demonstrated in the La Rose mine to a depth of 350 feet, and inasmuch as there has been a great amount of rock eroded by glaciation, it hardly seems that secondary enrichment would extend down to such depth. In the Butte district this secondary enrichment only extended down to seven or eight hundred feet, where they found very rich copper ore. In Arizona, where there has been no glacial erosion, it goes down to 1,000 feet or more. In this district, where there has been so much erosion, I would not expect secondary enrichment to go down more than a few feet. In the Sudbury district whatever secondary enrichment there may have been, has been cut off.

DR. BELL—I was present at Silver Islet before the discovery by the Montreal Mining Company during the whole time of its working, and I remember that hydro-carbon gases were quite common to the depth of 1,000 feet. The pressure was such that they kept up a flame of natural gas there. Pure carbon was deposited here and there all through it, and gas right down to the bottom.

PROF. VAN HISE—I fully agree to the idea that if hydrocarbons were present, they are capable of reducing silver and gold. That is one of the methods of reduction where such compounds occur. I simply said that in the Cobalt district I did not know of the presence of hydro-carbons or carbonaceous material to do the reducing work. However, I meant to make it clear that their presence is not necessary. If the cobalt minerals are present and secondary shattering occurred, after which the silver solutions entered, the cobalt compounds are sufficient reducing agents for the precipitation of the silver without any secondary atmospheric concentration. I tried to make it clear that I did not speak dogmatically upon that question. I said I did not know how much of this silver in the zone now worked is deposited by the secondary surface concentration nor what proportion was produced under deep-seated conditions. I intimated that this is one of the problems to be solved.

MR. HIXON—I think that the ordinary mineral of secondary enrichment is generally horne silver, chloried rather than metallic silver. At least it has been so in my experience in Leadville and other places where after passing through the zone of comparatively lean ores, they found large deposits of very valuable chloride. They did not find very much native silver. So that I am quite inclined to believe that the native silver will extend much deeper than secondary enrichment can possibly account for. Further than that, I believe that native silver is a direct product of the reduction from those solutions by hydro-carbon gases that came out along with the solutions themselves. Instead of two periods you only have one. While the mineralization is going on, silver was deposited in those channels where the hydro-carbon reduced it.

PROF. MILLER—As regards two periods of deposition, Dr. Parks has asked that question and Mr. Hixon has referred to it. I don't think there is any question at all that there are two periods of deposition. Professor Van Hise has referred to the differences exhibited by veins in their horizontal extent. There is another point to which I might refer. I might say that I have taken up this point in a paper in the first issue of the *Canadian Mining Journal*, because when I was in Cobalt the other day the question was asked me by one of the leading mining men, and I felt called on to give an explanation, or try to. There are a number of veins there which pass from the conglomerate down into the Keewatin. They hold their width pretty well in passing—not all, but some of them. Now, in practically all cases the silver values, that is in the area west of Peterson Lake, disappear when you get to the Keewatin, but the smaltite and nickelite continue below the contact. Now, the only explanation I can give for that is that during this period of secondary disturbance the silver filled in the cracks through the smaltite or older minerals. The silver is always found in the secondary cracks; but during this period of secondary disturbance, the Keewatin being the older mass, the igneous formation differing from the conglomerate seems to have escaped the effects of this slight disturbance, hence there were no cracks in it; the solutions could not get through the Keewatin. They could work through the vein in the other lining of the conglomerate, but the vein in the Keewatin escaped. It seems to me that is pretty conclusive evidence of two periods of deposition there—an older period of deposition of nickel and cobalt minerals, and a later period of deposition of silver minerals. As Prof. Van Hise said, this silver in many cases has been more or less decomposed. Mr. Hixon has referred to the point of the carbonaceous material. I may say that the greatest deposition we have gone through, we have considerable graphite in one of those veins; and there is a considerable body of it. That is at the La Rose Mine. There is also much graphite in the Cobalt Hill deposit, where there is no silver at all—a massive vein of smaltite and nickelite 14 in. wide, lots of graphite, no silver. In several other properties in that vicinity graphite occurs.

Mr. Tyrrell—Professor Miller's determination of the fact that the diabase in the Cobalt district is a laccolitic, rather than a batholitic, intrusion is one of the most important and interesting additions that has been made for some time to the knowledge of the structure of that north country. From it we may conclude that the fissures now occupied by the mineral-bearing veins in the conglomerate and greenstone, both above and below the laccolite, were formed through the heating of these rocks by the molten diabase and their consequent expansion vertically; after which they gradually cooled, and the whole mass, including the diabase itself, contracted, the contraction being chiefly lateral with the consequent formation of numerous vertical fissures. These fissures would be widest and most extensive close to the diabase, and would gradually pinch out and disappear at a distance from it. This distance must, of course, be computed from where the diabase was originally, before any of it was removed by erosion.

If the thermal waters associated with the intrusion of the laccolite of diabase carried the cobalt and silver ores into these fissures and formed the veins which now fill them, and Professor Van Hise has shown us clearly that the veins were probably so formed, then in the productive area underlain by Huronian and Keewatin rocks, which area was doubtless formerly covered by diabase, though this latter rock has now been eroded away, the veins were originally formed not from ascending solutions, like most normal veins, but by heated waters charged with cobalt and silver descending from the diabase; or in other words, leaving out of consideration the question of later secondary enrichment, that the ores were originally introduced into their present positions in the fissures from above and not from below.

I would ask Professor Van Hise if he does not agree with this deduction from the principles just enunciated by him.

Prof. Van Hise—I should agree with that altogether. I used the term deep circulation. I did not mean deep circulation in the sense of the barysphere as used by Posephny. I meant only a circulation sufficiently deep to be below the oxidizing effect of atmospheric waters. So far as the principles of ore deposition are concerned, the essential thing for the waters of a deep circulation is that they shall have travelled far enough below the surface to have lost their oxygen. Non-oxygenated circulation is what I meant in using the words deep circulation. The fundamental distinction between the two classes of circulation is as to whether they are oxygenated or non-oxygenated rather than whether they are deep or shallow or ascending or descending. I further agree with Mr. Tyrrell exactly that so far as the ores were deposited under the diabase, the solutions have travelled down from the zone of derivation and therefore the ores were in part, at least, originally deposited by descending solutions.

Mr. Brock—With reference to the secondary origin of the native silver in the Cobalt district, I was shown a specimen from the La Rose mine, last spring, which came from underground, I don't know at what depth it was taken; they had not remembered; but that specimen showed clearly that the silver was secondary and later than the cobalt nickel mineral. There was in the specimen a neucleus of nickelite, which was the earliest formed mineral. Around that the cobaltite or smaltite was developed. After their formation these minerals had been fractured. There were several small fractures formed, and native silver was developed in them. Regarding Mr. Hixon's statement that the secondary silver mineral is usually the horned silver and not native silver, in Canada, in various parts, we have a number of examples of secondary concentration of ores near the surface. Many of these are in silver-bearing veins, and in very few cases—in fact at present I do not recall a single case where a secondary mineral was horne silver. It is almost always rich silver sulphides or arsenides, and in very many cases native silver that are produced. In many of the silver lodes in British Columbia you have native silver developed secondarily, and native gold also, in small fractures, evidently late formed and recent. In some of those veins they have gone below the zone of secondary enrichment, getting argentiferous galena, blende, tetrahedrite, etc. Probably on account of the glacial effects in almost all parts of the country, we do not as a rule, have the zone of highly oxydised minerals such as oxides and carbonates, and it is usually in that horizon, I think, that the horne silver is developed.

MR. COSTE (Acting Chairman)—I am glad to be in the Chair to thank Professor Van Hise for bringing this very important subject so ably before us. I would like to point out to Mr. Hixon that there might have been an old secondary enrichment—not at all in the sense of an enrichment that could have been affected by a glacial period in any way. In very ancient times no doubt these oxides and secondary phenomena were taking place just as they were during the tertiary and quaternary, and there might have been a very old secondary enrichment affecting these rocks almost immediately after their deposition. I believe that that is the solution of this problem. That it is a very old secondary enrichment. I would point out to Mr. Tyrrell that it would not necessarily result from the fact that the diabase is laccolite to say that the solution came directly from the diabase, and in that sense descending; because it is quite certain to my mind that where these masses of volcanic rock were being intruded through in the laccolith form, and those prove to be the veins themselves, the joints descending away below this laccolith, no doubt the whole vein was fissured open and no doubt the laccolith, as all the igneous rocks are—intrusions—were accompanied by quantities of vapors and gases containing all those minerals in solution. So that I think it certainly was ascending in those fissures that were all through the districts, and some small quantity was intimately mixed with the igneous rock, and the gases and aqueous product, but a large quantity of the silver, it seems to me, is a perfect physical proof of the independent deposition of the interior.

THE COBALT MINING DISTRICT.

By Dr. Robert Bell, F.R.S., Ottawa, Ont.

(Toronto Meeting, 1907.)

In the present paper the writer proposes to confine his remarks mainly to some points in connection with the geology of the Cobalt district and the nature of the metalliferous deposits, the most important of which are those of silver.

The silver-bearing area is comparatively small, the most productive portion, so far as known, not exceeding about fifteen square miles, although fresh discoveries are being constantly made, some of which tend to increase its extent. The general appearance and the physical characters of this area are similar to those of the region which surrounds it for many miles. It is an undulating, rocky, forest-clad district, with numerous small lakes among the hills, which latter are not high or conspicuous, the general aspect, on the large scale, being that of a mammillated peneplain.

The centre of the productive area is about three and a half miles west of lake Temiscaming, in latitude 47°30′. The rocks within the above fifteen square miles belong to the series, all of which was formerly called Huronian.

A few words of explanation may here be advisable in reference to the history of the Huronian system, and the evolution and nomenclature of the divisions which are now more or less recognised by geologists. It is well known that some sixty years ago the whole of the upper series of the azoic or archæan was named Huronian. This was before discovery had advanced sufficiently or geologists had had time to properly classify and subdivide the great series of crystalline rocks overlying the Laurentian, which Logan and Murray had already found in the region of lakes Huron and Superior.

It required much time and labor to ascertain the general nature, the importance, the geographical extent and distribution, the volume and the probable natural divisions of the system. While the whole series may be described as of a pyro-clastic type, an igneous character prevails towards the base and the sedimentaries become more and more abundant and diversified towards the top. The underlying igneous type has been called the Keewatin division, while the term Huronian has always been applied to the higher portions, and these may be again separated into a lower and upper Huronian, although no continuous dividing line has been established.

One of the characteristics of the Huronian proper, is the want of continuity of any particular belt or division. The lithological divisions which may exist in one district, all thin out and terminate in both directions, and gradually become interlocked or dovetailed with new formations which gradually introduce themselves from both sides. In other words, a general cross section of Huronian strata, covering a considerable distance, would show a series of interlocking lenses of different rocks, which are gradually replaced on the strike by other kinds. For this reason an identity or difference in any set of these rocks in widely separated localities is no criterion as to a similarity or a difference in age.

The recognised Keewatin rocks of the Lake of the Woods lie at a distance of seven hundred and fifty miles in a straight line from the Cobalt district, and the two formations have not yet been separated from each other in any part of the intervening distance, in the course of which the Huronian areas are broken up and separated by wide intervals of the Laurentian series. Too much stress, therefore, should not be laid on differences of age which are supposed to exist among the rocks of the Cobalt district. It may be better to defer an exact separation and classification until some general work in this line has been done over this great interval and until this whole subject is better understood. It is worthy of notice that some persons who make frequent use of the word Keewatin apparently believe that it is a lithological term, like conglomerate, diorite, slate, etc., and could point out where a few yards of it might be seen. The writer should here observe that he has done no work personally in the way of mapping out and classifying the rocks of this district, and as the geologists who have been engaged upon it do not agree, it might be better for the present to confine our geology to making as correct a petrographic map as possible, which is all the prospector or the miner requires, and leave the classification to be determined later on.

The silver-bearing rocks have so far been found to consist of massive or crystalline diabase, but more especially of a volcanic breccia or agglomerate having a bluish and grayish matrix consisting of hornblende porphyrite, while the contained fragments are mostly reddish and grayish granite, together with others of the porphyrite itself and various forms of greenstones. The fragments are generally of rather small size, and mostly angular or subangular, although in some parts many of them are more or less rounded. They stand at all angles in the mass and are very irregularly distributed; sometimes well scattered throughout considerable volumes of the rock, sometimes occurring in large and small bunches or "flocks," or they may be sparingly distributed or almost entirely absent. This agglomerate has a general horizontal attitude and is the rock which is most in evidence at the surface in the more productive parts of the district. Associated with the two kinds of rocks which have been mentioned, are fine grained drab and gray slatey rocks and dark and light coloured greywacké, passing into impure quartzite. These also lie horizontally or conformably with the great sheet of brecciated hornblende porphyrite.

In the Cobalt district itself, the brecciated rock extends beyond the silver-bearing area and similar breccia occurs abundantly on lake Temagami, around Rabbit lake, and in other parts of the region, but holding little or no silver, as far as known. The presence of the silver at Cobalt would therefore appear to depend upon an original local impregnation of the parent breccia and diabase with the metal. It would thus seem to be a mistake to suppose that silver is to be looked for wherever the breccia is found. The occurrence of the silver in the Cobalt district appears to be regional and to be confined (with some exceptions) to a comparatively small area. This is not the only example we have of these local occurrences of some one metal. The great abundance in this same locality of the hitherto rare and expensive metal, cobalt, affords another example of this phenomenon. The immense deposits of nickel, within a very limited area at Sudbury and in New Caledonia on the opposite side of the planet, belong to this mode of occurrence. In various parts of the world, some of the other metals, such as tin, mercury, platinum and manganese, exhibit the same tendency to regional limitation. Only the other day it was announced that the hitherto rare metal tantalum had been found in great abundance at a single spot in Australia. The cause of this local or circumscribed occurrence of certain metals has not yet been explained, any more than the reason why the specific gravity of the whole earth is more than twice as great as that of the average materials which form the crust. The latter fact is probably owing to the existence of various heavy metals at great depths and the former to the occasional ejection of one or more of these from great depths, especially during early periods of the earth's history.

Some of the shafts in the Cobalt district have been sunk in the agglomerate and the associated slaty ash rock and arkose, and this rock-formation including all is supposed to have a total thickness of upwards of three hundred feet. It is traversed by two sets of vertical joint planes, recalling the jointed structure of argillites, clay slates, etc. One of these sets has an average course of north-east south-west and the other is at right angles to this. The silver-bearing part of the district is also traversed by fissures or planes of disturbance, along which, from time to time the rocks were crushed by slight movements, under great pressure, forming spaces in which mineralising waters could rise from considerable depths. The agglomerate and perhaps the whole of the crust of the earth to the very surface would probably have an elevated temperature when this occurred, while the waters from a depth would be still hotter. On approaching the surface they would be relieved of pressure and somewhat cooled.

The reason why some mining men, on visiting the district in the earlier days, did not appear to be favourably impressed, seems to have arisen from the fact that nearly all the veins were small; few of them were well marked or continuous for any considerable distance. In fact, most of them lacked the typical character of good fissure veins of the ordinary kind. When development had proceeded far enough and a sufficient number of openings had been made to enable one to properly observe the phenomena, it became evident that the supply of ore did not depend upon the individual small veins, but that there was some more general kiud of mineralization. This, the writer believes to be connected with the above planes of fracture or disturbance which are more continuous and deeply seated than the small individual veins on and near their course. The fissure-plane may, in places, be indicated by only a small vein or a dry fault without any vein-matter or gangue, but the wallrock itself along such sections of the general rent will often be found to be rich in silver for some inches or even a foot or two inward from the line of fracture. Small cracks and branch veins running out from the main fissure may carry the silver to a considerable distance into the country rock.

If the above view be correct, a continuous production of the silver is to be looked for by following these vertical zones of crushing and disturbance. Along these planes, the temporary formation and subsequent breaking up of veins, from time to time, was only one of the phenomenon of their history. In some instances, especially where the line of fracture has been nearly straight, the vein or group of veins has not been thus broken up, but has preserved its continuity for some distance and has become enlarged or has produced new parallel veins by the widening of the fissure. The La Rose vein or group of veins appears to be of this character.

On the other hand there are usually many minor irregularities in both the horizontal and vertical courses of the lines of dislocation, and at any new movement of the walls there would be a fresh breaking up of the materials which had accumulated along these lines and new spaces would be formed for further mineralization. This repeated brecciation has resulted in what we now see in the openings made on these lines of disturbance. Both the vein matter and the wall rock are much split and broken up; dislocated fragments are cemented together again along lines of small faults and there are many miniature horses surrounded with the cementing gangue. Secondary dislocations, branching from the main ones, are often rich in silver, which may also penetrate into the shattered wall rock and form a body of rich ore, even if the vein matter be of insignificant amount or altogether wanting. The foregoing explanation of the formation of the mineralised zones and of the mode of occurrence of the silver in the Cobalt district was given in the writer's report on the district, published in the Summary Report of the Geological Survey for 1905.

The volcanic nature of the fragmental rock of the Cobalt district is manifest both in fresh fracture, and on every weathered surface. One of the localities where this is particularly convincing is the south-facing slope of the hill near openings 12, 13, 15 and 21 of the Nipissing Mines Company and not far from the power house at the shore of Peterson Lake, on lot R L 404. Here the rocks have been well exposed by recent hydraulic washing and show very distinctly their volcanic or plutonic character. Areas of different varieties of diabase and agglomerate are mixed together and cut by dykes which have evidently been formed before the masses which they traverse had been completely hardened by cooling. At the contact, some of the dykes became fused or amalgamated with the rocks they penetrate and have no sharp line of division. The smaller dykes are in some instances broken and interrupted, as if by the movement or flow of the semi-fluid mass into which they had been intruded. The weathered surfaces of different adjoining small areas of the diabese present different shades of colour and different degrees of texture. Some of the brecciated parts show large inclusions; some are irregularly charged with the brecciated debris, while other parts are quite free from it. A cherty rock, having lines of foliation, is associated with the foregoing. A few small veins containing smaltite and argentite traverse the diabase and the agglomerate at this locality. Lines showing limited faulting or dislocation also occur in these rocks.

Up to the present time, twelve or more different metals, either native or combined with one another or with other elements, have been found in these rocks, and this fact alone would point to an igneous rather than a sedimentary origin of the matrix.

In connection with the supposition that some of the rocks of the Cobalt district may be correlated with those which have been called Keewatin, at the Lake of the Woods, and the unfounded theory that the Keewatin rocks are not argentiferous, the fact may be mentioned that the leading feature of these rocks at Lake of the Woods is the prevalence of greenstones, having a concentric spheroidal structure. On the Lawson property, which lies immediately south-west of Kerr Lake, the writer found, near the centre of the lot, an exposure of a dark greenish gray, rather fine-grained diabase, having a conspicuously concretionary structure. The cross-sections of the spheroids are nearly circular and vary from six inches to three feet in diameter, the average being two feet. This rock is here cut by a well defined vein of smaltite with silver, and several other silver-bearing veins occur in the immediate vicinity.

The foregoing conclusions as to the Cobalt district have not been formed as the result of a single trip to the camp, but have been gradually matured by five different visits to the district. There is a great advantage in paying repeated visits to any locality of geological interest. In the intervals between examinations one has time to think over what he may have seen and to consider points on which he requires further evidence in order to clear up uncertainties or doubts.

DISCUSSION.

DR. ROBERT BELL—I listened with intense interest to Prof. Van Hise's paper, especially from the fact that we have not exchanged a word in regard to this subject. I have not spoken to him nor he to me about the subject of his paper and yet, in regard to many points, not all, I agree substantially with what he has said. My views, which are the essential part of my paper, were set forth in my report of the Geological Survey for 1905, and again to some extent in 1906. I have visited the district five times, and have had abundant opportunities to make observations, and although I differ from some geologists, it is a matter of opinion which is susceptible of discussion, whom may be right. In regard to this district I may say that it was not neglected by the Geological Survey of Canada, although the Geological Survey of Ontario has been more in evidence in regard to it since; but immediately after the discovery in 1903, which was made known in November, and it was impossible to do anything that winter, I corresponded with Prof. Parks and arranged with him to commence a regular survey of this district in the spring of 1904. Prof. Parks went up there about the same time as Prof. Miller, and after they had worked together for some weeks, Prof. Miller wrote to me to say that it was a pity to duplicate work on the same ground, and if I would ask Prof. Parks to move on northward, that his own work would be at our disposal, and equally Dr. Parks' work would be at his disposal, that the two would operate in harmony, and the work would be to the credit of the

Geological Surveys in common. At that time the country was not known as well as it is now, and it was thought that the Cobalt rocks might belong to a formation equivalent to the silver-bearing rocks of Thunder Bay. Therefore, I agreed, on the strength of Prof. Miller's letter, that Prof. Parks should work northwards and throw light on the whole subject generally, while Prof. Miller was to work in detail in the district which he has so well done, and that his results were to be at our disposal at any moment. I merely mention this to show that the Geological Survey began work there at the earliest moment, and that we have kept up observations there ever since. Mr. E. D. Ingall, Dr. Barlow, myself and others of the Department have been there repeatedly, and we have made important observations, I think, basing the work as to the geological map on Prof. Miller's labors.

PROFESSOR PARKS—Dr. Bell has referred to my work in the region lying to the north and east of Cobalt, if the members are at all interested I might briefly describe the conditions as I found them in that region. The recent Larder Lake rush has made us all familiar with the geography of the district I refer to, we all know that a small chain of lakes leads off to the north-east from the Abitibi Branch of the White River and gives access to Larder Lake. To the south and east of this chain of lakes there is a large area of Lower Huronian rocks which extends to the Height of Land and beyond into Quebec. The great hills of the divide are composed of this series, notably the so-called Swinging Hills and the peculiar mountain known to the Indians as Chaminis. This hill rises 750 feet above Larder Lake and exposes a vertical section of hundreds of feet of slate quite similar to that at Cobalt. The upper 50 feet or so is likewise a conglomerate of the same character as the Cobalt example. I have always held that the presence of the proper diabase or gabbro is the first requisite in prospecting for silver and cobalt in this country. We do not find any considerable basic eruptions towards the Height of Land, but to the south of Windigo Lake, extending into the township of Ingram and Pense, are large exposures of a diabase very similar to the masses in the vicinity of Cobalt. These basic rocks are undoubtedly in the form of sheets, as Professor Van Hise has just shown to be the case at Cobalt. In the Township of Pense, large masses of diabase are to be seen overlying slate, and where valleys are eroded through the rocks, one can find the contact at practically the same level on the different hills. It is interesting to note that towards the east of the diabase and at points in the second and third concessions of Pense, one finds a conglomerate of a very different character, being composed of large fragments of felsite in a rather light colored matrix. This conglomerate is notably coarser than the Cobalt variety and is also distinguished by the complete absence of Keewatin fragments. About the middle of the township there is exposed a narrow band of felsite from which the boulders in the conglomerate were doubtlessly derived.

Where the large diabase laccoliths lie over the slate, one is unable to find a sharp contact as the two rocks fade into each other. Even under the microscope, one is in great doubt as to whether the specimen is an eruptive or clastic rock. It is possible that the slate (really an ash rock) is of the same ultimate composition as the diabase and the baking consequent upon the eruption has rendered the border of the slate indistinguishable from the finer border of the diabase mass. It would be interesting to have complete analyses of the two rocks. The important economic bearing of these remarks lies in the fact that the diabase is extensively cut by veins of quartz and calcite showing in many places large quantities of Cobalt bloom. I am not aware of any silver being yet found in these veins. Now the question arises—Does the occurrence of Cobalt bloom in these veins, occurring as they do under conditions so similar to the veins in Coleman, justify attempts at development, or are all such attempts to be classed as wildcats? Here comes in the application of Professor Van Hise's theory as to the secondary nature of the silver. There is no doubt that secondary enrichment has produced the rich tops at Cobalt as Professor Van Hise has so well shown. But if we return to the original deposition of the two metals I question if the silver is always secondary. There are veins at Cobalt where the silver is so intimately connected with the smaltite as to make its secondary nature extremely doubtful. Further, in the La Rose mine I have seen idiomorphic crystals of calcite with silver penetrating the mass of niccolite. If the calcite and the silver is secondary to the niccolite how is it that the former mineral retains its idiomorphic outline? The whole question teems with economic importance. I believe Professor Van Hise admits that the secondary silver was derived from the same vein. How about the original deposition of the two minerals?

PROF. VAN HISE—I agree with what has been said as to the indications that the silver did come from the diabase somewhat later than the cobalt.

PROF. PARKS—Do you think there is any economic justification in spending money on a vein which shows only a small quantity of cobalt?

PROF. VAN HISE—I would hate to answer that question without seeing the deposit. (Laughter). That depends on so many circumstances—the association, the relation of the rocks—that I would not be able to give a categorical answer.

DR. BELL—What reason is there for saying there are only two concentrations? Might there not have been several, in accordance with the view I have expressed, that there were repeated dislocations, and localizations through each?

PROF. VAN HISE—Three, certainly there might very well have been.

DR. BELL—Four or five. Is there any line to mark off two?

PROF. VAN HISE—I think there were two, in all probability three, and there may have been more.

DR. BELL—Have you noticed that the silver is intimately embedded in the smaltite in large flakes? In this hotel down stairs there are two or three masses which show little grains of silver particles of nuggets of silver in the very midst of that smaltite. Would that be consistent with a double secondary deposition of silver after the smaltite?

PROF. VAN HISE—We do not know that the solutions did not enter in cracks now closed by cementation.

DR. BELL—They seem to be regularly distributed through the smaltite.

RICHNESS OF COBALT ORES.*

By Dr. Albert R. Ledoux, New York.

I have been asked by several members of the Institute what is the grade of Cobalt ores, as determined by my sampling works in Jersey City. Since January, 1905, we have handled at our works 366 carload lots of this ore, and 52 other lots— ess than carloads—including what we call nuggets, the nuggets either coming separately consigned or as part of a carload. I do not feel at liberty to state the assays of any particular lots of nuggets, as there have been some delicate questions concerning the value of some of these "Bonanza Shipments." These nuggets, as you are aware, are not pure silver, but run anywhere from 700 parts to 870 parts of silver in the thousand. There are more or less gangue and other minerals associated with the silver, and the metallic silver itself, visibly free from gangue, runs about 950 fine.

Leaving out of consideration the nuggets and native silver, and including only the lots of regular ore, a review of 394 lots sampled, shows that the highest lot ran 7402 ounces of silver to the ton, the next in order being 6909, 6413, 6163 and 5948 ounces per ton. In the 394 lots we found:—

Over	6000	ozs.				4	lots	(say)	1%
Between	5000	"	and	6000	ozs.	3	"	"	0.75%
Between	4000	"	"	5000	"	12	"	"	3%
Between	3000	"	"	4000	"	17	"	"	4.25%
Between	2000	"	"	3000	"	39	"	"	10%
Between	1000	"	"	2000	"	72	"	"	18.25%
Between	900	"	"	1000	"	11	"	"	2.75%
Between	800	"	"	900	"	7	"	"	1.75%
Between	700	"	"	800	"	12	"	"	3%

* The above formed the subject for a brief address by Dr. A. R. Ledoux, following the reading of papers on the Cobalt District at the Toronto meeting, 1907.

Between	600 oz.	and	700 ozs.	21 lots	(say)	5.25%
Between	500 "	"	600 "	10 "	"	2.5%
Between	400 "	"	500 "	13 "	"	3.25%
Between	300 "	"	400 "	20 "	"	5%
Between	200 "	"	300 "	44 "	"	11.25%
Between	100 "	"	200 "	66 "	"	17%
Less than	100 "	"		43 "	"	11%

You are of course aware that while the greater part of shipments of cobalt have come to New York, some have gone abroad and many have gone to Copper Cliff.

It seems to me that this is a remarkable showing for a camp so young as Cobalt, the first car having reached our sampling works about the first of February, 1905.

Silver, of course, in point of value, is the more important element. The highest percentage of cobalt found in any one shipment is 11.96%, the average being 5.99%. The highest assay for nickel in any car is 12.49%, the average being 3.66%. The highest percentage of arsenic is 59.32%, the average, 27.12%.

DISCUSSION.

Mr. CAMPBELL:—Could you tell us, in the case of these nuggets and of the silver, what it was which makes them less than one thousand fine?

Dr. LEDOUX:—There are mixed up with the nuggets other minerals; sulphides, arsenides, etc., and the gangue matter. We have paid no attention as to what reduces the fineness of the native silver—we do not know what it is.

THE SMELTING OF COBALT ORES.

By Hiram W. Hixon, Victoria Mines, Ont.

(Toronto Meeting, 1907).

The smelting of the cobalt ores and the recovery of the valuable metals has proven a difficult problem. This paper is submitted with the object of inducing the smelting of these ores in Canada.

Miners, being by nature suspicious of smelters who will not pay the full market value of the metals, have attempted to treat their ores with the hope of recovering greater profits. The success of this plan is doubtful as the many conflicting interests would naturally become restive unless immediate results are obtained and cash returns follow the shipments of ore.

The nature of the problem will not admit of such results, and the time necessary for the treatment of the ores as well as their great value necessitates a locking up of a large amount of working capital. This is not satisfactory to the average mine promoter who wishes to pay dividends on a large capitalization in order that he may sell stock to the public and get rich quick from the profits on the stock.

The writer's experience in custom smelting business suggests a system of smelting these ores based on well established principles, which is herewith submitted:

1st: The ores should be sorted and the metallic silver separated for direct smelting by cupellation with lead or melted in crucibles and poured into bars to be sold to refiners.

2nd: The ore should be ground in a dust proof ball mill to such a fineness that it can be accurately sampled.

3rd: The ground ore should be roasted in a suitable furnace to expel the arsenic and sulphur.

4th: The gases from this roaster should pass through a long sheet iron dust chamber to cool it and then be passed through a bag house where all the dust and volatilized arsenic will be recovered.

5th: The roasted ore should then be briquetted with a strong bond of red clay and lime water and dried or frozen, after which it should be smelted in a blast furnace with about an equal weight of galena or lead concentrates containing about 50 to 60% lead. The necessary iron and lime would have to be added to the charge to produce a slag of the proper composition.

The sulphur for matte formation would be supplied by the galena and the arsenic remaining in the ore will form some speiss.

The base bullion resulting from this smelting to be sold to lead refiners, or refined to separate the silver.

The matte and speiss will contain all the nickel and cobalt that can be recovered from the first smelting and also some lead and silver. This matte and speiss should be accumulated until sufficient for a special run and then ground in the ball mill, roasted and smelted separately with more lead to free it from silver. The resulting bullion to be sold or refined.

The second matte should be run into a converter and converted to free it from iron. In the process of converting, the lead and most of the cobalt, will oxidize at the same time as the iron and go into the converter slag, except that portion of the lead which is volatilized along with the remaining arsenic. This will pass off with the flue gases and should for safety be passed through the bag house as they are both poisonous.

The converter slag will, therefore, contain the greater portion of the cobalt as oxide, and in order to recover, it should be re-smelted in a separate blast furnace along with a portion of the briquetted flue dust from the roasting of the ore.

The flue dust highest in arsenic should be used, as the recovery of the cobalt would depend upon the formation of a cobalt speiss or arsenide of cobalt.

This would be separated from the slag in the same manner as the matte and its further treatment for cobalt would be by chemical methods after roasting to expel the arsenic, which should be recovered in the bag house in the same manner as first described.

The flue dust containing arsenic would have to be roasted separately to sublime the arsenic which should be recovered in a separate flue and bag house provided for that purpose.

The arsenic would be marketed as white arsenic, and great precaution would be necessary to provide against poisoning.

By the scheme outlined, the silver would be produced either as silver or in base lead bullion.

The nickel would be produced as high grade nickel matte containing some cobalt suitable for further refining by the Orford, Mond, or other processes, the cobalt would be produced as cobalt speiss, and the arsenic as white arsenic.

As regards the percentage of metals that could be recovered by all these various smeltings and resmeltings, it is not possible to make any statement based on actual results.

The smelters who have bought these ores have not seen fit to give out any information, but the fact that they have allowed nothing for nickel, cobalt or arsenic is significant. To make even an attempt at a partial recovery of each of the metals, is a long, tedious process and the most complicated, from a metallurgical standpoint, that has been presented for solution. Under these conditions any association of miners attempting to smelt their own ores are hardly likely to succeed.

For the economical working of this plan, the smelter should be located at North Bay, where lead concentrates from the western mines can meet the ores. A working capital of at least half a million dollars would be necessary and the plant would cost at least two hundred thousand ($200,000.00) dollars.

THE NEW TILBURY AND ROMNEY OIL FIELDS, OF KENT COUNTY, ONTARIO.

By Eugene Coste, E.M., Toronto.

(Toronto Meeting, 1907).

Oil was first struck in the new Tilbury field in December, 1905, on the John Kerr farm in the north-west part of lot 10 of the Middle Road, North Range of the Township of Tilbury East, in the County of Kent, Ontario. The first well was drilled by the Acme Oil Company of Detroit. This company had been operating unsuccessfully in the narrow Leamington pool in the adjoining county of Essex. Before finally abandoning its venture in oil it decided to take another chance, and this time of a purely "speculative" nature, as the location selected was in an entirely new and undeveloped territory. As luck would have it, it turned out to be a winning throw. At the depth of 1,360 feet a rather strong gas vein was struck; then another at 1,375 feet; then the first oil pay with more gas at 1,385 feet; then a second oil pay at 1,410 feet and a third one at 1,430 feet. A little below that some salt water was found and the drilling was stopped at 1,450 feet. The well after the shot started to flow at the rate of 40 barrels of oil per day, the gas being quite strong, about half a million cubic feet per day.

The second well was drilled in at the end of March, 1906, on the Janes farm about three-quarters of a mile south-west of the first well. It struck gas and oil at about the same depths, but it proved to be a small well, not starting at better than eight or ten barrels per day after the shot.

The third well was completed on April 6th, 1906, on the J. Smith farm, half a mile south-east of the first well, and it started at the rate of sixty barrels per day after the shot; the first gas was struck at 1,363 feet and the first oil at 1,393 feet; the second oil at 1,418 feet and the third pay of oil, which was the best, with some salt water, at 1,430 feet.

A great many other wells followed rapidly thereafter, and to date not less than 150 wells have been drilled. These prove that the good oil territory of the Tilbury field extends at least over an area of two miles east and west by five miles north and south and the limits of the field to the south and north are still unknown. Only three or four dry wells have as yet been encountered over that large area of 6,400 acres, and a number of very good wells (century wells) have been struck. The largest of these is the A. Simard well of the Central Oil and Gas Company in the north-west part of the field, as at present developed, which started to flow naturally, that is without being shot, at the rate of 1,500 barrels per day of fluid, 1200 barrels of which were salt water and 300 oil. This well is now over two months old and is still flowing naturally about 200 barrels of salt water and 50 barrels of oil per day. The oil, water and gas were all struck at the same time at a depth of 1,445 feet. Only about 150,000 cubic feet of gas per day having been reached at the depth of 1,436 feet.

Large gas wells have also been struck in this field, the largest being the Volcanic Oil and Gas Company's well on the David Halliday farm in the north west part of Lot 1 in the Sixth Concession of the Township of Raleigh, which adjoins the Township of Tilbury East to the north-east. Gas was struck at 1,417 feet, drilling being stopped at 1,421 feet in the middle of the gas pay, as the well was then measuring seven million cubic feet per day of dry gas. It was tubed with 3 inch tubing, packed with a Dresser packer and closed in on the 16th of September, 1906. The regular rock pressure of the closed-in gas was 650 lbs. to the square inch.

The gas from this well has since been piped to the city of Chatham, ten miles distant, where it would now be sold for 15c. and 25c. per thousand cubic ft., if, instead of facilitating the advent of such a cheap and incomparable fuel, an antiquated law known as the "Gas Inspection Act" (which declares that there should be no trace of sulphuretted hydrogen in any gas used for illuminating purposes) had not prevented its use by the people of Chatham for the greater part of this winter. Backed by the provision of this old law some of the aldermen of the city of Chatham entertained the idea that this natural gas from the Tilbury field, which certainly contains some sulphuretted hydrogen as evidenced by the smell of it, would poison the Chatham consumer. The writer mentions this matter here as he believes that it is the first time on record that this question of the supposed poisonous nature of natural gas has been raised on the introduction of it into a city. At the instance of the City Council of Chatham this natural gas from the Tilbury field has just been analysed by Prof. E. B. Shuttleworth of Toronto, with the following results:—

Hydrocarbons, principally methane	92.20
Carbon dioxide	1.40
Oxygen	Trace.
Carbon monoxide	0.21
Hydrogen	0.40
Nitrogen	5.59
Sulphuretted hydrogen	0.20
	100.00

which compares as follows with the natural gas from Ohio and Indiana, according to analyses published by the late Prof. Edward Orton in his Geology of Ohio, volume 6, page 137:—

TABLE OF ANALYSIS OF NATURAL GAS FROM OHIO AND INDIANA.

GAS	1	2	3	4	5	6	7
Hydrogen	1.89	1.64	1.74	2.35	1.86	1.42	1.20
Marsh gas	92.84	93.35	93.85	92.67	93.07	94.16	93.58
Olefiant gas	0.20	0.35	0.20	0.25	0.49	0.30	0.15
Carbonic oxide	0.55	0.41	0.44	0.45	0.73	0.55	0.60
Carbonic acid	0.20	0.25	0.23	0.25	0.26	0.29	0.30
Oxygen	0.35	0.39	0.35	0.35	0.42	0.30	0.55
Nitrogen	3.82	3.41	2.98	3.03	3.02	2.80	3.42
Sulphuretted hydrogen	0.15	0.20	0.21	0.15	0.15	0.18	0.20

LOCALITIES.

1. Fostoria, Ohio.
2. Findlay "
3. St. Mary's "
4. Muncie, Indiana.
5. Anderson, "
6. Kokomo, "
7. Marion, "

It will be seen from the above analysis that, so far as the sulphuretted hydrogen is concerned at any rate, there is absolutely no difference between the Tilbury field gas and the Ohio and Indiana gas taken at a number of places widely scattered over these two States and where it has been used for all purposes without the slightest harm to anyone for a great many years by thousands of people. It is clear, therefore, that our gas inspection act is onerous and needs to be amended to permit in Canada the use of natural gas for domestic and other purposes, as unrestrictedly as it is used in the United States. It is clear, also, that the City Council of Chatham has been altogether too particular in its acceptance of so well and so favorably known an article as natural gas.

The oil of the Tilbury field also contains some sulphur which gives it a strong odour peculiar to the crude oil known in the States as "Lima" oil. It is a dark green in color, of 38 to 41 degrees Baume gravity, and belongs to the same class as the Lima, Ohio, the Indiana, and the Petrolia and Oil Springs, (Ontario) oils. It is bought from the producer at the present time only by the Imperial Oil Company of Sarnia, Ont. This company has established a pumping station and tankage in a central part of the field, from which it pumps the oil through a 4 inch and also through a 2 inch line owned by them to Merlin, Ont., on the Père Marquette Road, four and a half miles distant. From there the oil is taken over that road in tank cars of the Imperial Oil Company to their large refinery at Sarnia. The oil is bought by the Imperial Oil Company at the tanks at each well and they pay at present for it $1.14 per barrel. After the oil has been accepted and the tank has been guaged, the oil is run by means of a donkey pump through 2 inch lines owned by the Imperial Oil Company to their tanks erected at the central station. The well tank is again guaged after the run and the difference in the two guages gives the amount of oil sold, for which the Imperial Oil Company gives the producer a run ticket and also a voucher ticket in order to enable him to collect the Government bounty of 52½c. per barrel. The total price, therefore, at present obtained by the producer for his oil is $1.66½ per barrel, less the royalty, generally ⅛ to the owner of the land, the oil and gas rights of which are generally only leased by the producers. Two years ago, before the Dominion Government removed the import duty protecting Canadian crude oil, the average price of it in Canada was, for the previous year, $2.12. By the bounty system, therefore, versus the duty, system, the net result is a loss to the oil producer of $2.12 less $1.66½ or 45½c per barrel, and another loss to the Dominion Government of 52½c. per barrel, while the refining companies make all the gain, which I am not aware that they share with the consumer. With the duty removed they can now obtain their crude oil cheaper from the States, so much so that the Canadian Oil Company, the only independent refiner now in Canada, gets all its supply of crude oil from Ohio and, the writer believes, buys no Canadian oil from any of the fields, certainly none from the Tilbury field. The price of Canadian oil is therefore governed and controlled by the American market, while the Canadian producer operating in the deep fields is at a disadvantage in being called on to pay a heavy duty on his drilling outfits, machinery, cordage, tubing, lead lines, etc. As mentioned above the oil in the Tilbury field is in a deep sand (about 1,400 feet) and consequently all the drilling done there is done by the American cable tool system; the Canadian pole tool system being too slow and not suitable for wells of that depth. These American cable tool outfits cannot be obtained in Canada, nor can the 1,500 lb. test 2 inch tubing and other 2 inch high pressure lines which the Tilbury field producer must have, and on all of this he must pay a heavy import duty. It is quite clear, therefore, that the Canadian deep oil producer would receive greater encouragement to test and develop deep oil fields in Canada if he had no duty to pay on his materials, which he necessarily imports from the States; and if the price of his product was protected by an import duty on American crude oil instead of as present receiving a bounty on his product from the Dominion Government which he practically returns in the form of duty on his equipment, while at the same time his price is slaughtered in competition with cheap American crude oil.

Geology.—The Tilbury oil and gas field lies under a flat drift covered section of the country, the elevation of which is about 600 feet above the sea. The drift is about 150 feet thick in the south end of the field and about 100 feet in the north end, and is composed of boulder clay on the top and sands and gravels varying very much in thickness below. The first strata struck under this drift are the grey blue shales of the Hamilton or Middle Devonian formation—the so-called upper soap stone or soap of the Petrolia driller; then comes the middle lime and the lower soap of the same formation followed by the Corniferous or big lime of the Lower Devonian, which is struck at depths ranging from 230 to 285 ft., and is about 150 feet thick. Below this are the Dolomitic lime stones with flint and gypsum of the Onondaga, or Upper Silurian, a little more than 1,000 feet thick; then comes the Guelph and Niagara, Silurian dolomitic limestones in which, so far, the drilling of the wells has been stopped, but it is likely that, in future in some parts of that field or not far from it, the wells will be drilled deeper still and will obtain their gas and oil either from the Clinton limestone immediately underlying the Guelph and Niagara and about 150 feet thick in that section of the country, or from the still deeper strata of the Trenton limestone lying about 900 feet under the Clinton from which it is separated by the Medina, Hudson River and Utica soft shales, which can be drilled through very quickly and cheaply.

The gas and the two upper oil pays in the southern part of the field are found in the lower brown dolomites and gypsum of the Onondaga, while the lower oil pay is struck in the upper beds of the Guelph and Niagara. In the north end of the field, north of the Michigan Central Railway, the lower beds of the Onondaga are barren of oil, which is there altogether found in the Guelph, but the gas is still found there in the lower beds of the Onondaga in the strata which form the first and second oil pays of the south end of the field. In the east middle part of the field on the other hand, the oil is struck in the Onondaga strata which constitute the gas pays in many of the wells of the middle western part of the field, such for instance as at the J. W. Campbell No. 1 well of the Central Oil and Gas Company, the log of which is here appended:—

LOG OF THE CENTRAL OIL AND GAS CO. WELL No. 1 ON THE J. W. CAMPBELL FARM (S.E. corner of Lot 6, in the IX Concession of the Township of Tilbury East, Kent County, Ont.) Elevation 600 feet. A.T.

Formation	Description of Strata	Thickness feet	Depth feet	Remarks.
Drift.	Boulder clay.	95 to	95	
	Grey sand.	5 to	100	A little gas.
	Clay and gravel	28 to	128	10″ drive pipe to 138 ft.

Formation	Description of Strata	Thickness feet	Depth feet	Remarks.
Hamilton	Blue clay shale (upper soap)	37 to	165	
	Middle lime	10 to	175	
	Blue clay shale (lower soap)	67 to	242	
Corniferous or Big Lime	Yellow limestone	158 to	400	8″ casing to 243 ft. A show of oil at 250 ft.
Onondaga	Grey, drab, brown and blue dolomites with gypsum and flint (shaly, series with darker shaly dolomites and more gypsum from 835 to 1185)	1020 to	1420	$6\frac{1}{4}''$ casing to 835 ft. Gas at 1250 ft., 1362 ft., 1370 ft., 1376 ft., 1382 ft. Oil at 1392 to 1400 ft. and at 1416 ft.
Guelph	Blue, white dolomitic limestone	9 to	1429	Oil at 1426 ft.

A little gas is also often found in this field in the sand or gravel at the bottom of the drift, also in the upper part of the Corniferous in some of the wells, while in other wells some gas and a little oil were found in the upper beds of the Onondaga between 500 and 600 feet. There is also another vein of gas in some of the wells at about 1,250 to 1,280 feet in the Onondaga, all of which shows the adventitious nature of the gas and oil in the different porous strata or reservoirs of this field which does not in this differ from many other oil and gas fields. This fact, as I have shown in one of my papers before this Institute (The Volcanic Origin of Natural Gas and Petroleum, Vol. 6 of the Journal of the C.M.I.) that gas and oil always impregnate the porous portions of the great thicknesses of strata from the Archean to the drift many of which strata are very impervious, constitutes one of the very strong proofs of the volcanic nature of these products. For other proofs of the volcanic origin of oil and gas, reference may be made to the above mentioned paper, the arguments in which have not yet been successfully refuted.

The Romney oil field, or rather pool, as it is yet only about three-quarters of a mile long and only a few hundred feet wide, is situated some seven miles south-west of the Tilbury field in the north parts of Lots 21, 22 and 23 in the IV Concession of the Township of Romney, Kent County, Ont. It is only a few months old and there are now seven producing wells in it, several of which came in as very large wells, making each over 1,000 barrels per day of oil. The oil is struck at the shallow depths of 200 to 270 feet, in the upper part of the Corniferous formation or Big Lime, the top of which is struck there at 180 feet. The oil is heavier than the oil of the Tilbury field, about 28 to 30 Baumé. It is piped and shipped from Coatsworth station on the Père Marquette to the Sarnia Refinery of the Imperial Oil Company, which now pay 84c. per barrel for it at the wells.

Five miles further south-west again, in Lot 11 of the 2nd Concession of Romney, oil was struck some few years ago in the Guelph formation at 1,290 feet. The wells were pumped for quite a while but abandoned on account of their making too much salt water with the oil.

It will be seen from the facts presented above that a great many other interesting oil and gas developments are to be anticipated in the near future from this district, and in fact from many parts of the County of Kent and of several of the neighboring counties.

DISCUSSION.

MAJOR CURRY.—Will Mr. Coste inform us why the presence of sulphuretted hydrogen in the gas should be penalised.

MR. COSTE.—The law referred to is a very antiquated one. Under the British law standardizing gas it was provided that coal gas should contain no trace of sulphuretted hydrogen ; and when some years ago legislation was introduced in the Canadian Parliament relative to natural gas, this provision was included without reason or proper consideration. Natural gas had been used on this continent for many years by thousands of people for lighting and heating purposes, at the time this Act was passed, and its absolute safety had been clearly demonstrated. The presence of sulphuretted hydrogen in natural gas to the extent of two-tenths of one per cent. is of course entirely harmless.

CANADIAN GRAPHITE.

By H. P. H. Brumell, M.E., Buckingham, Que.
(Toronto Meeting, 1907.)

Of the many useful minerals of common occurrence and wide distribution in Canada, probably less is known of graphite than any other, yet in a quiet and unostentatious way there is being developed an industry in this mineral that promises, in the near future, to be of no small importance to the Dominion. Already there are several companies busily at work with the expectation of producing considerable quantities during the present year. Unfortunately with regard to the higher grade of graphite, (the so-called flake or crystalline quality,) the business becomes a milling rather than a mining one as the ore is usually a disseminated one requiring expert knowledge and special machinery. In the latter respect careful experiment has been required, and the present apparent success has only been won by large expenditure of both time and money.

The industry, which dates back to about 1860, has until very recently not been successful in this country, although with leaner ores it has been profitably conducted in the United States for many years, notably by The Joseph Dixon Crucible Co., the pioneers, on this continent, in the production of graphite from low percentage ores. They began operations as early as 1827.

Character of Graphite.—This mineral, which is according to locality, termed graphite, plumbago or black-lead, is essentially a crystalline form of carbon, although its occurrence in that form is practically unknown. It has a specific gravity of from 2.09 to 2.29, according to the percentage of impurity almost invariably found with it; is steel-grey to black in colour; feels greasy; lustre, in the crypto-crystalline form, metallic; laminæ thin, flexible and inelastic. The impurities referred to above are usually some form of iron or calcite, while in an ore mined at Calabogie, Ont., the foreign substance is almost invariably one or other, as yet undetermined, of the chlorite group. For commercial purposes and those of this paper the mineral may be divided into three groups, viz.: anthracitic, amorphous and crystalline, the last being again divided into "vein" and "disseminated" ores. Of the anthracitic variety there is a comparatively large deposit near Lepreau Harbour, on the Bay of Fundy, N.B., while the amorphous is found at a number of points in Nova Scotia, New Brunswick and Ontario. The last and most important variety is found, in commercial quantities, to a very great extent in the Archæan rocks lying to the North of the Ottawa River and to a smaller extent in these rocks in Eastern Ontario. Although widely distributed over large areas of both these provinces the most important deposits of economic value in Quebec are confined to the counties of Labelle and Argenteuil, while in Ontario the counties of Lanark and Renfrew show a considerable development.

As to the relative value of disseminated and vein ores the writer has always held that the advantage has lain with the former variety by reason of its uniform character and continuity of deposit. Experience in the mining of both has proved this, and the writer is upheld in his opinion by the late H. G. Vennor, who, in the Report of the Geological Survey, 1873-74, writes:— "Pure as is this vein-form of graphite, my experience shows that it is to the bedded deposits of this mineral that we must look for our chief supplies, and in this opinion I follow Sir William E. Logan, who, in the report already cited, says:—'The veins of this mineral hitherto found in the rocks of this country, although affording a very pure material, appear to be too limited and too irregular to be exclusively relied on for mining purposes, which should rather be directed to making available the large quantities of graphite which, as we have seen, is disseminated in certain beds.' Such beds are particularly well developed in the portion of Buckingham examined, as well as in the contiguous township of Lochaber."

Distribution.—It has not been thought necessary for the purpose of this paper to go very deeply into the geographical distribution of this mineral as very good descriptions of most of the known deposits may be found in the reports of the Geological Survey of Canada; nor is it necessary to go into its geological history for the same reason. Speaking generally, the only deposits of value are confined to rocks of pre-Cambrian age, the mineral being found usually in the Grenville series, or upper beds of the Laurential system. Certain less important deposits of amorphous ore are occasionally met with in rocks of Devonian or lower Carboniferous age.

It may not be amiss to quote here a brief but very interesting description of the occurrence of graphite in Ceylon. This description constitutes part of the report of Mr. Joseph Hyde Pratt on Graphite in the "Mineral Resources of the United States" for 1904:—"The bulk of the world's supply of the crystalline graphite is obtained from the island of Ceylon. These deposits are located in the western and south-western portions of the island, the mineral area in which the graphite occurs being approximately 95 miles long in a north and south direction, with a width of 35 miles at its northern and of 43 miles at its southern end. The commercial graphite deposits occur in veins which traverse a garnetiferous granite rock. These veins vary in width from a few inches to 8 feet, and one has been followed to a depth of 720 feet; but from all accounts such a depth is exceptional. Horizontally the veins are very irregular and limited, and well-defined veins constantly pinch out. There does not seem to be any evidence of a main lode or series of lodes in any part of the district, but there appear to be two zones of the country rock, 4 miles and upward in width (the widest part being 20 miles), which seem to contain the veins that carry the graphite. These deposits have been described in some detail by Mr. George S. Stonier in a paper presented before the Institute of Mining Engineers of London, entitled 'Graphite Mining in Ceylon and India.' He states that horizontal veins seem to be entirely disconnected, and that not only is there no indication of a main lode, but that there does not seem to be even a series of connected lodes or veins. A vein four inches wide is considered as profitable mining. The largest mass of graphite which has been discovered in this district weighed nearly 6 tons. From the data at hand, Mr. Stonier considers that the fissures were formed first, and that the graphite, quartz, etc., were deposited in them. The graphite may have been introduced by sublimation not of carbons but of hydrocarbons, as is suggested by the fact that a deposition of graphite-like material is often found in the cracks of upper layers of coke made in the closed ovens."

"There are about 300 mines and quarries in operation, which, with the exception of 3, are all worked by the old native methods. Attempts have been made to work the graphite deposits by modern methods, but on account of the uncertainty of the occurrence of the graphite it has been found more profitable thus far to work the mines according to the old methods. This generally means that the graphite deposits are simply worked to water level. This is done by means of shallow shafts sunk 50 or 60 feet, the ore being hoisted in barrels and the mineral conveyed in boxes to the dressing sheds, where it is roughly picked and packed in barrels for transit to the shipping port, either Colombo or Galle. Here the graphite is re-sorted and screened, the larger pieces being broken up. In some cases the poorer portions are further concentrated by washing. It is then classified into five sizes, known as lump, ordinary, chips, dust, and flying dust, and these grades are further divided according to quality. It is estimated that Ceylon furnishes about 30 per cent. of the world's output of graphite and 75 per cent. of the value."

Origin.—Regarding the origin of graphite there has been no small amount of controversy, equally strong claims being set forth to prove an organic as those pointing to an inorganic origin. It is not considered necessary, nor within the province of this paper, to go into the subject deeply. Attention may, however, be drawn to two points, which, in the writer's opinion, would point to an inorganic genesis. First the occurrence of graphite in the silver veins on Silver Islet on Lake Superior. In his report on "Mines and Mining on Lake Superior" (Geo. Surv. Report, 1887-88) Mr. E. D. Ingall says:—"Graphite also occurs in considerable quantity and seems to be connected in some way with the occurrence of the silver. On enquiring of Mr. R. Trethewey as to what connection he had noticed between the existence of this graphite and the occurrence of the silver, with a view to ascertain its value as an indication, he told me that although they never had silver without graphite, they sometimes had graphite without silver." . . . . "In a specimen of the ore collected by myself are to be seen pieces of trap and graphite enclosed in pink spar, whilst in the graphite start out dendrites of silver." Secondly, and coming directly under the observation of the writer, and applying to practically all the deposits in Labelle county, is the fact that wherever the beds of disseminated ore are cut or in any way traversed, as they often are, by diorite, or other dykes, there is a very pronounced enrichment of graphite. At these points there is always an entire absence or marked lessening in quantity of calcic carbonate (calcite) and a very considerable quantity of calcic sulphate (selenite) while the pyrites is replaced by pseudomorphous ferric oxide. Without going into a lengthy argument on the above, might it not be concluded that under certain favorable conditions the calcite gave up part of its carbon, which was re-deposited as graphite, while the pyrites afforded the sulphur which, with the calcium, produced the selenite, leaving the iron to be resolved into ferric oxide. Again, all the known deposits, of vein graphite occur in intrusive masses of diorite or pegmatite. Prof. A. Osann of Mulhausen, Alsace, writes (Rep. Geo. Surv. 1899) :—"The occurrence of graphite at Graphite City is connected with the appearance of massive eruptive rocks which in mineralogical composition are very similar to those described in connection with the apatite occurrence." . . . . . "As far as I could see on my short visit, the occurrence of the graphite is connected with the contact of this eruptive rock with gneiss and granular limestone. The limestone is in these places very much altered; there has been especially a large production of scapolite, pyroxene and titanite."

In the limestones, as at Grenville and Calumet, the mineral occurs invariably, as segregated masses rather than in veins. In writing the foregoing, reference is made only to the occurrence of the mineral in pre-Cambrian rocks; the amorphous graphite of Devonian and lower Carboniferous age being very probably due to the carbonization of organic remains.

History.—The history of graphite may be given in but few words. Knowledge of the existence of the mineral in Canada antedates the birth of our Geological Survey, whose staff was, however, not long in taking cognizance of its existence. On 20th June, 1850, Mr. William E. Logan, later Sir William E. Logan, issued a circular letter from Toronto, asking for specimens for the

Grand Industrial Exhibition to be held in London the following year, and we find in the catalogue of the Canadian Exhibit, note of a specimen of plumbago from Lot 10, Range 5, Township of Grenville, Argenteuil County, Quebec, with the remark that there were two veins. Again in 1862, at the London International Exhibition, the Geological Survey exhibited specimens from Pointe du Chene, Grenville and Lochaber in Quebec. Shortly after, in 1867, work was begun in earnest and a small mill erected by the Canadian, afterwards the Montreal Plumbago Company, on a water power on Lot 28 in the Fifth Range of Buckingham Township, Labelle County, Quebec, the ore being obtained from Lot 28 in the Sixth Range immediately to the north and known as the "Castle" property. This mill was operated successfully until 1872, after which work was not carried on very actively, the only product being stove-polish, made from material previously mined and at the mill. In 1873, the mill was destroyed by bush fires and all operations ceased. Work at about the same time was being prosecuted on a pure lump vein by Messrs. Pew & Weart on lots immediately to the east and shortly afterwards a mill was erected in Lochaber Township on the Blanche River by the Lochaber Plumbago Mining Company, the ore to supply which being obtained from lots to the north, in the neighborhood of Long Lake. This mill proved unsuccessful, and after treating some 600 to 700 tons was abandoned. In reference to this mill and in general to graphite mining in the County of Labelle at that time Mr. H. G. Venner writes (Rep. Geo. Surv. 1876-77):—"From information gathered from several of the old settlers in this township, I learned that the mining operations had been conducted here in a most unsystematic manner, and this fact was borne out by the shape and position of many of the openings which had been made. Mr. Pearce, who acted as general mining captain for this Company, spent much of his time in devising plans for the mechanical separation of the plumbago from foreign matter, but with the exception of making some amusing mechanical toys, and adding greatly to the working expenses of the Company, accomplished but little. While Mr. Pearce thus experimented, each miner was his own mining captain, and as might have been expected, the greatest confusion prevailed until the Company suspended work. I mention these facts here to explain the true cause of the total failure of this mining enterprise in Lochaber, for the suspension of work at one after another of the plumbago mines in both Buckingham and Lochaber has greatly discouraged those who are interested in their development. In conclusion, I would remark that plumbago yet abounds in both Buckingham and Lochaber, and all that is requisite for its successful mining, is a cheap and effectual method of separating it from the impurities which are mechanically mingled with it." During 1875-76 the Dominion of Canada Plumbago Mining Company erected an extensive mill on Lot 19 in the 8th Range of Buckingham, which was in operation for some years. Lack of proper management and an over lavish expenditure of money, however, forced the Company into bankruptcy in 1879, when the extensive property was bought in and the business rehabilitated under the name of the Walker Mining Company, which continued somewhat intermittently to operate the property until 1895, when all work ceased. The property lay fallow until 1905, when it was taken up and has since been operated by the Buckingham Graphite Company. In 1890 a mill was erected on the Pew & Weart property, north of Donaldson Lake, on Lot 26, Range 6, of Buckingham. It was re-built in 1892, and continued to produce in a spasmodic manner until about 1900. In 1872 a mill was built and operated at Olivers Ferry, Ontario, with, it is said, considerable success, the ore being obtained from Lot 21, Range 6, Township of North Elmsley; details as to subsequent years are not available. This is, as far as is known, the only mill erected in Ontario in the early stages of the industry.

To come down to more recent years, the mill of the North American Graphite Company was built on Lot 28, Range 6, Township of Buckingham, in 1895, and in 1904, the mill of the late Walker Mining Company was entirely remodelled by the Buckingham Graphite Company. In Ontario, the mill of the Ontario Graphite Company was erected in 1902, and continued in operation for about a year when a cave in of the roof under Whitefish Lake flooded the mine and all work was abandoned. In the same year the Globe Refining Company erected a small mill at Port Elmsley, which is in operation, though not financially successful, it is said, at the present time. Two mills are at present being erected, one near Calumet Station on the Canadian Pacific Railway and another on the Lievre River, about six miles north of Buckingham, while extensive development work is being carried on at the Belle Mine, about three miles east of Buckingham. Rumor says that a mill will be erected on this property during the coming spring.

Crude ore has been, in the past few years, shipped from several points in Canada, the most important producers being the Ontario Graphite Company, who exported large quantities of amorphous ores, from their mine in Brougham Township, Ontario, previous to the flooding of their pit. Large quantities of a poorer quality of amorphous ore were shipped from Allanhurst in Ontario, and from St. John and Petitcodiac in New Brunswick, while a considerable shipment of flake or crystalline ore, was made from Grenville, Quebec, by the Keystone Graphite Company in 1900.

Methods.—Like many other industries not wholly proven, there is, in the treatment of the ore, a considerable amount of secrecy observed, which makes it very difficult to write with confidence of the various methods employed. Speaking generally of the earlier efforts at milling, it may be said that in all instances the operators used the old system of stamping: in point of fact, with the exception of the Pew & Weart mill, all mills were so equipped until 1902, when the first dry mill was erected by the Globe Refining Company at Port Elmsley, Ontario. This Company was followed, in 1903, by the Anglo-Canadian Graphite Syndicate of Birmingham, England, who took over the mill erected by the North American Graphite Company and re-built it on a dry principle, different, however, to that of the Globe Company. In the earlier mills, after crushing and stamping, concentration was had by stationary buddles and, in some of the earliest plants, by keeves. The concentrates, after drying, were put through a system of buhrstones and revolving screens, until they were more or less finished, the resultant products being then graded for the various markets for which they were intended. At the mill of the Globe Refining Company, while the writer has not personal knowledge, concentration is had, after crushing and rolling the ore, by means of the Krom Separator or pneumatic jig, after which the concentrates are bolted and only two grades made, all material finer than 60 mesh being discarded. The plant erected by the Ontario Graphite Company in Brougham Township, Ontario, is equipped with the old, and now obsolete, system of stamps and buddles; a treatment to which the ore does not readily lend itself. This ore is unique, in as much as that it is practically amorphous, carrying about 10% of crypto-crystalline or flake graphite, and as both varieties are similar in gravity, but a very poor separation is made. As the crushed and buddled ore had to be dryed after the so-called concentration and all the material in the buddles moved by hand, it will be seen that considerable extra expense was saddled on the finished product. The mill of the late Anglo-Canadian Graphite Syndicate, formerly the North American Graphite Company, was originally equipped with stamps and buddles but was, under the regime of the former company, remodelled and now contains Blake and roll-jaw crushers, between which the ore is dried by means of a cylindrical revolving fuel dryer. After coming from the roll-jaw crusher the ore passes through two sets of ordinary belted rolls, passing thence to a series of sizing screens fitting it for the dry pneumatic concentrators. The tailings from these machines are then treated on the Brumell concentrator, a wet separator which relies on the floating quality of graphite, when dry, upon the moving surface of a body of water. The resultant concentrates from this wet separator are then dryed by means of a revolving steam dryer when all concentrates are taken to the buhrstones by means of which, with the necessary accompanying screens and graders, the material is finished and ready for market. The mill of the Buckingham Graphite Company is equipped similarly to the foregoing, though its capacity is very much greater. In this mill the roll-jaw is replaced by a Gates rotary crusher and, in addition, a dry separator, known as the barrel concentrator, is used. In regard to the mills being erected at Calumet and Buckingham great secrecy has been observed, and it is only from hearsay that the writer is led to say that the methods to be employed will be practically the same as are now used at Port Elmsley, Ont.

Market.—Much has been said, in the markets of the world, with a view to creating a prejudice against Canadian flake graphite, and as the trade has always looked to Ceylon, and old established connections still hold with that country, it has been found no easy matter to introduce the Canadian product. However, as we are now putting on the market material of such high percentage and have always maintained an uniformity of product, we are gradually breaking down the barrier of prejudice and annually gaining ground in the open market. As illustrative of the purity of our finished material the following assays, made from stock, may prove of interest.

I.—By Milton L. Hersey, Montreal, from Anglo-Can. Synd. Mill.

II.—By A. E. Tucker, Birmingham, Eng., Anglo-Can. Synd. Mill.

III.—By Milton L. Hersey, Montreal, from Buckingham Graphite Co. Mill.

	I.	II.	III.
GR.	93.96	94.68	96.10
GA.	93.80	94.63	96.08
GP	94.14	94.24	93.60
GH.	93.94	94.49	94.90
GI.	93.50	94.04	96.51
GT.	92.74	93.16	81.16
GE	91.18	91.77	77.90
G12	.....	.....	78.08
No. 80	.....	.....	71.30

The foregoing stocks are of higher percentage than any other similar ones now on the market.

In his report on Canadian Graphite, Mr. G. C. Hoffmann (Rep. Geo. Surv. 1876-77) goes very thoroughly into the relative value of Canadian graphite compared with that of Ceylon, which is, and has always been, taken as par. In summing up his work, Mr. Hoffmann says: "From these experiments it will be seen that in respect to incombustibility the Canadian graphite may claim perfect equality with that of Ceylon; and that consequently—apart from any consideration of the proportion and nature of the associated foreign matter—it is in no wise inferior to the latter as a material for the manufacture of crucibles." In this report it will be seen that high percentage graphite was being produced, though not with financial success, as early as 1876, during which year the Dominion of Canada Plumbago

Mining Company produced and marketed a small quantity of the following grades:—

A0	For	electrotyping	82.31%
A1	"	lubricating	94.85%
A2	"	"	89.26%
A3	"	crucibles	92.35%
A4	"	"	94.30%
A5	"	"	95.59%
A6	"	"	96.36%

The following table, from the same report will illustrate the relative graphite values of vein graphite from Canada, Ceylon and Ticonderoga, N.Y. (the mines of the Joseph Dixon Crucible Company.)

Buckingham,	vein	graphite,	variety	foliated,	sp. gr.	2.2689	carbon	99.675.
"	"	"	"	columnar	"	2.2679	"	97.626.
Grenville,	"	"	"	foliated	"	2.2714	"	99.815.
"	"	"	"	columnar	"	2.2659	"	99.757.
Ceylon	"	"	"	foliated	"	2.2664	"	99.679.
"	"	"	"	columnar	"	2.2671	"	99.792.
"	"	"	"	foliated	"	2.2484	"	99.284.
"	"	"	"	columnar	"	2.2546	"	98.817.
Ticonderoga,	"	"	"	foliated	"	2.2599	"	96.656.
"	"	"	"	"	"	2.2647	"	97.422.

After careful experiment, Mr. Hoffmann prepared and incorporated the following table as illustrative of the relative combustibility of Canadian graphite when compared with that of Ceylon, the latter being taken as par.:—

Ceylon,	vein	graphite,	variety	foliated	1.00
"	"	"	"	"	0.99
"	"	"	"	columnar	1.01
"	"	"	"	"	1.25
Buckingham,	"	"	"	foliated	1.00
"	"	"	"	columnar	1.01
Grenville,	"	"	"	foliated	1.02
"	"	"	"	columnar.	1.12
Buckingham, disseminated					1.02
" "					1.01

Demand.—Generally speaking, the graphite industry has, for some years, shown a marked annual increase, due, largely, to the growth of electricity and consequent increased use of copper and its alloys, while, notwithstanding the introduction of open hearth steel, the demand for steel crucibles appears to increase. The average price, as well as the production, has also very materially increased as is evidenced by the fact that in 1895 the combined markets of the United States and Great Britain were 23,513 tons, valued at $1,199,772, or $51 per ton, while in 1902 (the latest figures available to the writer) the same was 34,474 tons, valued at $3,321,525, or $96.45 per ton, of all grades. The fact that high grade Ceylon "lump" sold in 1895 for from three to four cents per pound and is now selling for from six and a half to nine cents, according to quality, shows either a shortage or an increased demand. If all the mills now built, or in course of construction, were operating to their full capacity and turning out goods of high quality there would be no difficulty in disposing of their production, as there are in the United States alone crucible manufacturers enough to take all the high grade flake produced, while the stove-polish, paint, foundry facings, lubricating and electrotyping trades would easily look after the balance. Again there is a very large market in Europe, especially in London, Hamburg and Vienna. It may be of interest to know that the North American Graphite Company were, in 1895, very glad to get three and a half cents for flake, while the Buckingham Graphite Company are, to-day, getting for the same quality from six and a half to nine cents per pound. During 1902 only about one-tenth of the consumption of graphite in the United States was of domestic origin.

Mr. Joseph Hyde Pratt, in the "Mineral Resources of the United States" for 1904, gives the consumption of crystalline graphite, in the arts and manufactures, approximately as follows: For crucibles 55%, stove-polish 15%, foundry facings 10%, paint 5%, all others 15%. The last named division includes powder polishing, electrotyping, steam packing, pencils and various minor uses.

Uses.—To go thoroughly into the subject of the various manufactures of graphite and the many uses to which it is put would require a paper much longer than this. In addition to those mentioned by Mr. Pratt, it enters largely into the manufacture of shoe polish, printer's ink, electric light carbons, electrodes, rheostats and other electrical appliances and supplies, and is used by shot, bolt and nut, piano, wire, hat, and many other manufacturers; the means of using it are, however, not all known to the writer. As a lubricant, graphite has attained in late years a position of considerable prominence, and its use as such is rapidly growing. In the original Webster's Dictionary we find a lubricant defined as "that which lubricates: specifically, a substance, as oil, grease, plumbago, etc."

William Kent, M.E., in his "Mechanical Engineers' Pocket Book," says: "Graphite in a condition of powder and used as a solid lubricant, so called, to distinguish it from a liquid lubricant, has been found to do well where the latter has failed." Rennie in 1829 says: "Graphite lessened friction in all cases where it was used." General Morin, at a later date, concluded from experiments that it could be used with advantage under heavy pressures; and Professor Thurston found it well adapted for use under both light and heavy pressures when mixed with certain oils. It is especially valuable to prevent abrasion and cutting under heavy loads and at low velocities."

At a meeting of the American Society of Mechanical Engineers, held in New York in December, 1895, Professor Albert Kingsbury, of Durham, N.H., read a paper on "Experiments on the Friction of Screws," wherein he describes certain tests made by himself. The author did not consider that the tests showed that any one of the metals developed less friction than any of the others, but the tests are specially interesting because of the great lessening of friction by means of graphite, as is shown by the following:—

Lubricant.	Mean.
Lard oil, heavy machinery	11
Oil, (Mineral) heavy machinery	14
Oil and graphite, (equal volumes)	07

The following notes are taken from a pamphlet on lubrication, issued by the Joseph Dixon Crucible Company, and refer to part of a report on exhaustive tests made by Professor W. F. M. Goss, of Perdue University. "Graphite does not behave like oil, but associates itself with one or other of the rubbing surfaces. It enters every crack and pit in the surfaces and fills them, and if the surfaces are ill-shaped or irregularly worn, the graphite fills in and overlays until a new surface of more regular outline is produced. When applied to a well-fitted journal the rubbing surfaces are coated with a layer so thin as to appear hardly more than a slight discoloration. If, on the other hand, the parts are poorly fitted, a veneering of graphite of varying thickness, which in the case of a certain experiment was found as great as 1-16 inch, will result. The character of this veneering is always the same, dense in structure, capable of resisting enormous pressure, continuous in service without apparent pore or crack, and presenting a superficial finish that is wonderfully smooth and delicate to the touch."

"The experiments with flake graphite as a lubricant justify the following important conclusions:—

(a) The addition of graphite to oil results in a lower frictional resistance of the journal than would be obtained by the use of oil alone.

(b) When graphite is used with oil, the amount of oil required for a given service is reduced.

(c) By the use of graphite a light or an inferior quality of oil may be employed for a given service.

(d) By the use of graphite, water under favorable conditions may serve as a sufficient lubricant.

(e) A small amount of graphite only is required.

(f) The supply of *too much* graphite unduly thickens the oil and correspondingly increases its internal friction due to viscosity.

(g) The benefits derived from the use of graphite persist long after its application has ceased. The supply, however, should be constant, though small, for the best results."

In conclusion, it may be stated that, by reason of the high degree of purity attained in the mills of the late Anglo-Canadian Graphite Syndicate and the Buckingham Graphite Company, a considerable demand has arisen for their flake product for lubrication, both in the United States and Great Britain, as well as in Germany, where graphite lubrication has probably reached its highest point.

Statistics.—It is extremely difficult to obtain correct statistics relative to graphite, more especially on this continent, where it is a notorious fact that incorrect returns are almost invariably supplied to the various Government statistical offices, while from the various diverse figures obtainable from official centres of foreign countries, it may be assumed that this notoriety is universal.

In the following tables it has been the endeavour of the writer to obtain the most correct figures, though, of course, he does not vouch for them.

The annual production and imports and exports of Canada are given in the two following tables, and are taken from the reports of the Section of Mines of the Geological Survey.

ANNUAL PRODUCTION IN CANADA.
1895–1905.

Year.	Tons.	Value.
1895	220	$6,150
1896	139	9,455
1897	436	16,240
1898	——	13,698
1899	1130	24,179
1900	1922	31,040
1901	2210	38,780
1902	1095	28,300
1903	728	23,745
1904	452	11,760
1905	541	17,032

IMPORTS AND EXPORTS OF CANADA.
1895–1905.

Year.	Imports.	Exports.
1895	$38,496	$4,833
1896	40,796	9,480
1897	38,943	4,325
1898	54,153	13,098
1899	62,803	22,490
1900	64,955	46,197
1901	77,893	35,102
1902	67,772	24,839
1903	72,546	43,642
1904	69,365	16,507
1905	——	8,114

The production, imports and total consumption of the United States are contained in the following tables, taken from the "Mineral Resources of the United States" for 1904.

PRODUCTION AND CONSUMPTION OF THE UNITED STATES.
1895 to 1905.

Year.	Production		Imports.		Total.	
	Tons	Value	Tons	Value	Tons	Value.
1895........	3,115	$52,582	8,814	$260,090	11,925	$312,672
1896........	1,028	48,460	15,230	437,159	16,258	485,619
1897........	1,751	65,730	8,533	270,952	10,284	336,682
1898........	2,070	75,200	13,482	743,820	15,552	819,020
1899........	3,774	167,106	20,793	1,990,649	24,567	2,157,755
1900........	3,365	197,579	14,417	1,390,141	17,782	1,587,720
1901........	2,793	167,714	14,325	895,010	17,118	1,062,724
1902........	3,297	182,108	18,201	1,168,554	21,498	1,350,662
1903........	18,857	225,554	16,007	1,207,700	34,864	1,433,254
1904........	19,767	321,372	12,674	905,581	32,441	1,226,953
1905........	24,971	318,211	......	......	......	......

The exports of graphite from the United States would not materially change the above totals. According to official returns, they were in 1901, $365; in 1902, $834; in 1903, $13,365; and in 1904, $12,417.

In the "Mineral Resources of the United States" for 1903, Mr. Joseph Hyde Pratt says:—"The importance of the graphite industry in the United States is well emphasized by this table, and also the benefit that would be derived by this country if large deposits of commercial graphite could be found. There is a general increase in the quantity of graphite consumed, although there has been a very wide variation in the value of the production each year."

Deducting the cheap and low grade amorphous graphite produced in the United States, and combining the crystalline product only with the imports we find a market there as follows (the last full figures available):—

Year	Production		Imports		Total		Value per ton
	Tons	Value	Tons	Value	Tons	Value	
1900	2,754	$178,761	14,417	$1,390,141	17,171	$1,568,802	$91.35
1901	1,984	135,914	14,325	895,010	16,309	1,080,924	63.20
1902	2,088	153,147	18,201	1,168,554	20,289	1,321,701	65.15
1903	2,269	154,170	16,007	1,207,700	18,276	1,361,870	74.50
1904	2,840	238,447	12,674	905,581	15,514	1,144,028	73.75

Note.—In the above imports are included large quantities of Austrian crude ore worth only about $14.00 per ton.

The following table illustrating the world's production is taken, intact, from the "Mineral Resources of the United States" for 1904.

WORLD'S PRODUCTION OF GRAPHITE, 1895–1903.

(Quantity in Metric Tons.)

Country.	1896		1897	
	Tons	Value	Tons	Value
United States	933	$48,460	1,589	$65,730
Austria	35,972	410,081	38,504	439,610
Canada	126	9,455	396	16,240
Ceylon	10,463	414,405	19,275	1,159,885
Germany	5,248	72,108	3,861	66,126
India	......	......	61	316
Italy	3,148	10,193	5,650	11,300
Japan	215	6,925	204	16,075
Mexico	620	5,287	907	8,663
Sweden	14	491	99	3,240
Totals	56,739	977,405	70,546	1,787,185

Country.	1898		1899	
	Tons	Value	Tons	Value
United States	1,878	$75,200	3,424	$167,106
Austria	33,062	421,058	31,819	395,280
Canada	......	13,698	1,188	24,179
Ceylon	78,509	9,243,263	29,037	2,904,970
Germany	4,593	97,916	5,196	120,250
India	22	110	1,548	7,572
Italy	6,435	17,423	9,990	55,944
Japan	346	10,265	53	5,120
Mexico	1,857	18,237	2,305	22,847
Sweden	50	1,620	(*a*)535	1,674
Totals	126,752	9,898,790	85,445	3,704,942

Country	1900		1901	
	Tons	Value	Tons	Value
United States	3,054	$197,579	2,533	$167,714
Austria	33,663	418,126	29,992	369,157
Canada	1,744	31,040	2,005	38,780
Ceylon	19,168	*b*875,190	22,707	*b*3,203,215
France	......	......	......	......
Germany	9,248	136,500	4,435	58,000
India	1,858	9,104	2,530	(*c*)
Italy	9,720	55,720	10,313	59,211
Japan	94	12,215	88	8,930
Mexico	2,561	25,650	1,473	7,385
Sweden	84	3,186	56	1,900
Totals	81,194	1,764,310	76,226	*d*3,930,359

Country.	1902		1903	
	Tons	Value	Tons	Value
United States	6,085	$183,108	17,110	$225,554
Austria	29,527	368,186	29,589	382,148
Canada	994	28,300	700	23,985
Ceylon	25,593	3,505,455	24,492	1,952,529
France	150	1,140	126	702
Germany	5,023	41,755	3,720	35,462
India	4,648	(*c*)	3,448	(*c*)
Italy	9,210	35,934	7,920	28,855
Japan	97	9,876	114	10,950
Mexico	580	3,176	1,952	42,985
Sweden	63	1,900	25	988
Totals	81,970	4,177,830	89,196	2,704,158

(*a*)—Includes crude.

(*b*)—These values were taken from the official year books of the United Kingdom.

(*c*)—Statistics not available.

(*d*)—Latest available figures used in making up total.

In tabulating the production of the island of Ceylon, there is to be noted a very great fluctuation both as to total value and value per ton. It will be also seen that the year 1904 afforded the greatest tonnage, with two exceptions.

PRODUCTION OF GRAPHITE IN CEYLON FROM 1896 to 1904.

(Metric Tons.)

Year	Tons	Value	Value per Ton
1896	10,463	$414.405	$39.60
1897	19,275	1,159,885	60.20
1898	78,509	9,243,263	117.70
1899	29,037	2,904,970	100.00
1900	19,168	(*a*) 875,190	50.90
1901	22,707	3,203,215	141.00
1902	25,593	3,505,455	137.00
1903	24,492	1,952,529	79 70
1904	26,478	(?)	(?)

(*a*)—These values are taken from the official year books of the United Kingdom.

Artificial Graphite.—The introduction of artificial graphite into the market did not, as was feared at one time, revolutionize the industry as the production of this substance by artificial means consists largely in the graphitizing of electrodes and similar electrical supplies, small quantities only being produced and sold for the manufacture of paints, dry batteries, commutator brushes, etc. The following notes regarding this product are taken from the "Mineral Resources of the United States" for 1903:—

"Methods for the production of artificial graphite have been known for a great many years, but it is only within the last eight years that a method has been devised for manufacturing it commercially. The three principal methods by which artificial graphite has been made are; (1) By heating amorphous carbon to a very high temperature in the electric furnace. (2) By dissolving an excess of carbon in a molten metal at a high temperature; on allowing the metal to cool down, the excess of carbon separates out as graphite. (3) By the dissociation of certain carbon compounds by means of metallic iron, or iron oxide, at high temperatures. The method now employed in the manufacture of artificial graphite was discovered by Mr. E. G. Acheson, who also discovered carborundum. Mr. Acheson defines his method of manufacture as follows:—'This method of manufacturing graphite I would define as consisting in heating carbon, in association with one or more oxides, to a temperature sufficiently high to cause a chemical reaction between the constituents, and then continuing the heating until the combined carbon separates in the free state. It is not, however, limited to the use of oxides, as pure metals, their sulphides and other salts may be used, but for various reasons the oxides are to be preferred.'" (Jour. Frank. Inst., June, 1899).

The following table of the production of artificial graphite is taken from the "Mineral Resources of the United States" for 1904:—

PRODUCTION AND VALUE OF ARTIFICIAL GRAPHITE, 1897 to 1904.

Year	Pounds	Value	Unit Value per Pound, cents
1897	162,382	$10,149	6.25
1898	185,647	11,603	6.25
1899	405,870	32,475	8.00
1900	860,750	68,860	8.00
1901	2,500,000	119,000	4.76
1902	2,358,828	110,700	4.70
1903	2,620,000	178,670	6.82
1904	3,248,000	217,790	6.71

NEW DISCOVERIES IN NORTHERN QUEBEC.

By J. Obalski, M.E., Director of Mines, Quebec.

(Toronto Meeting, 1907.)

Since last summer a number of prospectors have been in the field exploring the Chibogomo District, the valley of the Bell River and the north of Pontiac county. In many cases the parties were formed under the auspices of small syndicates, the expense of travelling in these remote regions being considerable. In consequence of these investigations rather more is now known concerning the mineral potentialities of these areas, and this knowledge is strongly corroborative of the opinions previously expressed by geologists in charge of reconnaissance surveys. The writer, last year personally visited the regions between the Hanicanaw River and Lake Abitibi. Below is summarized the more important discoveries made and the geological features in connection therewith.

In the Chibogomo District some work has been done on the big quartz vein of Portage Island, showing the continuity of the vein at depth and its larger mineralisation in the form of chalcopyrite. This development includes a number of open cuts on the vein covering a distance of about 1,000 ft., and the sinking of a shaft to a depth of 35 ft. From tests made, the value in gold and silver appears to be greater than previously supposed. In the north-west section of McKenzie Bay, new discoveries of asbestos are reported, while north-west of Island Bay a large occurrence of magnetic iron has been discovered. Some large bodies of pyrrhotite carrying high copper values, have, moreover, been found north-west of Lake Dore, assays of specimens of this ore, have also yielded as high a return as an ounce to the ton.

North-east of Lake Assinibastot and south-west of Chibogomo River, cobalt bloom was recently discovered, but too late in the season for the significance of the find to be ascertained.

The discovery, however, is seemingly confirmatory of opinions expressed by Mr. A. P. Low, and Mr. J. E. Hardman, regarding the similarity of the geological formations here to that of the Cobalt area. It is probable that the district will be well prospected during the coming summer, and other important discoveries will doubtless be made. Meanwhile a good winter trail is now completed from Lake St. John to Chibogomo.

In the north of Pontiac, the writer has explored from the Baie des Guize following the Ottawa and Kinonge rivers, Lake Kewagama, Lake Askikwaj and northward down the Hanicanaw River 20 miles north of the proposed route of the Transcontinental Railway and thence to Lake Abitibi, White Fish River and south to the Baie des Guize. Outcrops of Laurentian gneiss occur south of Askikwaj Lake, north of Kewagama Lake, North of Long Bay of Kinonje River and south of the height of land on the shore of Lake Opasatica. However, the area south of that line, is of course, not all Laurentians, bands of Heronians being found in several places as shown in Dr. A. E. Barlow's map of 1899. The country crossed by the Transcontinental Railway is covered by a thick layer of clay, but shows in places outcrops of rocks, undoubtedly of Huronian age.

The north-east shore of Lake Kewagama is Huronian as is too the district around Askikwaj Lake. Descending the Hanicanaw River the same rocks outcrop for same distance; but further down the surface is covered by clay, with occasional outcrops of rocks. The exposures of rock down the river for the distance travelled of forty miles, and also along the route of the Transcontinental Railway for twenty-five miles were very few. Nevertheless, the rock in sight is Huronian, being diorite, serpentine, schist, and a granite similar to that found on the height of land, near Lake Opasatica. It is reported that chalcopyrite has been found on the shore of the Hanicanaw River, below the Transcontinental line.

In the serpentine above mentioned the writer has observed small stringers of asbestos. On the southern slope of the height of land, some molybdenite occurs, and it is reported that another deposit has been found in the big peninsula of the Lake Kewagama. In a more westerly direction, the country is rocky and less difficult to prospect, and no important discoveries have been made except in the vicinity of Opasatica Lake. To the north-east of this lake, not far from the height of land, a very remarkable piece of quartz showing abundant visible coarse gold, was picked up, and exploration since has apparently resulted in the discovery of gold-bearing quartz in place. Two blocks of land have been purchased from the Quebec Government in that section, of which one by the King of the North Gold Mines Company, recently organized to develop the property. The writer visited the district in July last, and although he did not see any visible gold in the quartz, he obtained good colours by panning the debris in the vicinity of the deposit.

To the south of Lake Abitibi and close to the shore, a guide of the party found some rock containing gold, and the fact was ascertained that rock of the same character, also showing gold was here *in situ*.

Some indications of chalcopyrite have also been found close to the boundary line, not far from the 35th mile.

A number of lots have been prospected in the surveyed townships near Temiskaming Lake, and a large variety of minerals found there including galena, iron pyrites, copper pyrites containing some gold, cobalt bloom, and iron; one undertaking, the Jessie Fraser Mining Company purchased a block of land in Fabre Township, on which a small steam plant has been installed. The geological formation of these townships appears to be a succession of bands of Huronian and Laurentian not yet accurately determined.

On the Bell River, some prospecting has been done, but no new discoveries of importance are reported.

Last season the Geological Survey explored from Lake Abitibi, towards the east, following the surveyed lines of the Transcontinental Railway. Mr. W. J. Wilson gives a summary report of this exploration in the last publication of the Geological Survey. Dr. A. E. Barlow also reports on the geology of the eastern part of Temiscaming District, but neither of these report indicate the occurrence here of minerals of economic value.

IRON MINING POSSIBILITIES IN THE PROVINCE OF QUEBEC.

(By Fritz Cirkel, M.E., Montreal.)
(Toronto Meeting, 1907).

The establishment of a mining industry in the Province of Quebec is of long standing, and it were, therefore reasonable to expect that mineral production from this Province should be, proportionately considerable. But this is not the case. In 1905 the total value of the minerals produced amounted only to $3,750,-000, an insignificant aggregate in relation to the importance and the varied mineral resources of the area. The question arises, to what cause is this unsatisfactory state of affairs attributable?

The public as a rule finds ready explanation in blaming government for slow industrial progress; but in the present instance this can not be done in fairness. Enquiring into conditions connected with the Quebec mining industry we find that the Provincial Government has done much to promote mining, and the laws governing the latter are as liberal as can be found in any other mining country, where conditions are similar; and we must, therefore, look elsewhere for reasons.

Meanwhile if we examine statistics published annually by the Quebec Government we will observe that the precious metals are absent from the list, and the entire production, practically, is that of minerals not classed as precious.

Thus we have, among others, mentioned:—

Iron ore, with gross value of production of		.	$35,268
Chromic iron	"	" ..	$104,565
Copper ore	"	" ..	$128,850
Asbestos	"	" ..	$1,476,450
Asbestic	"	" ..	$31,100
Mica	"	" ..	$95,460

Considering the mineral potentialities of the Province of Quebec this showing is most inadequate, and the reason thereof is solely as evitable to the indifference of the public. Nowadays fabulously rich finds in other provinces of the Dominion have attracted wide attention and it is not difficult to find capital for the exploitation of precious mineral deposits of even questionable value. But it is difficult to interest investors in deposits of bare minerals in this Province promising safe and fair returns on money invested. This point might be illustrated by numerous examples which have come under the writer's notice. But reference need only be made to the inattention paid to our magnetic iron resources by way of demonstration.

It is well known that the Province of Quebec is very rich in iron ores, especially in magnetic iron; these deposits are distributed along the banks of the St. Lawrence, Ottawa, and Gatineau Rivers and are of good quality, quite equal in this respect to the Swedish ores.

The magnetic sand deposits on the north shore of the St. Lawrence were discovered over 40 years ago, but remain still undeveloped. These deposits are of considerable magnitude at certain points, such as at Moisic, Mingan, Betsiamits, Natashquan, Kagashka.

The magnetic sand is found almost on the surface in stratified beds from ½ inch to 6 inches thick, but sometimes attaining a thickness of from 1½ feet to 2 feet. These deposits extend over large surfaces on the coast, in some instances for several leagues. Besides magnetic iron, this sand contains quartz, red garnet and titanic iron.

The following analyses are taken from the report of Dr. Sterry Hunt: (Geol. Survey, Canada, 1866-69).

		Moisic	Betsiamits	Mingan.
Protoxide of iron ..	70.10	92.68	92.44	86.92
Peroxide of iron....	"	"	"	"
Titanic acid.......	16.00	4.15	3.40	6.50
Oxide of manganese	"	0.40	undetermined	0.52
Lime.............	"	0.90	traces	0.75
Magnesia	"	0.90	"	0.70
Insoluble..........	5.92	1.95	3.85	4.20
	92.02	100.08	99.67	99.59
Metallic iron	55.23	66.73	66.56	65.58

Analysis No. 1 was that of the raw sand, 2, 4 and 6 of the magnetic portions.

It will be remarked that all the iron is indicated in the state of protoxide in the analysis of the raw ore or of the non-magnetic portion, on account of the difficulty of determining the degree of oxidation of the iron in the titanic mineral, which explains why the totals of the analyses are so much below 100.

The two next analyses were made in Belgium in the laboratories of metallurgical companies:

Protoxide of iron	28.04
Peroxide of iron	71.07
Sulphur and phosphorus	00.00
Equivalent to metallic iron	70.56

But the principal magnetic iron ores are located in the Township of Pontiac and in Hull, north of Ottawa. In each of these localities, mining operations was carried on some 30 or 40 years ago; but work was discontinued not on account of a falling off in the quality or quantity of ore, but in consequence of loss in handling. Separation methods for the purpose of freeing the iron ore from the gangue are of comparatively recent date and by these means mines, which formerly could not be profitably operated, can now be made to pay handsome returns. Most people, acquainted with the early operations of these mines, when approached for an opinion regarding their present value, refer to former failures and express an unfavourable view, forgetting that conditions now have greatly changed for the better, and that these former failures were ascribable to the one cause already explained. In proof of this contention the mines of the Adirondack region may be instanced.

There has ever been a disposition to under-estimate the great importance of the magnetic iron ores of the Ottawa and Pontiac Counties, the specific objection raised against the availability of these ores in that region, being that the cost of fuel to melt the ore is prohibitive. With the steadily decreasing quantity of coal required per unit of finished product, due to the better utilization of fuel by modern methods, this objection is, however, of lessening importance, while on the other hand we have these favorable factors:—The ores are rich, the bodies are large, and cheaply mined, for little timbering or pumping is necessary. The objection is occasionally raised that magnetic ores are not as readily reduced in the furnace as hematites, and are therefore not worth as much to the smelter. In a general way this is true, although one fact deserves consideration, and that is that magnetites are practically free from moisture, so that their carriage is proportionately less. It is estimated by one of the leading furnacemen in the country, that magnetite involves an extra expenditure in smelting of about 25 cents per ton of pig, and even that is only a general statement, since there is considerable difference in the ease with which different magnetites are reduced in the furnace. An interesting practice bearing on this point has been developed at the Wharton furnaces, where New Jersey magnetites are roasted in kilns fired with waste furnace gas or with producer gas before being charged into the furnace, a practice for which important economies are claimed.

Another feature which speaks greatly in favour of cheap reduction, is the enormous amount of available water power in the vicinity of the mines which could be readily used for the production of electric energy in electric smelting, as suggested by Dr. Haanel, Dominion Superintendent of Mines; and reference may be here made to the Chats Falls, on the Ottawa River, near the Bristol Mines and to the Chelsea Falls on the Gatineau River in the vicinity of the Ironsides Mines, where more than 50,000 horse power can be cheaply produced for general mining and smelting purposes.

Referring to the concentration of these iron ores, which are to a great extent of low grade, it should be stated that the Port Henri mines in the Adirondacks, where conditions are similar to those obtaining in the Ottawa and Pontiac counties, have successfully adopted separation processes.

For years the concentration of low grade ores by some form of electro-magnetic separator has attracted the interest of the miner and inventor alike. Among the first to test and develop processes of magnetic separation in the Adirondacks were Witherbee, Sherman & Co.; who were called upon to meet two sets of conditions. The New Bed and Harmony ores, low in phosphorus and varying in purity from 40 to 69 per cent. iron, form one group; while Old Bed ores, practically of uniform grade at 60 per cent. iron, but high in phosphorus—1.35 to 2.25 per cent.—

form the second group. The magnetic separation, or rather purification, of the latter is particularly interesting and unique, the problem being to eliminate the apatite or phosphorus bearing gangue, which is practically non-magnetic. The apatite varies in colour and in the size of crystals. These two characteristics have a bearing upon the degree of concentration possible. In the case of the apatite of a deep red colour the magnetic characteristics are sufficient to carry at times, an appreciable percentage of the free crystals into the iron concentrates. Then, too, these deep red crystals adhere more tenaciously to the crystals of magnetite than the green or yellow varieties. The yellow apatite crystals break away most freely from the magnetite. When the magnetite is a shot ore, or of large crystalline structure, it is not difficult to bring the ore into a condition admitting of practical concentration. When the ore is massive, or the crystals of magnetite and apatite are both small and finely disseminated throughout the mass, finer crushing is necessary for the same degree of concentration.

In order to meet these conditions of the ore it has been found necessary to carefully prepare the ore by crushing, drying and sizing before treating it on the magnetic separators. Aside from this treatment for physical peculiarities of the ores, a rough cobbing is made at the pit head, the first-grade product being sent direct to the furnaces and the second-grade ores being sent to the separators, except at such times when the whole run-of-mine is concentrated.

To make the Old Bed high phosphorus ores of more value to the blast furnaces, Witherbee, Sherman & Co., built a separating plant about two years ago, and later erected another mill, to care for the total output of this grade of ore. During the two years of operation of the plants the methods of treatment have been improved from time to time to assure uniformity of product. While from the start the process has been a commercial success, the improvements introduced have tended to lower the percentage of phosphorus. It is very doubtful if a true Bessemer product can ever be made from Old Bed ores, yet the limits of variation in the phosphorus of the concentrates are being narrowed.

The separating plant is divided into three main divisions, the crushing plant, the separating plant and the re-treating plant. Each of these product divisions is also made a power division, a

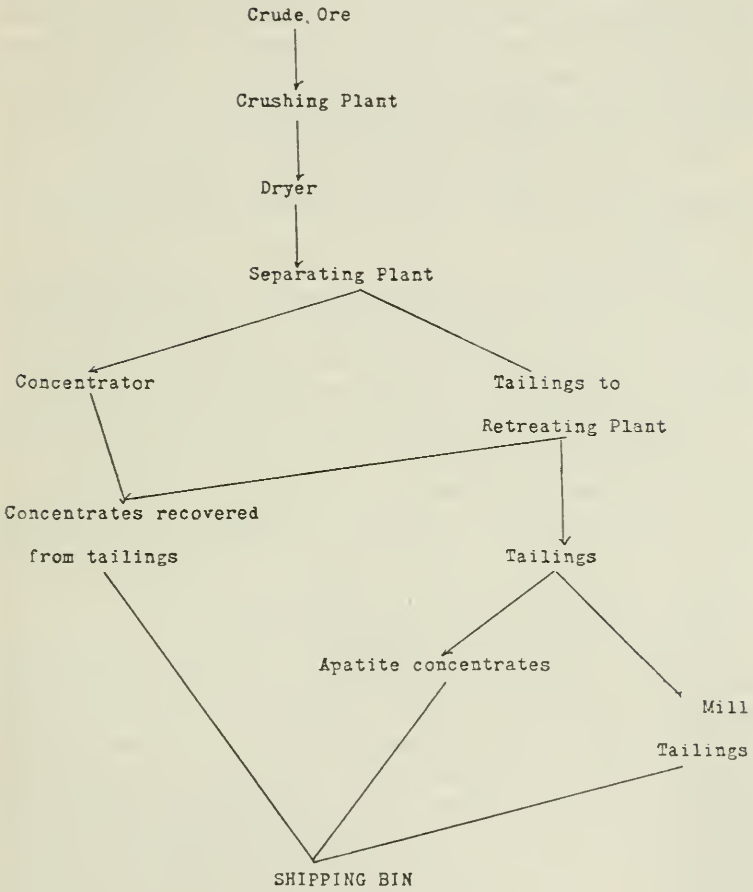

Diagram showing Method of Magnetic Separationand Purification.

motor being so placed as to control the machinery and conveyors in each division without reference to the others. In the original plant direct current motors are in use; in the second plant alternating current is the motive power. Between each division there are interposed bins, which through their storage capacity make it possible to operate each section individually for about two hours without obtaining fresh supplies from the preceding section.

The course of material through the mill is clearly shown in the accompanying diagram, with the machines which are a part of each division.

Crushing Division—As will be observed by reference to the diagram, the crude ore is first crushed in a 30 x 18 inch Blake crusher, operating at a speed of 250 revolutions, to 1.50 to 2 inch cubes. The resulting product is then passed over a screen of 0.75 inch opening, the oversize being crushed to 0.75 inch cubes in a Blake 36 x 6 inch double jaw crusher running at 225 revolutions. The material passing through the screen and the crushed product unite, and are again screened over a six-mesh screen, the ruling size of the mill. The oversize is crushed in a set of 36 x 14 inch Reliance rolls of Allis-Chalmers make, running 100 revolutions. The troughs of the screens and the product of the rolls unite, and the combined materials are passed through a dryer.

The dryer is a square vertical stack with baffle bars placed at right angles to one another in alternate sections, there being eight sections with six rows of bars to a section and six bars to a row. In falling over these bars the body of ore is broken up and permits a free circulation of hot air throughout the mass. The ore being fed in at the top of the dryer passes constantly into a hotter zone, the heated gases from the grate passing from bottom to top of the stack. On discharging at the bottom of the dryer the ore is elevated to a tower screen having 288 square feet of screening surface. This screen is divided into equal sections of 30, 16, 10 and 6 mesh screens. The product of each size screen is delivered to a separate pocket in a bin. The oversize of the screens is returned to a set of 36 x 14 inch Reliance rolls, so placed that the product of the rolls meets the original stream from the dryer. By this arrangement material is confined to a closed circuit, the only outlet being through the screens. The finest screens of the series are placed at the top, in order that the coarser particles may scrub the fine material through and cause a more effective sizing.

The object sought by frequent screening is the elimination at each stage of the coarse ore, thus preventing pulverization. That the process amply pays is shown in the fact that of the total shipping product about 65 per cent. consists of particles larger than ten mesh—an ideal ore for blast furnace use, as has been fully demonstrated during the past two years.

Separating Division—Under each pocket of the bin is placed a Rowand Type F magnetic separator treating one size ore. Ball & Norton separators have lately been introduced on the 30 and 16 mesh sizes. These separators operate in conjunction with the Rowand machines. Both makes of separators are so arranged as to make heads and tails. The heads, or concentrates, are sent direct to the shipping bin, and the tails, containing iron, apatite, hornblende and a small quantity of silica rock, are re-treated.

Re-treating Division—The tails from the Rowand Type F and Ball & Norton separators are passed over a screening surface of 72 square feet equally divided into 20 and 16 mesh sizes. The oversize is passed to a Wenstrom magnetic separator, where the free iron remaining in the tails of the previous separation is recovered, the Wenstrom tails being returned to the 20 and 16 mesh screens after having been recrushed in a set of 36 x 14 inch Reliance rolls. The product of the rolls meets the original stream from the Rowand Type F and Ball & Norton separators. As in the previous instance, the tails for re-treatment are in a closed circuit and must pass through the screens or over the Wenstrom separator. That portion which has passed through the screens is then treated upon two Wetherill Type E separators. The iron is first removed and is passed into the iron concentrates along with the concentrates from the Wenstrom separator mentioned above. The hornblende forms a middlings product from these separators and is passed off as mill tails. The apatite and silica being non-magnetic form the tails of the separator and are classed as apatite concentrates, carrying from 60 to 65 per cent. bone phosphate. The mill tails carry sufficient apatite to raise the percentage of bone phosphate to from 40 to 45 per cent. and form a second or low grade apatite concentrate. Both of these grades of apatite concentrates find a ready market with the fertilizing plants.

The concentration operation thus produces three products of market value, iron concentrates, apatite concentrates and second-grade apatite concentrates.

The mills are each capable of treating 800 tons of crude Old Bed ore in 20 hours. Of the crude material 85 per cent, is recovered as iron concentrates, the 15 per cent. of tailings being equally divided between the first and second-grade apatite concentrates. On a basis of 800 tons of crude ore the products would be as follows:—

	tons
Crude ore	800
Iron concentrates	680
First-grade apatite concentrates	60
Second-grade apatite concentrates	60

The average analyses for the past ten months are as follows:—

	Per cent.		
	Iron	Phos-phorus	Bone Phos-phate
High phosphorus Old Bed crude ore	59.59	1.74	......
Old Bed concentrates	67.34	0.675	......
First-grade apatite concentrates	3.55	12.71	63.55
Second-grade apatite concentrates	12.14	8.06	40.30

The other elements of Old Bed concentrates are:—

	Per cent.
Silica	2.20
Manganese	0.08
Alumina	0.90
Lime	3.84
Magnesia	0.31
Sulphur	trace

These mills are also capable of treating 600 tons of Harmony and New Bed crude ore in 20 hours. Of the product 77 per cent. or 462 tons, are recovered as concentrates, the remaining 23 per cent. or 138 tons, being discharged as tailings. These tailings are used for granolithic and concrete purposes, railroad ballasting and marble facing and cutting, the sharp edges of each particle being a far superior medium than water washed sands, where the edges have been destroyed by the action of the water.

Analyses of Harmony concentrates from October 2 to November 13, 1903, gave the following results:—

	Per cent. Iron	Per cent. Phosphorus
Lean Harmony crude ore	50.26	0.295
Harmony concentrates	64.10	0.133
Harmony tailings	13.97	0.877

From the above general description of the Port Henry Mines it will be seen that most of the successes is due to the elaborate system of concentration and mine equipment and that the initial difficulties which had to be overcome in preparing the lean ore for the market are similar to those confronting us in Canada. No attempt has yet been made in this country to concentrate our magnetic iron ores on an economic scale, although the deposits contain very large quantities of lean ore accompanying the rich streaks. It is impossible to make these mines pay by simply cobbing the ore as was done many years ago, but if capital were to undertake in earnest the utilization of these resources by the employment of modern methods of concentration, it might expect with assurance a rich reward.

THE ORIGIN OF DEPOSITS OF PYRITES.

By A. B. Willmott, Sault Ste. Marie, Ont.

(Toronto Meeting, 1907.)

On studying the literature concerning the origin of deposits of pyrites it becomes evident that there are several theories each with strong supporters, and that even for the same deposits observers are not agreed. For a number of our deposits in Ontario the mode of origin seems to be fairly clear. This paper deals with the occurrences in Ontario, and only incidentally with others.

The four most important theories regarding the origin of pyrites may be tabulated as follows:—

(1). Impregnated beds.
(2). Veins.
(3). Sedimentary beds.
(4). Magmatic segregations.

The first assumes that iron and sulphur as a soluble salt has found its way into porous beds, and been there precipitated as the sulphide. The country rock has in most cases been more or less replaced. Fracturing of the rock has promoted circulation. The mode of formation is similar in most respects to the second or vein deposits, and there are cases where the two methods are indistinguishable. The third theory assumes the precipitation of iron sulphide from solution as a bed at the bottom of shallow water. Other chemical and mechanical sediments occur above and below such beds. This theory is common with the first and second, presupposes the iron and sulphur in the form of a soluble salt, and precipitation brought about through a change in conditions. The fourth theory supposes that the iron sulphide has separated out of a cooling igneous mass. Several physical principles are suggested to account for the segregation. The following citations and quotations are given to illustrate current opinions.

(1). Beck in his treatise on ore deposits cites no instance of a pyrites deposit formed by sedimentation, magmatic segregation, or deposition in a vein. Under his division of Epigenetic Ore Deposits in Stratified Rocks, exclusive of veins, he gives a number of examples. These are subdivided into those occurring (a) In Crystalline Schists; (b) As impregnations within non-crystalline strata. Both varieties are considered to be due to ore-bearing solutions depositing their load in porous strata. The deposits at Bodenmais, Germany; Sain-Bel, France; Ducktown, Tennessee; and several ones in Norway are described as examples of the first. As examples of impregnations within non-crystalline strata, Beck mentions the deposits of Rammelsberg and Meggen, Germany, and of Rio Tinto and others, Spain. Beck quotes other authors holding different views on some of these deposits, whose opinion he, however, controverts.

(2). Beck sums up his conclusions upon epigenetic ore deposits as follows:—

"The two fundamentally opposite genetic views, whose "rivalry at the present day is keener than ever before in the history "of economic geology, have been presented and weighed one "against the other in the descriptions which we have given of "numerous stratified deposits of sulphide ores of the most diverse "composition and age.

"The sedimentary theory assumes that strata consisting of "sulphide ores, sometimes of considerable thickness, have been "deposited on the bottom of the ocean or sometimes of a shallow "coastal sea, exactly like limestone or rock salt beds, or at any "rate purely chemical precipitates of such sulphide ores were de- "posited by sea water in small particles associated with the normal "sediments.

"The other is the infiltration theory, according to which "such deposits are due to a subsequent mineralization of ordinary "sediments, at a much later geologic period, by means of an "infiltration of ore solutions derived from fissures.

"We believe that the reader must have gained the conviction "that the conditions of structure and position actually observable "argue, in most instances, rather in favor of the second hypothesis. "This is particularly true of the beds of sulphide ore in crystalline "schists. The lack of constancy of position in otherwise uniformly "stratified ore deposits, the limitations of the beds to portions of "rock strongly influenced by dislocations and traversed by erup-

"tive rocks, the occasional occurrence of offshoots (Ueberschnei-"dungen) at the boundary of such ore bodies with the sediments, "the occasional presence of vein-like spurs and stringers, and "above all the microscopic relations of the ores to the other rock "constituents, which often point to a later segregation of the "metallic compounds—all these speak in favor of the infiltration "theory."

Beck then considers to what extent chemical precipitates of sulphidic ores are now being made, and concludes that there is nothing now forming which would account for the vast pyrite accumulations of earlier ages.

(3). Kemp groups "Pyrite Beds" with magnetite deposits which they closely resemble in form and occurrence. "Some pyrites lenses may have accumulated in a way analogous to the bog ore hypothesis, cited under 'Magnetite,' but instead of the iron being precipitated as the oxide, it has probably come down as the sulphide from the influence of decaying organic matter, and has subsequently shared in the metamorphism and solidification of the wall rock. At the same time it must be admitted to be an obscure point. By many they are thought, with more reason, to have originated like a bedded fissure vein whose overlapping lenticular cavities have been formed by the buckling of folded schists. The Ducktown veins are on lines of dislocation beyond question. Replacements of pinched beds of limestone are always to be considered, and the presence of intruded dikes, though disguised by metamorphism, is always to be kept in mind."

In the following chapter he describes pyrite or pyrrhotite beds (veins) with intermingled chalcopyrite, and writes: "Whether the deposits are true beds or veins parallel with the foliation, is as yet a matter of dispute. The resemblance to magnetite suggests a bed and this view is generally taken by German writers. The California mines occur closely associated with the auriferous (pyritous) quartz bodies, which are always esteemed veins. But as detailed knowledge increases, it is more and more appreciated that the ore bodies are mostly if not entirely veins, and have been deposited along lines of dislocation."

J. H. L. Vogt has been the leading exponent of the theory of magmatic segregation of pyrites deposits, and also of pyrrhotite.

Doctors Coleman and Barlow of our own Institute are strong supporters of this origin for our Sudbury pyrrhotites.

From the quotations given it is evident that the present tendency is to consider all pyrites deposits as veins or impregnated beds. In this paper the position is taken that for many of our Ontario deposits a sedimentary origin must be predicated. If some deposits are undoubted sediments, it probably follows that at least some of the foreign deposits which have been explained both on the sediment and impregnation theories were made in the former way.

Turning now to the Ontario deposits several may be considered in detail. Among the most important is that near the Helen iron mine, Michipicoten. The ore is a mixed hematite and limonite which in places holds pockets of fine granular pyrites resembling artificial concentrates. The ore runs 40 to 50 per cent. in sulphur, and is free from impurities. The pockets found vary from a few cubic feet up to chimneys 20 feet across and 100 feet high. The line of separation between the pyrites and hematite is usually very marked. At times there is a gradual transition. At points in the hematite mine hard ore is found carrying considerable intermixed pyrites. Usually this ore is somewhat banded and quite silicious. North of the hematite ore body there is several hundred feet of banded hematite and chert standing almost vertical. To the east of the iron mine a steep hill rises 400 feet along the brow of which a band of impure cherty siderite is seen. Scattered through this siderite is a considerable amount of pyrites. The siderite weathers much more rapidly than the pyrites.

On the west the iron ore now being mined is bounded by a diabase dike which crosses the iron formation nearly at right angles. West of the ore body there was originally a small pond known as Boyer Lake. This pond was about a quarter of a mile long, hardly as wide, 133 feet deep, and rock-rimmed throughout. Diamond drill holes have shown, beneath forty feet of mud in the bottom of this lake, 140 feet of pyrites fines. Exploration is not complete, but a pocket of over 100,000 tons has been shown. The only explanation of the origin of this rock-rimmed basin is by solution. (4). The siderite with its contained pyrite, which is found at both the east and west ends of the lake, undoubtedly was continuous, and has been removed. The lose granular pyrites can best be accounted for as a residual product. That the pyrites is much more stable than the siderite is abundantly proved.

Adjoining Boyer Lake and along the strike of the iron formation is another pond, Sayer's Lake of similar size and description. On the north side of the lake a railway cutting shows a small deposit of pyrite, pyrrhotite, and carbonaceous shale. On the south side a short tunnel discloses pyritic quartz rock which in places is almost pure pyrites. This material resembles the pyritic quartz mentioned before as occurring in the iron ore body, except for the lack of hematite. Where the outlet of Boyer Lake has been lowered a similar silicious pyrite, carrying 30 to 35 per cent. sulphur, occurs.

Everywhere along the Michipicoten Iron Range similar associations are found. A mile west of the Josephine siderite with large amounts of pyrites occurs. Near this a railway cut shows a lens of silicious pyrite carrying 25 per cent. sulphur. It is enclosed within the iron formation, and is undoubtedly part of it. One mile east of the Josephine banded silicious pyrite occurs. At Paint Lake oxidation of silicious pyrites has given rise to a bog deposit on the shore of the lake. For fuller descriptions reference must be made to the writings of Coleman, Bell and myself in the reports of the Bureau of Mines (5) on the Michipicoten Iron Range. The great majority of these numerous occurrences along the iron range are too lean to be of commercial value as sulphur ores.

The Goudreau Lake deposits in township 27, range 26, west of Missanabie on the Canadian Pacific Railway, are perhaps the largest in Ontario. Comparatively little work has been done, but from the known areas, and allowing a depth of only 100 feet, one million tons of pyrites exist. Some of this may be too low in sulphur to be of commercial value, but the prospect is very encouraging to the owners. The deposits are six in number and cover an area two miles in length by one in width. The country rocks are mainly Keewatin schists with some intruded greenstones. Characteristic iron range rocks also occur. The richer pyrites bodies are marked by depressions 10 to 50 feet in height. The smaller ones are only a few feet across; the larger as on the Bear claim 250 feet. In some cases these depressions are roughly circular or oval as at deposit A; at others they are long and narrow as at C, where the depression is 500 feet long, and about 40 wide. Some little ponds in the vicinity of several of the deposits may fill depressions due to weathering of pyrites, but this is not yet proven. The resemblance of these weathered pits on a small scale to Boyer Lake near the Helen is striking.

The ore is silicious, and granular silica similar to the iron range rocks is frequently found. The character of the ore is exactly like the better quality of hard pyrites found at the Helen. Bands of siderite have not yet been noticed, but at several of the deposits crystalline limestone occurs near the pyrite. A diamond drill hole, put down at an angle of 42° under deposit A, passed through three narrow bands of pyrites separated by calcareous schist before reaching the main deposit 96 feet thick. A vertical hole from the bottom of the pit, after passing through a few feet of broken and oxidized material, went through four feet of ore higher in sulphur and much less dense than the usual ore. Either it is a layer from which the silica has been dissolved, or a bed formed by the precipitation of solutions from the gossan above.

Typical material from these deposits analyses as follows:—

Silica	6.00%
Iron	44.36
Sulphur	40.28
Lime	.25
Magnesia	.53
Copper	Trace.
Arsenic	Nil.
Lead	Nil.
Zinc	Nil.

That these deposits are only an extreme phase of the Helen Iron Formation is, I think, admitted by all who have seen them. The agreement is founded on the similarity of the adjoining rocks; the presence of banded chert and magnetite, though only in a small degree; the similarity of the silicious pyrites. The silicious pyrites along the south side of Sayer's Lake at the Helen, and the deposits along the south side of the lake at deposit B, Goudreau Lake, are extremely similar in appearance and mode of occurrence.

At Kaministiquia, 20 miles west of Port Arthur on the Canadian Northern Railway, the Davis Sulphur Ore Company opened a shaft on a pyrites bed. Here, also, the accompanying rocks are those typical of the iron formation as it occurs all through Ontario in the Keewatin. Hand specimens of this ore can be exactly matched at Michipicoten. Undoubted iron range rocks occur in close proximity.

At Strawhat Lake, near Atikokan, on the Canadian Northern Railway there is another occurrence of pyrites resembling those at Goudreau Lake. This deposit was originally opened by prospectors who were searching the iron range for iron. That the deposit is part of the iron range cannot be doubted. It must have been formed with it, though possibly secondary concentration might be argued.

Near Schreiber on the north shore of Superior is a pyrites deposit of a different character. The ore is associated with an eruptive diabase, and is considerably mixed with pyrrhotite carrying small amounts of nickel and copper.

Associated with the iron ranges in the Temagami Reserve are several belts of pyrites. These have been described by Professor Miller, (6) and it need only be stated that in character and associations they resemble other pyrites beds found with the Keewatin iron formations. Several openings have been made at points on Temagami Lake, but the ore has proved rather too low in sulphur. In this it resembles the great majority of occurrences along the iron ranges. Only in places has the pyrites been accumulated sufficiently free from quartz to be of value. At these places, naturally, the resemblance to the pyritous chert of the iron ranges has been so much modified that it is not easy to recognize the connection. The deposit at Net Lake is, I believe, only a richer part of the pyritous cherts of the Temagami iron range. To be certain one should trace out the belt which I have not done.

In Hastings county are a number of deposits several of which were originally opened for hematite iron. The deposits occur as beds in various green schists and are frequently associated with limestones. The boundaries of the ore-bodies are not always distinct, but the ore gradually diminishes outwards until too poor to be of value. Parallel beds occur. The ore contains more lime and less silica than the deposits in Northern Ontario. The writer has not observed the pyritous chert of the iron ranges anywhere in the vicinity. The enclosing rocks are, however, very similar to those of Goudreau Lake.

In Lanark county there is a deposit differing from those so far described. It occurs in crystalline limestone and has the appearance of a vein rather than a bed. The crystals of pyrite are frequently large, well formed, and very pure.

Other large deposits in Ontario, as those at Nickel Lake and Dinorwic, the writer has not seen, and so will pass over; also other pyritous cherts of frequent occurrence, but not differing from those already described.

The larger number of deposits in Ontario and the more important in size, are, as shown above, closely associated with the iron ranges. Following along the strike, pyritous chert succeeds sideritic chert and is succeeded by silicious pyrite. More commonly these changes are noticed in crossing the strike. Cross-sections of the range made by diamond drills show many alterations —banded cherts and hematite, pure hematite, pyritous hematite, silicious siderite with and without pyrite, pure pyrite, cherts free from all iron. No regularity of sequence has yet been noted if any exists. Descriptions of the Ontario Iron Ranges by Coleman, Miller, Bell and the author in various reports of the Bureau of Mines all agree on this close association. Van Hise (7) regards the pyrite as a chemical sediment and in part the source of the iron ore bodies. He writes:—

"In the Michipicoten district of Ontario, pyrite and marcasite "occur rather plentifully within the original iron bearing carbon-"ates, and also very abundantly with quartz in associated rocks. "Pyritic quartz rocks also occur in the Vermilion district in sub-"ordinate quantity. The iron sulphide to some extent has un-"doubtedly been a source of the ores. But however one may "emphasize the importance of ferrous silicate and iron sul-"phide as a source of the ore bodies, it still remains true that the "iron bearing carbonates are the dominant original sedimentary "rocks out of which the iron bearing formations and ore bodies "have been produced."

The rocks of the Helen iron formation have been more carefully studied than those of the corresponding formations in other parts of the province. As all are closely similar the description of the Helen series may be taken as applying to all. I quote from Dr. Bell (8) rather than from the earlier reports by Coleman and myself.

"The Helen formation consists of a series of allied and re-"lated rocks named in order of their importance in the region as "follows:—Banded chert, massive granular chert, sideritic chert, "pyritous chert, banded jasper, rusty quartzite, gruneritic and "other amphibolitic schists, cherty siderite, and iron ores—"hematite, magnetite, pyrites and even pyrrhotite. Between "these rocks there is every phase of gradation. Besids these "ferruginous rocks the formation includes a number of argilla-"ceous rocks, phyllites, and biotitic and epidotic schists—all un-"doubtedly sedimentary which are found not only inter-stratified "with the ferruginous rocks, but also both above and below them, "although always in intimate connection with them.

"The sideritic chert consists essentially of two minerals—"quartz and siderite, with which are almost always associated "chlorite, sericite, pyrite, oxidation products of pyrite and car-"bonate, and sometimes microcline and other feldspars. Ex-"amined microscopically, some of the quartz is seen to be clastic, "but most of it is chemically precipitated, often in the form of "chalcedony. Both microcline and chlorite, the former in round-"ed grains and the latter in plates with frayed edges, are frag-"mental, and their areas have been greatly reduced by the in-"vading carbonate. Pyrite is frequently an inclusion in both "the chlorite and carbonate, and it occasionally develops in secon-"dary veinlets in association with chlorite, carbonate and quartz. "Some of the sideritic cherts contain so much chlorite that they "pass into cherty sideritic phyllites, or so much microcline that "they become sideritic arkoses.

"The massive grayish, pinkish or whitish chert, when quite "pure and undecomposed, is holocrystalline and beneath the "microscope is seen to consist of an interlocking mosaic of quartz. "This is the 'sandstone chert' of the Michipicoten prospector. It is "often markedly rusty, due to the oxidation of iron carbonate, "and less frequently iron pyrites, both of which are nearly always "present. With an increase of one or other of these minerals, "the rock passes into a sideritic chert or pyritous chert."

These iron bearing rocks are mainly chemical sediments though some mechanical sediments are included. The adjoining rocks at Michipicoten are quartz porphyry schists supposed to have originated as volcanic tuffs. These, no doubt, fell as ashes on both land and water, in the latter case being rudely stratified. At intervals the volcanic activity naturally diminished and chemical precipitates formed a relatively larger portion of the sediments. Solutions of lime, iron, silica, and sulphur were carried to the water there to be precipitated. The recurrence of volcanic activity would overwhelm the chemical sediments in the mechanical ones. In this way the small lenses of siderite and silica in the tuffs adjoining the iron formation proper can be accounted for. Then came a long period of volcanic inactivity when chemical sedimentation again predominated. Silica and cherty siderite and pyritous chert were precipitated until beds several hundred feet thick were formed.

How the silica iron and sulphur were dissolved and precipitated is not absolutely clear. Presumably the iron was partly transported as a carbonate and partly as a sulphate. Winchell (9), Clements (10), and Bell (11) have speculated on this point. How was the silica dissolved and how precipitated? The intimate mixture in the cherty siderite suggests that both the iron carbonate and the silica were precipitated together. The iron sulphide was doubtless reduced from the sulphate through the action of carbon. Considerable is still found in the shales adjoining the iron formation. Pyrite and silica were, however, precipitated together as shown by their intimate mixtures.

The pyrites in the iron ranges can be satisfactorily accounted for as a chemical precipitate. Can it be otherwise accounted for? The only alternative would be as a precipitate in porous beds introduced after their folding. One notes, however, that all the beds are not equally porous, and yet the pyrites is found in compact siderite, in very porous chert, in loose hematite and in hard compact almost flinty quartz. Where the beds are brecciated one would expect to find abundant pyrites and there is often none as at Sayer's Lake. Soluble rocks like the siderite should contain pyrites in larger amounts than the compact flinty cherts, but the reverse is the case.

In Temagami, Professor Miller (12) finds two parallel iron ranges several miles apart and separated by an intrusive greenstone mass. They dip in opposite directions as the legs of an anticline. Overlying and parallel with them are two belts of pyrites. The occurrence can be explained as a bed of iron and silica covered by one of pyritous silica, the two folded into an anticline and the summit eroded. Or if the pyrite is not a bed, then one must suppose that solutions came up several miles apart, and impregnated beds parallel to the two iron beds. Obviously the former is the more likely.

We conclude, then, that for a number of our Ontario pyrites bodies the origin has been one of chemical sedimentation. For Strawhat, Lake Kaministiquia, Helen, and the Michipicoten range, Goudreau Lake, and the Temagami ranges this seems proven. For the Hastings occurrences there is not so good proof, though nothing is known pointing more strongly to another origin. The similarity of the Virginia deposits in Louisa county to those of Hastings appeal to me strongly. Possibly they may be replacement deposits as suggested by Nason (13), but the writer has seen nothing about them unexplainable as a sediment.

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THE ELECTROTHERMIC PRODUCTION OF STEEL FROM IRON ORE.

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At the last meeting of the Institute, a paper was read by Mr. J. W. Evans, giving an account of some laboratory experiments in making steel directly from iron ores in the electric furnace. The experiments were interesting, as showing perhaps the very smallest scale on which the electrothermic extraction of iron from its ore has been attempted, but it would hardly be safe to conclude that the results obtained in Mr. Evans' experiments would also be obtained in a large furnace working continuously.

Mr. Evans made experiments with a view to determine whether steel can be obtained directly in the electric furnace from high sulphur ores, an important question on which very little information is available. In the blast furnace, sulphur can be eliminated by the aid of limestone as calcium sulphide, but the conditions must be strongly reducing, yielding usually a pig iron rich in silicon. It is difficult to obtain, from sulphurous ores, a pig iron which shall be low in both sulphur and silicon. In making steel direct from the ore, the conditions must obviously be less reducing than in making pig iron, and so the possibility of obtaining it low in sulphur, from sulphurous ores, could not have been directly deduced from blast furnace practice or from the important work that has been done on the production of pig iron in the electric furnace.

Stassano has made numerous experiments on the direct production of steel from iron ores, but he only used pure Italian ores which were nearly free from sulphur, and the recent experiments at the Soo, were only directed, as far as they have been published, to the production of pig iron.

Mr. Evans has shown that an iron ore with 1% of sulphur mixed with suitable proportions of charcoal and lime and heated electrically in a crucible will yield a steel low in carbon and silicon and containing from .08% to .17% of sulphur. Most of the sulphur had been removed, and as Mr. Evans states, it may be possible to remove more, but the amount left is above the limit for Bessemer or open-hearth steels. It would be interesting to know the proportions of ore, charcoal and lime used in the charge, and the composition of the resulting slag.

With regard to the value of the results obtained, although, in general, electric furnaces are more efficient and economical as they increase in size, so that it is usually more difficult to carry out a smelting operation in a small than in a large furnace, and that whatever can be done in a small furnace can usually be done more certainly and better in a larger furnace, yet there is a distinct difference between the conditions in a furnace in which a definite amount of charge is heated in a crucible until reduction takes place, and then superheated to any desired temperature for the removal, for example, of any volatile ingredient, and the conditions in a furnace which is smelting continuously, fresh amounts of charge constantly descending to the smelting zone, and less opportunity being afforded for any superheating of the resulting steel, or reaction between this and a very basic slag. On a laboratory scale it is very much easier to operate electric furnaces intermittently than continuously, but the results obtained are not always the same, and it appeared to be very desirable to repeat the work on a scale sufficiently large to allow of continuous charging and periodic tapping of the products before drawing definite conclusions as to the possibility of obtaining steel, low in sulphur, direct from sulphurous ores in the electric furnace.

Two of the author's students, Messrs. W. G. Brown and F. E. Lathe, attempted to repeat this work during the past session, and, in spite of numerous difficulties, due chiefly to the somewhat limited amount of power available for the furnace, they succeeded in producing regularly low carbon steel in a small electric furnace, which was tapped at intervals of about half an hour, yielding 2 or 3 lbs. of steel per tap.

The special problem they attempted to decide was whether, in smelting iron ores for the production of steel, phosphorus and sulphur would be eliminated.

It was expected that, in the presence of an oxidized basic slag, phosphorus could be eliminated as in the basic open-hearth furnace, but that more difficulty would be experienced with the sulphur, and this proved to be the case.

The furnace was similar in design to the one used by Dr. Heroult at the Soo, but, as low carbon steel was desired, the carbon lining of the crucible was omitted. The lower electrode was a rod of iron and the lining was made of crushed magnetite bricks, rendered coherent with a little clay.

About 250 amperes of direct current was the maximum available and the furnace used 30 to 60 volts when running well; the power delivered to the furnace being as a rule only 7 or 8 kilowatts.

The ore used was a pure hematite from Lake Superior, containing 97% Fe_2O_3, 2.23% of silica and 68% of alumina. Clay, sand and lime were added to make a slag equal to about half the weight of the smelting metal, and 1% each of sulphur and phosphorus was added in the form of monosulphide of iron and calcium phosphate.

The analyses of the steel and slag from a number of the taps have been collected in a table (page 4) and show very clearly the effect of lowering the carbon in the charge, and so producing steel instead of pig iron.

If sufficient carbon had been added in the charge, a pig iron would have been produced rich in carbon and silicon, low in sulphur, and with more than 1% of phosphorus. As the carbon in the charge is diminished, the resulting metal contains less carbon and silicon, and at the same time the phosphorus in the steel is progressively reduced, until in the lowest carbon steels the phosphorus becomes low enough for structural purposes. The sulphur, on the other hand, which is nearly eliminated in the production of pig iron, increases with the decrease of carbon, no doubt because there is less opportunity for its removal as calcium sulphide, but further decrease of carbon, resulting in a highly oxidized slag, serves to remove a portion of the sulphur, probably as calcium sulphate, in the same way that it is removed in the basic open-hearth furnace.

STEEL AND SLAG ANALYSES.

STEEL.	1	2	3	4	5	6	7
	%	%	%	%	%	%	%
C.....	2.09	1.16	.54	0.88	.088	.088	.091
Si.....	.20	.15	.24	....	....	....	....
S.....	.75	.91	1.04	.54	.65	.68	.47
P.....	.49	.24	.20	.039	.046	.081	.031
SLAG.							
	%	%	%	%	%	%	%
FeO...	4.5	7.1	3.6	20.54	20.64	26.94	33.46
SiO_2 .	31.7	30.3	32.2	16.77	18.92	15.66	15.42
CaO...	30.7	30.8	36.0	27.07	35.17	35.17	32.54
MgO ..	15.8	21.3	17.6	22.34	13 90	13.84	11.34
Al_2O_3..	13.2	9.3	11.7	7.48	5.30	3.53	2.13

The first three analyses are from one run of the furnace, while the last four are from another run, in which less carbon was charged. This run appears to show that the carbon in the steel can be lowered to about 0.09%, but that any further reduction in the amount of carbon charged merely increases the already large percentage of iron oxide in the slag, without lowering any further the carbon in the steel. Mr. Evans appears to have had still more oxidizing conditions, reducing the carbon in his steel to .06%, with a corresponding reduction in the sulphur, which he succeeded in lowering to .08% in one experiment. The lowest sulphur in the present series of experiments was .34%.

While these analyses only represent the result of smelting an iron ore in an electric furnace with particular conditions of charge, shape of furnace, current density, etc., and changes in any of these conditions might influence the composition of the resulting steel, they indicate pretty clearly that in the electrothermic production of steel directly from a sulphurous ore, it will not be easy to remove the sulphur in an electric furnace operating continuously, like a blast furnace, although it may be possible with intermittent operation, as in an electric open-hearth furnace. Phosphorus, on the other hand, can be satisfactorily removed when low carbon steel is produced.

In regard to the electric smelting of titaniferous ores referred to in Mr. Evans' paper, important work has been done by Alexander Lodyguine (Trans. Am. Electrochem. Soc., vol. VIII, p. 157, 1905), who used a furnace of 11 kilowatts, holding 4½ lbs. of ore, and obtained from a titaniferous ore a low carbon steel carrying mere traces of titanium, or as much as 17% of that metal, by suitable changes in the charge. A. Rossi, whose work in that direction is well known, has smelted electrically as much as 50 tons of pig iron from titaniferous ores, besides accomplishing the same result in an ordinary blast furnace without any electricity at all.

On page 3 of his paper, Mr. Evans states that all preliminary treatment of the ores, such as magnetic separation, roasting, etc., can be omitted, and the ore smelted directly in the electric furnace, but on the next page he suggests the magnetic separation of the St. Lawrence river sands, and it is fairly obvious that on account of the high price of electric energy, the ore should be as rich as practicable before smelting. With regard to roasting, also, it seems likely that a preliminary roast of highly sulphurous ores may sometimes be more economical than throwing the whole work of its removal on the electric furnace.

THE SUPPLIES AND RESERVES OF IRON ORES.

By John Birkinbine, Philadelphia.

(Toronto Meeting, 1907.)

In technical publications and in trade journals attention has been given lately to the probable exhaustion of some mineral products, and it is proper that this be considered seriously, for in all business enterprises the important question of supply and demand should receive careful study. The fact that the minerals discussed are nature's products does not suggest a different treatment from others obtained artificially.

The weather conditions which affect agriculture are features in determining the probable supply of and demand for grain, etc., each season or year, but the supplies of the minerals of which this paper treats, are considered by decades or by cycles of years, for they are not reproductive. The reserves for the future exist to-day, and the problem to be determined is for what length of time these mineral reserves may be expected to supply the demand.

Progress in all metallurgical lines has been rapid, outputs of minerals and production of metals doubling and trebling in a few years, and these augmented quantities have directed attention to the problem of securing a practically permanent supply of raw materials. The question as to the time when the coal beds of the world, of different countries, and of portions of countries will be exhausted has often been presented, and the rate at which forest areas have been denuded, has directed attention to the supply of timber and vegetable fuel being curtailed.

Enormous increases in the use of copper; due primarily to the phenomenal development and utilization of electrical energy, have caused some writers to anticipate that in the near future there may be a shortage of this metal, and the probability of a scarcity of the precious metals has also been prophesied. Tremendous strides in the manufacture of iron and steel, the great combinations formed for the manufacture of these metals, and the purchases or leases of large mineralized areas have brought prominently into notice the possible exhaustion of the iron ore supply.

Some of the discussions have apparently been based solely on an assumption that if a certain rate of increment has been maintained for a specific time, that this rate will be continued, and then the calculation is simple, viz: to the known amount of material now mined, add percentages representing the increased demand for a term of years, and use this as a factor to learn how long the apparent supply will continue. But in any discussions of these problems many features must be taken into consideration.

In all mineral deposits we must face their ultimate exhaustion, because they are not reproductive, at least not to an extent which would make such reproduction appreciable in the supply and demand. In the forests different conditions prevail, but even there the rate of acretion is limited, for trees only mature after a number of decades. This, however, permits of judicious protection and propagation, and the growing appreciation of forestry gives promise, if the interest is maintained, of a supply of timber, which, though restricted, may be depended upon.

Among the features which demand attention in determining the probable exhaustion of supplies of minerals are the methods employed to win them, many of which are and have been wasteful. Mining in years past, and in some localities at the present time, removes the better mineral only, leaving the less desirable in the ground or consigning it to the waste heap, often mixed with refuse material.

A second factor to be considered is the composition of the mineral, for only occasionally are metals found in the metallic state. Nuggets of gold are not uncommon, placers yield gold in metallic particles; lumps and even masses of native silver or copper occur, and galena is fairly abundant, but, although aggregating large quantities, these represent but a small portion of the total metal marketed. Iron in a metallic state only occurs as meteorites, but the aggregate known weight of these hardly amounts to one hundred tons.

As a rule a number of metals or elements are combined in the mineral won from the earth, and the influences of some of these components are deleterious, especially for particular uses; consequently an ore, rich in a given mineral, may be much lessened in value for present use by reason of the association in which the metal is found. But in determining the possibilities of exhausting the supply of any natural product it is unfair to assume present practice and knowledge as limiting the use of the metal under consideration. Methods of treatment, or of beneficiating may bring into demand metallic ores which now are considered undesirable.

Taking the supply of iron ore as the subject for this paper, it must be admitted that in many localities ore has been rejected in the mines, or cast on roads or dump piles, superior to other ores which are successfully used elsewhere. This leads to the natural assumption that the deposit was wrought before its product was required, or that it was not judiciously operated, or that to reach points of consumption the mineral had to stand excessive transportation and handling charges.

In the early history of the iron industry of America the initial enterprises were developed by plants using ores, few of which to-day would be accepted as desirable. The prices received for pig metal were far in excess of what is now commanded, and the cost of production was relatively high, but the progress made in technology, and the improvement in equipment and practice which are responsible for the enormous development of iron manufacture may go far towards overcoming the objection to these now discarded minerals.

Beyond the use of ore, fuel and flux fed to vertical furnaces in which air blast accelerates combustion, there is slight similarity between the production of iron now and seventy years ago. May we not expect as radical changes in the future?

During the first visit of the Iron and Steel Institute and the Verein Deutscher Eisenheutenleute to the United States in 1890, the delegates were divided into two parties, one going north into the Lake Superior Region, and one South to Alabama. It was the writer's privilege to explain to those taking the northern trip that they were walking on a road largely composed of discarded ore, higher in iron, and lower in phosphorous, than their colleagues were contemporaneously examining in Alabama. To-day such ore is not cast into roads, but is shipped, and this shipment is profitable because of the perfected mining, handling and transportation facilities which prevail in the Lake Superior Region, and because of modern metallurgical processes.

A third factor is quantity, for the demands of a single industrial plant for a day are now as great as that of an original plant in a year's time, and the apparent extent of a deposit receives consideration not required in former years. Numerous iron ore mines which have been wrought are now abandoned and lie dormant, not all of them because of leanness of ore or of their composition, but because a number of mines would have to be combined and operated to make a material increment in the supply for a modern iron and steel industry. Most of these deposits had been used locally, but it is not improbable that a combination of several under efficient management would permit of operating them successfully, and delivering the material to consumers by moderate transportation methods at satisfactory cost.

A fourth factor is the utilization of metallic alloys and the possible substitution of other metals for specific purposes. In constructions the modern tendency is to study strains and forces, and prepare designs to secure the best distribution of material. Steel and concrete largely displace wood and brick in buildings, but each member of a structure, vessel, machine or tool, is carefully calculated to reduce the weight or quantity to a minimum. If we employ wasteful methods in mining, in smelting and manufacture, and apply masses of metal, rather than well proportioned parts, if we fail to make use of improved forms and combinations, we may expect to pay the penalty.

As to the future supply of iron ores, a number of papers written by gentlemen who are considered either as local or national authorities, indicate a tenor of anxiety, or prophesy the exhaustion of the iron ore resources of the world. It may be presumptuous to take exception to the opinions of these authorities, but the writer fails to find justification for many of the conclusions stated.

A geological survey is considered an essential feature for any progressive government, whether national, provincial or state, and a large number of academies and colleges educating the youth, teach the elements of geology, while the search for mineral wealth has encouraged the pioneer and the prospector to penetrate into the mountain fastnesses and wildernesses of all countries. But who of these is willing to assume that the world has anything like a complete knowledge of the earth's crust and its mineral wealth.

"The unexplored regions of the earth," is the caption of a recent magazine article by Mr. Cyrus C. Adams, which is illustrated with a series of continental maps, indicating by shaded areas the *terra incognita*. This shows graphically how much of the earth's surface is unexplored and the author states: "Unknown regions have wholly disappeared only from the map of Europe. Its entire surface has been scientifically explored, though much detailed research remains to be made. Its map is approximately correct, and we have a very large if not complete knowledge of its material resources. . . Many years will elapse before any other continent is as well mapped as Europe . . . and a large amount of pioneer work still invites the explorer, for many of the unknown areas have much territorial extent."

As to the North American Continent the statement is made that: "Archæologists say that their branch of science requires the exploration from their special point of view, of most of Western North America from Nevada to the Arctic; but they cannot enter parts of this area without cutting into regions that have never yet seen an explorer. . . Official surveys in Canada have in fifteen years reduced the unexplored areas more than one-half . . . parts of Alaska aggregating an area six times as large as that of New York State are still unmapped and practically unexplored."

There is scarcely a mining district which fails to show instances of early exploitation, abandoned because it was believed to be unproductive, but subsequently developed into important producing mines. The story of mines yielding good mineral, but which were considered as approaching exhaustion, being galvanized into new life by the discovery of parallel veins or deeper lenses is repeated, even in the older mining centres. Giving full credit to the ubiquitous prospector; to the energetic geologist who spends months in the field, and to the mining engineer who explores ahead of his working, can all these claim to have done more than "scratch the surface?" If not we must believe there are in the earth many deposits of value now unsuspected, or at least not located by research. Some deposits of iron ores, passed by because they are lean, or by reason of the phosphorus, sulphur, titanium, etc., which they carry, offer inviting fields for experiment by chemists and metallurgists, for these valuable allies of the iron industry have assisted in making some minerals which would otherwise be condemned, take place among those which are desirable. It is evidently unfair to eliminate from the list of iron ores those which carry considerable titanium without giving credence to the investigation of, and experiments with electric smelting made by the Dominion Government, or the exhaustive and conscientious work of Mr. Rossi. It would be equally unfair to cast aside a highly sulphurous iron ore without considering what could be done by roasting, nodulizing, and in some cases separating. Nor are we justified in designating a highly phosphoric ore undesirable until the possibility of separating this magnetically, or with jigs is considered, the utilization of the mineral to produce basic or foundry pig iron tested, and the possibility of value from the phosphate extracted determined. Some silicious ores formerly rejected, but which now are sought for to mix with less silicious minerals, form another illustration.

The largest iron and steel producer in the world, having enormous reserves, has lately added to these by entering into a lease whereby it has the privilege of mining large quantities of ore from the lands of a transportation company, and the liberal rates agreed upon for transportation to upper lake ports and for royalty, has influenced the general belief in the possible exhaustion of iron ores. This contract starting with the year 1907, provides for mining at least 750,000 tons of ore during the year, and paying therefor $1.65 per ton, on which, at existing transportation rates, 85 cents may be considered royalty on ore yielding 59 per cent. of iron when dried at 212° Fahrenheit. The contract also provides that in each year thereafter the quantity mined is to be increased by 750,000 tons or more, and the royalty advanced 4 per cent. For the year 1917 the minimum tonnage will be 8,250,000 tons, and the rate paid $1.99. Thereafter at least an equal amount of ore (8,250,000 tons) is to be taken out annually, but the 4 per cent. increase in the charge for royalty continues so that in 20 years the rate will be $2.33 per ton, and in 40 years $3.00 per ton will be paid for freight to docks and for royalty. This contract demonstrates that for at least 40 years a demand for metal is expected, and as the agreement continues until the mines are exhausted a continued advance in value is looked for.

That this lease would have a decided influence upon the iron ore trade generally was to be expected. A resume of its terms shows that for the

	Total which must be mined.	Royalty and Freight per ton.
1st 10 years	41,250,000 tons.	$1.65 to $1.96
2nd 10 years	82,500,000 tons	1.99 to 2.30
3rd 10 years	82,500,000 tons	2.33 to 2.64
4th 10 years	82,500,000 tons	2.67 to 2.98

But this contract does not necessarily indicate exhaustion of the iron ore supply of the United States, it rather insures a convenient and desirable supply of raw material to plants already in operation, or under construction, where the operating company has large investments. Believing that it has a market at its own furnaces for all the ores which it can produce, the contract insures the industry a continuous supply. The lease also eliminates a possible competitor with extensive mineral properties, large capital, and an assured market for manufactured steel.

The writer lays no claim to personal familiarity with the iron ore deposits in all countries, and is willing to concede to geologists, statisticians, and metallurgists of other nations a knowledge as to details which he does not possess, but an association with the United States Geological Survey for two decades brought him in correspondence with all the iron ore mines in the United States, and professional investigations of iron ore deposits in various parts of the United States, Canada and Mexico, has aided him in judging the North American reserves. Correspondence extending over a number of years with specialists, and a careful study of published data has also added information concerning the deposits which are available in other countries.

Examination of the various articles and papers which have appeared concerning the iron ore reserves show that some are evidently influenced by patriotic feelings, or affected by the intimate knowledge one has of his own country. As an instance the table presented by Prof. Törnebohm of Sweden may be cited. This table credits to various countries the following iron ore reserves:

Countries.	Workable Ore Fields, million tons.
United States	1,100
Great Britain	1,000
Germany	2,200
Spain	500
Russia and Finland	1,500
France	1,500
Sweden	1,000
Austria, Hungary and other countries	1,200
Total reserves	10,000

This table is not offered to criticize Prof. Törnebohm, nor to emphasize the national bias which may be expected to prevail, nor is it presented with any intention to be unfair to other countries, for the writer's basis of estimation may be open to similar criticisms in so far as the reserves of North America are concerned. An honest endeavor has been made to keep fairly within limits, for the purpose of this paper is a frank discussion of the iron ore resources of the world. If we are facing in the near future, or at any time, exhaustion of an important natural resource, the sooner this is appreciated the better.

Crediting Professor Törnebohm with superior knowledge of European ore deposits, and also of those from Asia and Africa, which have been drawn upon, his presentation of the problem may be discussed from the American standpoint. The estimated reserves allotted to the United States, 1,100,000,000 tons, are less than have been commonly credited to the Lake Superior iron ore region alone. One estimate given currency in the past year puts the total for this district above 1,500,000,000 tons, and the lease above referred to is generally accepted as covering a tonnage equal to 40 per cent. of the reserve allotted by Prof. Törnebohm to the United States.

Professor Törnebohm's figures for the United States are made up of 1,000,000,000 tons for the Lake Superior region, 60,000,000 tons for Alabama brown hematites (this omits any consideration of the red hematite deposits—the principal reliance of the Alabama-Tennessee Furnaces), with 40,000,000 tons left to complete the total of the unmined ores in New York, New Jersey, Pennsylvania, in all the Southern States (except the brown hematite mentioned) and the ores of all Western States, including Wyoming, Colorado and New Mexico where iron ores are now won.

In criticizing these quantities some vague optimistic statements have appeared which are not answers to the Swedish figures, and do more to befog than to clear the situation of uncertainty.

The writer had, while representing the United States Geological Survey, unusual facilities to be posted as to the iron ore reserves of the United States, but he has hesitated to offer estimates on these because the more the subject is studied the more favorable the outlook for the future appears, and he merely suggests the following:

If Professor Törnebohm's estimate of the United States is incorrect we may question his estimates for other portions of the world, at least those outside of Europe. The Swedish Professor credits his own country with ores of high metallic contents and with ore reserves equal to those of Great Britain, twice as great as for Spain, nearly as much as for the United States, two-thirds as large as for either Russia and Finland, or for France. This may be accepted as due to a more intimate knowledge of the enormous deposits of his own country and not to a desire to minimize those of other lands. If his total of 10,000,000,000 tons is accepted as representing the ore reserves of the world his apportionment of these must also be accepted, which is as follows:—

	Per Cent.
Germany	22
France	15
Russia and Finland	15
United States	11
Great Britain	10
Sweden	10
Spain	5
All other countries including Austria-Hungary	12

On this basis Europe would possess more than three-fourths of the iron ore reserves of the world.

He is certainly not optimistic concerning the United States, nor do his figures apparently recognize the known deposits of iron ore in Newfoundland, Canada, Mexico, Cuba or South America. He makes small allowance for Asia, with known iron ore deposits in China, Japan, India and in the Pacific Islands. Nor does he give sufficient credit to the geological reports of Australasia, nor allow for ore reported as existing in quantity in the great continent of Africa.

Of his total reserves 7,700,000,000 tons are given to Europe, 1,100,000,000 tons to the United States and but 1,200,000,000 tons to Austria-Hungary and other countries which include all of Asia, Africa, Australasia, the Pacific Islands, Cuba, South America and North America, outside of the United States. The limited exploitation of Canadian iron ores is evidently assumed as a basis for calculating the reserves, instead of the researches made by the Canadian Geological Survey and individual investigators.

Canada is not mentioned, but is included in "all other countries," attached as an appendage to Austria-Hungary. The known deposits of iron ore in the Dominion are believed to exceed those of Austria-Hungary and but few of these have been exploited. The possibilities of the British possessions in North America are vast, and they may be confidently expected to outrank as iron ore producers some of the countries specificially named.

The prophecies of exhaustion of iron ore depend for their fulfillment on a practical continuance of existing conditions, such as the relative location of iron ore producing mines, iron ore consuming plants, coal deposits and coke ovens, moderate changes in labor conditions; labor saving or transportation facilities ceasing to improve ; manufacturing and industrial centres being mainly limited to those now recognized; on little if any progress in the metallurgical processes. Moreover, such prophecies omit the possibilities of other metals or alloys being procured at a cost competing with iron at or near present prices.

Had the iron-master of half a century ago been informed that in 50 years the production of iron would reach the quantities now annually made, and had he believed this otherwise possible, he would have prophecied that sufficient ore could not be found to produce such an enormous output, and he would have expressed doubt as to the possibility of obtaining fuel to smelt the ores or of assembling the necessary raw materials at blast furnaces.

If we are to estimate the iron ore reserves for future use we must also consider their utilization, which we have no right to assume will be kept within the limits of present industrial development or transportation facilities, nor even confined to prevalent methods of metal production. They are also to be estimated in their relation to the coal reserves if the metallurgical processes of the present are to be followed. Such considerations may make available some ore deposits which are now remote from commercial centres or distant from exploited coal fields, for unless we assume that there are to be no further advances in this particular the utilization of various coal deposits.and of iron ores convenient to them is to be anticipated.

The practicability of electric smelting of iron ore, which has been the subject of detailed study and report in Canada, may be of importance in the future, especially in the treatment of ores whose composition or physical condition are in the present status of knowledge, undesirable for use in the blast furnace, and experiments with iron sands by the United States Geological Survey offer a possible reserve of iron ore of considerable importance. The same resource, ability and skill which have brought the iron and steel industry to its present status may be counted upon to overcome many objections to ores which are impure or distant, and with new metallurgical methods ores now avoided because of elements in their composition may be in demand.

It is well known that some iron ore deposits are removed from present or immediately prospective transportation facilities, are distant from fuel, are lean and must be beneficiated. But when we remember how iron ores of the Lake Superior region have been the incentive to gridiron that section with railroads and to build an enormous inland marine, equipped with loading and unloading facilities second to none, distance becomes comparatively unimportant where ores are conveyed by boat for less than a mill per ton mile, and where long railroad hauls can be provided at 3 mills per ton mile. Under such circumstances ore can be carried to fuels or fuels to ores, or the two can meet at desirable points at costs which need not be prohibitive.

The liberal use of Swedish, Spanish, African and other foreign ores by European and American furnaces and the large proportion of the ore supply of the United States and Canada coming from the Lake Superior region illustrate how transportation facilities affect the locality of supply. So beneficiating, modern mining methods, or economies in mechanical appliances, permit lean ores to be mined, roasted, comminuted or separated at small cost. In the existing stage of mining and mechanical development, and with the study which has been devoted to labour saving appliances, transportation facilities, methods of beneficiating ores, &c., the leanness of ores and present distances from points of consumption are not to be given too much importance.

Using the lease before mentioned as a basis we may assume that transportation costs will decrease rather than increase, and accept the present rate as fairly covering this item. Deducting, therefore, 80 cents from the rates fixed, the royalty or apparent value of the iron ore in place is expected to advance from 85 cents to \$1.16 per ton in the first decade, from \$1.19 to \$1.50 in the second decade, and from \$1.87 to \$2.18 in the fourth decade. In other words if the lease continues and the ore lasts for forty years its value in the ground will be nearly trebled.

Accepting for the purpose of discussion this increment of value, there would seem good reason for exploiting a number of iron ore deposits which are now inactive, because of their character or location. The convenience of using ores rich in iron and the facilities for obtaining such material as wanted by purchase have encouraged the transportation of desirable mineral over long distances to furnaces close to which relatively inferior ores lie unused. The freight added to the selling price of these more desirable ores in some instances brings the cost of producing pig metal above what may be expected by using relatively inferior and cheaper local ores.

It is hardly equitable to compare ore reserves on the basis of what is esteemed as desirable by the present practice in various countries. Thus in the estimates made by Professor Törnebohm for the Swedish Government, he credits Great Britain with as much ore as he allots to the United States and Germany with double that quantity of iron ore for future use; but for the United States he assumes a yield of from 45 to 67 per cent. and for Germany from 30 to 45 per cent. In other words the estimated 1,100,000,000 tons for the United States is all treated as of a grade superior to the richest of the British or German mineral. Dividing the ore reserves by the percentage of iron, Professor Törnebohm allots to the various countries the following:—

	Tons of Metallic Iron.
United States	603,166,600
Great Britain	295,000,000
Germany	825,000,000
Spain	249,375,000
Russia and Finland	637,500,000
Sweden	611,538,460

(This statement was prepared by Mr. Chas. K. Leith.)

Germany is thus given pre-eminence as an iron producer and Russia and Finland, Sweden and the United States are placed next in order, followed by Great Britain and Spain. The difference in labor and transportation costs in the various countries or districts will permit those where these items are relatively low using lean ore at a profit. But if necessary the United States could utilize, and some plants are now smelting, mineral closely approximating the yields of iron mentioned as employed in Great Britain and Germany.

The papers and discussions upon the probable exhaustion of iron ore supplies serve a good purpose by awakening interest in a subject of importance to all who produce, manufacture or use iron or steel. Results to be anticipated from such discussions are: that known deposits of iron ore classed as undesirable by reason of location, apparent volume, physical structure or chemical composition may receive consideration; that some ore bodies now unopened may be exploited and that mines which have been wrought in the past may re-enter the list of producers, while encouragement to develop new sources of iron ore may come from the discussion.

The fact that a number of ores considered unattractive by blast furnace managers can be made available has received less attention than would have been given had the better ores been more troublesome to obtain. But, roasting pyritiferous and other ores has been followed for many years; more complete desulphurization and nodulizing of comminuted sulphurous ores is now practiced on a commercial scale; a large tonnage of magnetite is passed through magnetic separators to reduce the silica or phosphorus contents; and practical demonstration has shown that titaniferous iron ore when properly fluxed may be economically smelted; while electrical smelting is being thoroughly investigated. The field for beneficiating and treatment of iron ores is large and promises a considerable addition to the possible iron ore reserves.

The writer fully appreciates the importance of a frank study of natural resources and the folly of wasteful use of them, especially such as are not reproduced. He also is satisfied that his record as an investigator of deposits of iron ore and his reports upon industries remove him from the class of optimists who expect every indication of ore to develop into a great mine, or that each locality where ore and fuel can be assembled advantageously will become an important prospective industrial center.

The problem is to be studied from the standpoints of deposits now exploited, of those unwrought, but concerning which ideas of their extent and character have been formulated by exploratory work, and of those whose locations are made known by prospecting, with allowances for probable iron ore supplies suggested by geological conditions.

If the study of the iron ore reserves is undertaken in connection with present or possible fuel supplies, with consideration of prospective producing and consuming centers, the time when iron may be a "precious metal" or the available supply of iron ore becomes exhausted may be so far in the future as to allay any present anxiety.

The greatly augmented production of iron ore is undoubtedly making such heavy draughts upon the developed iron ore mines in the world as to awaken interest in the question of future supply, and unless there are additions to these, one need not be pessimistic in anticipating a shortage.

On the other hand, when the probabilities of located, but not developed deposits, are considered, when the possibilities of advanced metallurgy are studied, and when we realize how much of the earth's surface and geology is still unknown, or imperfectly known, one need not be an optimist to express confidence that an ample supply of ore will be found to meet the needs of mankind.

But he who formulates estimates of quantities from which to prophesy the end of the world, as far as iron ore is concerned, or he who multiplies these quantities by vague percentages, demonstrates how little reliable data is available concerning the iron ore reserves.

THE BRUCE MINES, ONTARIO, 1846–1906.

By H. J. Carnegie Williams, Bruce Mines, Ont.

Toronto Meeting, March, 1907.

This history of Bruce Mines may, the writer believes, prove of interest not only on account of the property's value, but because of it's comparative antiquity. It is sixty years ago since the original locator, a Mr. Keating, who was connected with H. B. M. Indian Department, was shown by Indians the copper deposits of Copper Bay and Bruce, the latter being so named in honour of Lord Elgin, one of Canada's distinguished Governor Generals.

In the meantime the Montreal Mining Company had been formed, and an expedition, in charge of Mr. Forrest Sheppard, left Montreal in May, 1846. Mr. Sheppard selected eighteen tracts or locations, each one containing ten square miles. The price paid was, according to Mr. E. B. Borron, £150, Halifax currency, for each location and 20c. an acre. On a re-examination of these properties the Directors became dissatisfied and blamed Mr. Sheppard; although in fairness to him it should be stated that one of the locations covered the famous Silver Islet.

By the advice of Captain Roberts the Montreal Company purchased the Bruce Mines location for £40,000, Halifax currency, and concentrated all their efforts in opening up the Bruce section on the Cuthbertson location. In 1848, a small party, under Mr. Harris, examined the location adjoining to the west and known by the name of Huron Copper Bay on the Keating location. They appear to have done a little work, sinking a shaft within a hundred yards of Lake Huron. The lode here is small but of good quality. They also discovered and reported on two other lodes further inland, one of which has been rediscovered this year; whilst another discovery is attracting a great deal of attention on account of the value of the ore disclosed and the width of the vein. It is curious to note that apparently no attention had been paid to these discoveries since 1848.

Meanwhile, in the fall of 1848 the first engine house was erected and machinery installed. Unfortunately, the severity of the climate was not allowed for in the construction of the building, and in consequence, frost got in the stone work, and when the machinery was set in motion, it collapsed.

In this year the late Sir William Logan made a very exhaustive examination and reported very favourably on the property. In 1849, the small settlement consisted of 77 miners, 65 laborers, 4 boys, 11 blacksmiths, carpenters and other artisans, 2 mining captains, 1 engineer, 2 clerks and 1 superintendent, giving a population, including the families of the workmen, of about 250 souls. Cholera caused several deaths and delayed the erection of machinery, so that it was not until the summer of 1850 that any returns could be made.

The fact was early appreciated that the keynote of success was the smelting of the ore on the spot, and with this in mind the President of the company, the late Hon. James Ferrier, brought out from Wales a copper refiner and three furnace men. This first attempt, unfortunately, proved a failure and the smelting works were destroyed by fire. The slag was in later years sorted over and the richer portion shipped to England. Assays made by the writer from materials remaining show over 2% of copper. Ferrier's name is attached to the deepest shaft on this section of the property. The shaft is presumably three hundred feet in depth only, as a record exists of drifting operations east on the lode, in 1868, at the 50 fathom level. (See Plate I showing width of lode at eastern end.)

The dressing operations seem to have been very crude. Crushing with Cornish rolls, break staff jigs, and concave buddles appear to have been used. Evidently the crushing was not carried far enough and it is highly probable that they lost three-fifths of the ore contents. At any rate, the results obtained were so different to the estimates, that in 1851 all the officers resigned or were dismissed. In 1852, Mr. E. B. Borron took charge and introduced the tribute system, the men being paid £5 a ton on ore dressed to 15% and a bonus, varying in price according to market fluctuations, of seven shillings and six-pence per unit. As the ore was dressed to 20%, this would mean £6 17s. 6d. per ton of 21 cwts. A small dividend was declared in 1853, followed by a larger one in 1854. In the latter year the misfortune occurred of the loss of the company's steamer, with nearly all the materials and machinery required for mining and ore dressing operations during the winter. There being no other means of transportation it was impossible to replace this equipment until the following summer.

In 1854 Mr. Sampson Vivian, having acquired a lease for fourteen years from the Montreal Mining Company, of the western portion of the property on a royalty of 5% on the dressed ore, succeeded in forming a company in England, under the auspices of Messrs. John Taylor & Sons. This concern, which was called the West Canada Mining Company, commenced opening out what is known as the Wellington Section; but soon after a teamster, named George Clark, searching for strayed cattle, found a lode, from which the moss and leaves had been burnt off in a recent bush fire, in consequence known as the Fire Lode, which name it still bears. He was rewarded with a barrel of flour. A shaft was started on this new find, and in digging a water course another and a wider lode was encountered. On tracing these to the westward it was found that a junction took place on the adjoining Huron Copper Bay location, and Messrs. Taylor and Sons very wisely secured a lease upon this and eventually purchased the whole location, including the Bruce Mines, from the Montreal Mining Company in 1864. It would appear that the Bruce area produced, up to 1857, 3,239 tons of 2,000 lbs., with an average value of 18% copper, containing 583.22 tons of fine copper.

The capital of the West Canada Mining Company was £200,-000, and the cost of installation and development, with all the then existing difficulties of transport, were so heavy that it was not until 1861 that the mines commenced to pay dividends. Dressing floors were erected on the Wellington and Huron Copper Bay sections; but the buildings not being enclosed, operations were confined to the summer months, the ore being mined and a large proportion left underground during the winter. The following statistics have been kindly placed at my disposal by Dr. Robert Bell, F.R.S., etc.: —

		Tons (2000 lbs.)			Tons fine copper
1858	Bruce & Wellington produced .	1266 of	21.94%	copper	= 277.76
1859	do do do	1803	21.35	do	= 384.94
1860	do do do & Huron Copper Bay......	2411	20.50	do	= 494.25
1861	Bruce produced .... 555; " Wellington do .... 1381; " Huron Copper Bay do .. 485	2421	19.60	do	= 474.51
		7901 tons			1641.46

In 1862 a disastrous bush fire almost wiped out the entire village. The company sent a subscription of £300 to assist those who suffered most, but the men refused to accept anything and asked to be allowed to devote the money to form a nucleus for a public school fund, which was permitted.

From 1861 to 1868 an era of prosperity set in. The price of copper was good. At first the concentrates were shipped to England, but afterwards to the United States, until the war broke out; when a tax of five cents per pound was put upon copper, thus closing this market.

The average work done during nine years, according to the evidence given by Mr. William Plummer before the Royal Commission in 1890 was "sinking 87 fathoms, driving 113 fathoms and stoping 1,241 fathoms" per annum. This shows very plainly that the stoping ground opened up must have been very wide, taking into consideration the relatively small amount of the development work; in fact, quoting from the evidence of Mr. Frank Prout before the same Commission, "we generally paid about $35 a fathom; the ordinary width being ten or twelve feet; when wider we paid more." Forty dollars per lineal fathom, however, was nearer the average price paid, so presumably the lode was over twelve feet wide.

About 350 men and boys were employed, of whom 200 were underground. The cost of superintendence, wages and materials appears to have averaged $12,000 per month. An extraordinary method of working seems to have been adopted, the price for driving a level on contract being $120, the men finding powder, caps, fuse and candles, also steel sharpening; the company doing the mucking and hoisting. Whilst shaft sinking was $240 and stoping $40, but the men were only allowed to do a limited amount of work, so that their average earnings were $40.25 a month. The dollar was calculated on Halifax currency of $4 to the pound sterling.

During the years 1862–1868 the following shipments were made:—

		Tons	Tons (2000 lbs.)					Tons fine Copper.
1862	Bruce.	446						
	Wellington.	1501	3154	of	19.65%	copper	=	619.76
	Huron Copper Bay . .	1207						
1863	Bruce.							
	Wellington.		3719	"	20.00%	"	=	743.80
	Huron Copper Bay. . .							
1864	Bruce.							
	Wellington.		3457	"	19.48%	"	=	673.44
	Huron Copper Bay . .							
1865	Bruce very liitle from)							
	Wellington.		3332	"	21.24%	"	=	707.71
	Huron Copper Bay . .							
1866	Bruce (very little from)							
	Wellington.		4157	"	20.00%	"	=	831.40
	Huron Copper Bay. . .							
1867	Bruce (very little from)							
	Wellington.		3224	"	20.00%	"	=	644.80
	Huron Copper Bay . .							
1868	Wellington.							
	Huron Copper Bay . .		3297	"	20.00%	"	=	659.40
			24340					4880.31

In 1868 the visit is recorded of Mr. John Taylor, Jr., who made a very full report upon the property, and the following extract sums up the situation at that time in a few words: First, heavy costs of dressing; second, great losses of copper during the process of concentration; third, heavy freight from the mines to England. He made two important recommendations; the smelting of the ore on the spot; and the reduction of the copper by means of salt and iron, known as the Henderson process.

Presumably after due deliberation, it was resolved to send out, in 1869, Mr. Charles de Bussy to conduct a series of experiments as to the advantages of the Henderson process; and that these were successful is proved by the Company erecting during the years 1870-1871, a plant at a cost of $200,000 (see Plate II), showing all that remains to-day. From the returns it is evident that operations were conducted on a very limited scale during 1872-1873 and were then discontinued. It is stated that the cost of salt, scrap iron and coal was so heavy that the works could not be operated at a profit, although the extraction appears to have been as nearly perfect as possible. The writer has obtained 0.18% of copper as a maximum from the heaps of waste.

During 1868 a certain amount of activity was shown in trying to make fresh discoveries. A shaft was sunk on the north lode about one mile north of the Bruce section, and sunk 75 feet, but work was stopped, is stated, because the men objected to walk so far to their work, and the shaft house headgear, etc., was destroyed by fire. Nearly equidistant between the Bruce and Wellington sections the lode was found, and a trial shaft sunk 75 feet, then drifted on for 200 feet in each direction, viz., east and west, and a small stope put in on the west drift. Work was stopped here because it was said to cost too much to cart the ore to the dressing floors not half a mile away; but the reason is difficult to understand as the ore is of good quality and the writer's assays, taken every six feet, will average over 4%. Probably this was considered too poor in those days.

During the years 1869 to 1875 the following shipments were made:—

		Tons (2000 lbs.)			Tons Fine Copper
1869	Wellington & Huron Copper Bay........	2562	19.50% copper=		499.59
1870	do	2542	18.75 " =		476.62
1871	do	2030	19.00 " =		385.70
1872	do	1373 pyrites	18.00 "	= 247.14	398.78
		14.56 precipitate	80.00 "	= 11.64	
		140 ingots	100.00 "	= 140.00	
1873	do	1425 pyrites	18.00 "	= 256.50	360.88
		35.84 slags	10.00 "	= 3.58	
		89.60 precipitate	80.00 "	= 71.68	
		29.12 copper	100.00 "	= 29.12	
1874	do	1167	18.00 "	= 210.06	
1875	do	703	18.00 "	= 126.54	
		12111.12			2458.17

Thus showing that 47,593 tons, of 2,000 lbs., were shipped, with a copper contents of 9562.96 tons, and sold, according to the best authorities, for $3,300,000. The average copper contents were 20.09.

What quantity of ore was mined must be a matter of conjecture, but it is known that the late owners of the property sold 50,000 tons of tailings; or, as they are locally called "skimpings," and the writer has measured 117,000 tons remaining on the property, whilst a quantity has been washed into the Lake, and the Canadian Pacific Railway ballasted their line from here to Sault Ste Marie, a distance of 36 miles, from the same source. It may fairly be assumed that 400,000 tons of rock were mined, of which 100,000 remains as waste on the dumps, and 300,000 tons probably can be shown as having been treated. With the exception of sinking Bray's or No. 2 Shaft to 420 feet, all this tonnage was won from above the 360 foot level.

If the average value of the ore, after deducting the waste, was 4½%, it should have yielded 13,500 tons of copper, but as only 9,852 tons of copper are shown to have been shipped, it is evident that a loss of 41% was made in the treatment. Of course, this is merely an hypothesis, but is remarkably close to the estimates of both Messrs. Borron and Plummer, who compute a 40% loss. It will be noted that there are three epochs of seven years; the first, development; the second, bonanza; the third, gradual diminution for want of development. The debacle came in 1875, but after 1872 no developments were carried on, and presumably the costly experiment of the Henderson process so disheartened the proprietors that orders were given to take everything away worth getting out, at a minimum of cost. The result of this policy can be seen in the "Big Cave" (see Plate III.) Here the junction of the two lodes took place and the ore must have been surprisingly rich, as it is currently—and the writer believes,—truthfully reported that they had at one point 24 feet wide of ore. The greater part, known as "prill," was simply put in barrels and shipped. It is satisfactory to say that there is considerable evidence to show that this shoot of ore continues downwards, and the present Company will benefit thereby. At any rate, the result of this way of working caused the "Big Cave." A party of six men had been working on a stope from October, 1874, to March, 1875, and according to measurement, the record of which exists, they had broken 33 fathoms, 1 foot, 3 inches (width unknown, but probably 10 to 12 feet.) Following the usual custom the ore was left underground. Signs of what was coming were frequent, so much so that some men left the mine rather than run the risk. Fortunately for everybody "the cave" occurred on a Saturday night, so no lives were lost, and the stope not having been carried below the fifty fathom level, the sixty fathom level remained intact, the only loss being the ore accumulated as above stated. This was virtually the finish, although small parties of tributers worked during 1876. The mine was then closed down for it's long sleep until 1898.

The property was in that year secured by some English capitalists, who, after unwatering the shafts, had an examination made by the celebrated mining engineer, Dr. Hatch. The result of this report was so satisfactory, in spite of the fact as above stated that for three years the mine was literally robbed, that a company was formed in England and work resumed. Unfortunately, like so many other similar enterprises, the cart was put before the horse, a concentrating mill being erected to treat 400 tons a day, whilst underground development was not undertaken on an adequate scale. They, however, succeeded in proving that the lode is no less than 18 feet wide and over 3% in value, and this at a depth of 420 feet. Then a fire occurred burning down the newly erected pithead gear, shaft house, with crusher and ore bin, blacksmith's shop, men's dry, power and boiler house, etc. This, naturally, was discouraging, and occurring as it did during the South African War, the principal shareholders, who were greatly interested in the gold mines of the Transvaal, called the General Manager to England, and not being satisfied that an output of 400 tons a day could be guaranteed, determined to stop all operations except those necessary to keep the mine dry. Even this they eventually stopped on April 23rd, 1904, and in March, 1905, the writer was commissioned to pump out and make an examination. This was done, and, the report being satisfactory, a company was registered in Ontario, but with English capital, and Wellington and Huron Copper Bay sections have been again unwatered.

The property held by the Company consists of the entire mineral rights over the old original grant of twenty square miles;

but only 655 acres of surface rights remain of the former 12,800, of which about 300 form part of the town of Bruce and consist of valuable town sites, docks and water rights. In addition to the 400 ton concentrating mill there is all the plant and machinery necessary for the mine's development in full working order.

The copper ores, chiefly chalcopyritic, which are found in such abundance, apparently are distributed in well defined bodies or zones, but taking into consideration the wide area over which discoveries have been made in this section of the country, and recognizing that these are only a fraction of the whole, it is impossible to deal with this subject within the limits of this paper. Suffice it to say that hardly a township exists without one or more ore bodies, and that it might fairly be stated that in the more settled parts there is hardly a farmer but has some indications of mineral wealth on his property; and it is evident that whatever treatment or process may be generally adopted in the future, it should be one that would enable the smallest, as well as the largest, producer to participate in, and thus aid in the gradual development of what must prove an immense addition to the mineral wealth of the country. In fact, the Company is being constantly urged to erect a smelter sufficiently large to serve the general public in addition to its own requirement and this should prove a great boon to the ore in the locality on whose properties are showings of copper.

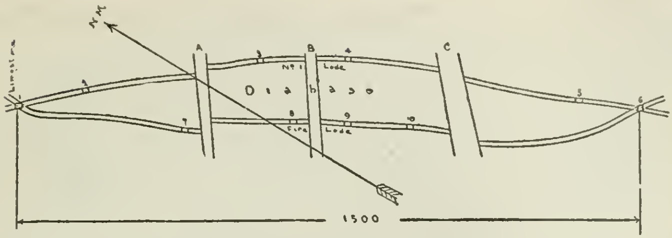
GEOLOGY.

The geological sequences from Lake Huron through the Bruce Mines to the north are diabase in the lower slate conglomerate, encircled by dolomitic limestone and followed by the upper slate conglomerate, red quartzite, red jasper conglomerate, with white quartzite forming an anticline of which the white quartzite is the apex. The lodes have an average strike of 25° W of N, and dip, as a rule, almost vertically to the S. W., until the summit of the anticline is passed, when the dip, if any, is reversed, although there are ore bodies found with an E. and W. strike and dipping S. W. These occur in the upper conglomerate, and appear to be true fissures. All these rocks belong to the Huronian series.

ORE OCCURRENCE.

We have to deal with three classes of ore occurrence. First, in the quartzite, specular iron is often associated with the chalcopyrite, and in places chalcosite is found on the surface. This, on weathering, assumes the appearance of iron, so that the prospector should be warned of the resemblance. The siliceous ores are often accompanied by veins of calcite. Secondly, the fissure veins of the upper conglomerate. Although these were known in the earliest days they appear to have been disregarded until recently, when a most important discovery was made on this property, and a most interesting one from a mineralogical point of view, as a collection of copper ores might be made from it, both black (melaconite) and red (cuprite) oxides, the latter followed by native copper in leaflets, besides the ordinary bornite, chalcosite and chalcopyrite, with apparently a little pyrrhotite. These can be seen *in situ*, not vertically as might be expected, but horizontally, the native copper being to the south and followed by the other ores. The only other instance of this order of deposition known to the writer is found at the Spassky Copper Mines in Siberia, where solid chalcosite forms one wall with ore diminishing gradually in value over a width of thirty feet, where it carries only 2%. As the gangue of these ores carries considerable lime they would furnish suitable fluxes for the siliceous ores. The third series are the lodes formed in the diabase. A peculiar characteristic of these is that the larger deposits of quartz are found on the sides of what are to-day merely rounded knolls protruding above the ordinary ground level. In many cases glacial action has sheared the crown off so that almost flat tables are formed and then the numerous reticulated veinlets are very clearly seen crossing in every direction. (See Plate IV.) At times the larger ore bodies cross one another and form important junctions, although continuing a serpentinous course with little or no alteration of their mineral contents, and yet preserving their average strike.

A typical plan of this occurrence can be seen on the Wellington and Huron Copper Bay sections, now being worked by the Copper Mining & Smelting Company of Ontario Limited.



A. Aphanitic Dyke, 25 feet wide.
B. " 20 "
C. " 40 "
No. 1. Palmer's Shaft, 360 ft. deep.
" 2. Bray's or No. 2 Shaft, 450 ft. deep.
" 3. Rowe's Shaft, 240 ft. deep.
" 4. Mitchell's or No. 3 Shaft, 240 ft. deep.
" 5. Scott's or No. 4 Shaft, 340 ft. deep.
" 6. Crazie's Shaft, 270 ft. deep.
" 7. Unknown. Depth about 75 ft.
" 8. Collins' Shaft, 200 ft. deep.
" 9. Gribble's Shaft, 200 ft. deep.
" 10. Knight's Shaft, 210 ft. deep.

The numerous shafts are relics of the time when hoisting was done by a horse whim.

Dolomitic limestone comes in at the N. W., and the northern portion has not been followed up. That on the south has been explored for 480 feet, by an adit parallel to the limestone.

This gigantic horse, 1,500 feet in length, is crossed by three dykes, the material of which differs but slightly from the ordinary country rock. The centre one has not caused any alteration, but the other two are fracture planes and the entire mass of ground has been forced twenty feet to the north, throwing the lodes accordingly. Whilst at the junction to the west of Palmer's shaft a very rich ore body was found, in parts twenty-four feet wide, to the east, at Crazie's, the junction did not produce anything like such high value, although the quartz is from eight to sixteen feet wide.

The principal ores are chalcopyrite with a little bornite, and the gangue is highly siliceous. At the surface some very fine deposits of chalcosite were mined and bornite at the 270 ft. and

360 ft. levels is again coming in. A typical analysis of poor ore shows:—

Silica	91%
Iron	4.35%
Gold	.01 oz.
Silver	.80 oz.
Copper	2.21%
Lime	.70%
Sulphur	Not stated.

The average run of the mine being $3\frac{1}{2}\%$, whilst the known extent of the lodes is 8,000 feet longitudinally.

TREATMENT OF ORE.

After being crushed to pass a $2\frac{1}{2}$ inch ring, the ore was fed to 24 inch rolls, from which it was elevated to sizing trommels, the over size coming back for recrushing, the finer feeding direct into the jigs. The waste from two series of jigs was again brought back for crushing, whilst the finer stuff went into spitzkasten and fed on to six foot Frue vanners, the waste from the second series of jigs being taken to a six foot Bryan mill and a 30 inch fine crushing roll. The resultant—product was lifted by bucket elevators and fed to Linkenbach double-deck tables, 16 feet in diameter. Eventually these finer slimes were put over another series of Frue vanners. This process of fine crushing appears somewhat complicated, but the idea was to crush very fine to make a high concentrate. They succeeded in obtaining 25.15%, whilst the tailings went 0.53%. (See Plate VII of Mill).

Having obtained the concentrates it was necessary to find a market for them and this meant heavy freight and smelter charges. Therefore it is quite apparent that if blister copper could be produced the bulk of the ore, not only of this property but of the neighbourhood, could be cheaply smelted, as they do not contain anything deleterious in the shape of zinc, arsenic, etc.

In order to do this a customs smelter should be built, so that the siliceous ores of our property might be mixed with the ores containing lime and iron, to form a suitable mixture for economic smelting. The district is traversed by the Canadian Pacific Railway from Sudbury to Sault Ste Marie, and bounded on the south by Lake Huron. Freight on coke and coal from the United States is low, and if it is settled that coal for coking purposes can be introduced free of the present duty of 53 cts. per ton of 2,000lbs., another industry would be added to the national wealth. In the event of the Provincial Government granting a bonus on refined copper, capital might be induced to erect a refinery, this indeed being the programme which the Copper Mining & Smelting Company of Ontario have seriously considered. The Governments, both Dominion and Provincial, have voted subsidies to the Bruce Mines and Algoma Railway, which traverses the property from south to north, and this, if pushed on to the C. P. R. main line at Chapleau, and thence on to the Grand Trunk Railway now in course of construction, would open out great wealth in timber and mineral, and tap the great Clay Belt, but nothing is being done. Aid to improve existing roads and make new ones would be highly beneficial, as the writer is of the opinion that the solution of the whole problem of making copper mining a great success may be found in the erection of local smelters.

Having thus brought the history of Bruce Mines up to the present date, it may be stated in conclusion that since the first Exhibition in Hyde Park, London, England, 1851, to the St. Louis Exhibition in 1904, exhibits from these mines have gained medals for the display of ore, etc.

The high price of copper must have been a great inducement for the first owners of the property, as the following will show:—

1853	£136–16–0	per ton
1854	£140– 2–0	"
1855	£141–10–0	"
1858	£140– 0–0	"

To-day the market price is £102 per ton. Is it possible that we are again approaching a period of high prices, when the present company, with modern appliances and easy transportation, will reap greater benefits than were ever derived by former shareholders at the highest point of their prosperity.

The writer has purposely not dwelt at length on the geological features of the area, as the report now in course of preparation by Messrs. Ingall and Denis, of the staff of the Geological Survey of Canada, embodying as it does the work of two years in this neighbourhood, will, when published by the Department (a preliminary report having already appeared), 1904*, afford a far more complete generalization than can here be attempted.

* Geol. Report, 1904, pp. 179-189.

PLATE I.—Easternmost Exposure, Bruce Main Lode.

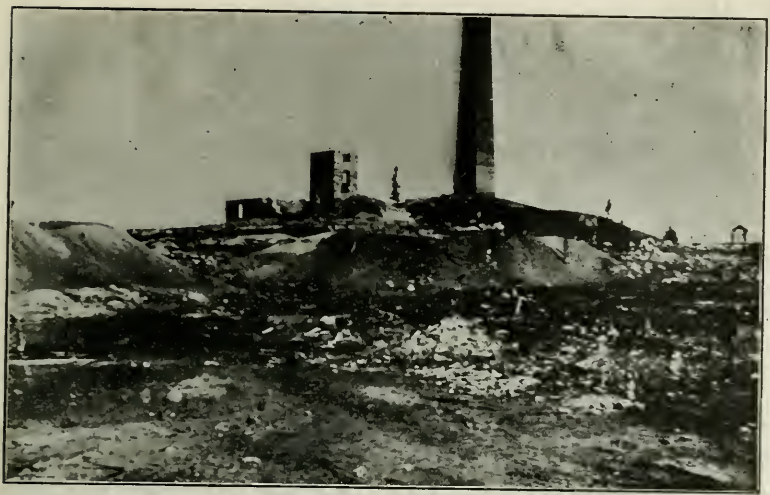


PLATE II.—Old Lixiviation Works, Looking North, Bruce Mines, Ont. The Smoke Stack has since been pulled down.

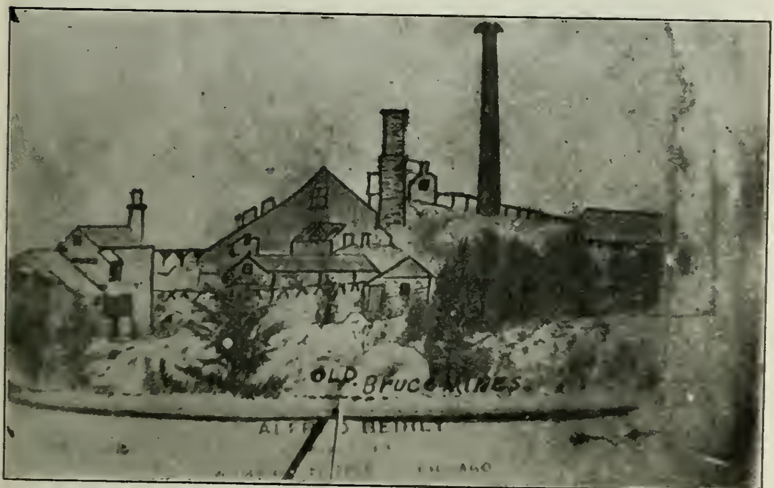


PLATE III.—Sketch of Lixiviation Work, 1871, Bruce Mines, Ont.

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PLATE. IV—No. 1 Lode. No. 2, or Fire Lode. East End of Big Cave, Bruce Mines, Ont.

PLATE V.—View of Cave taken further back from East, 1898, Bruce Mines, Ont.

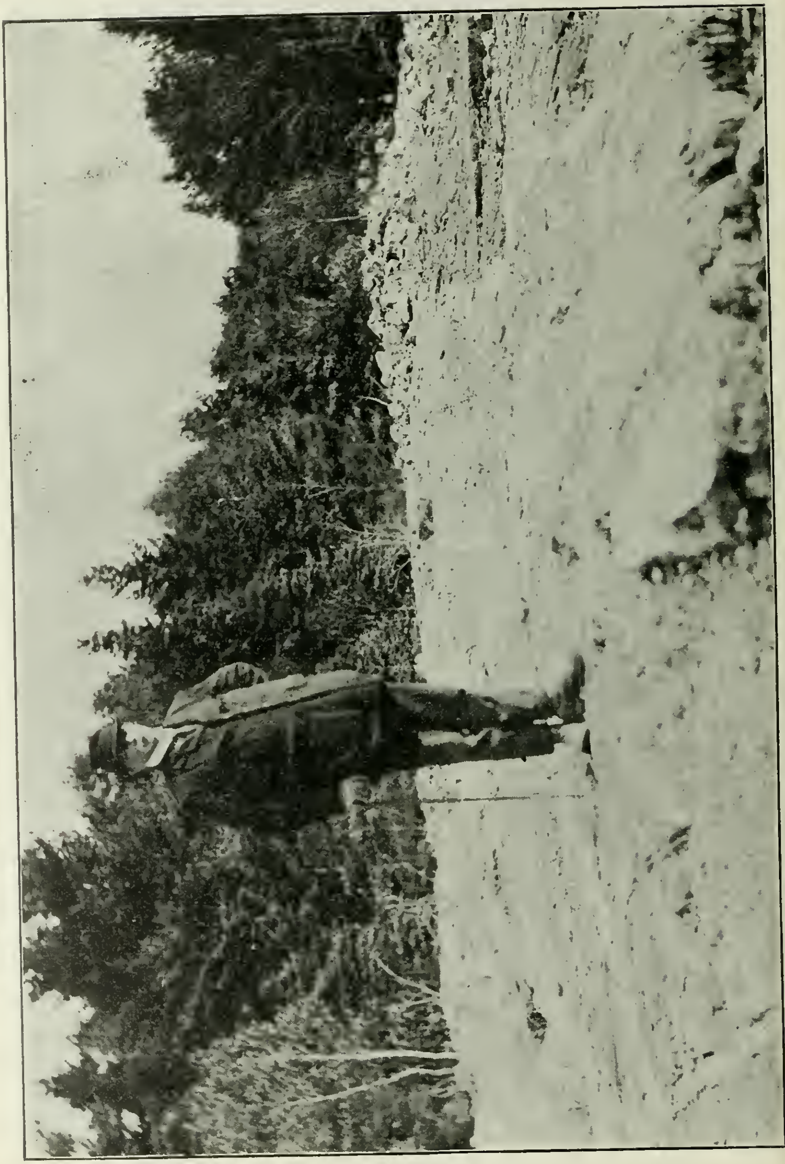


PLATE VI.—Quartz Veinlets in Diabase, South Lode, Bruce Mines, 1906.

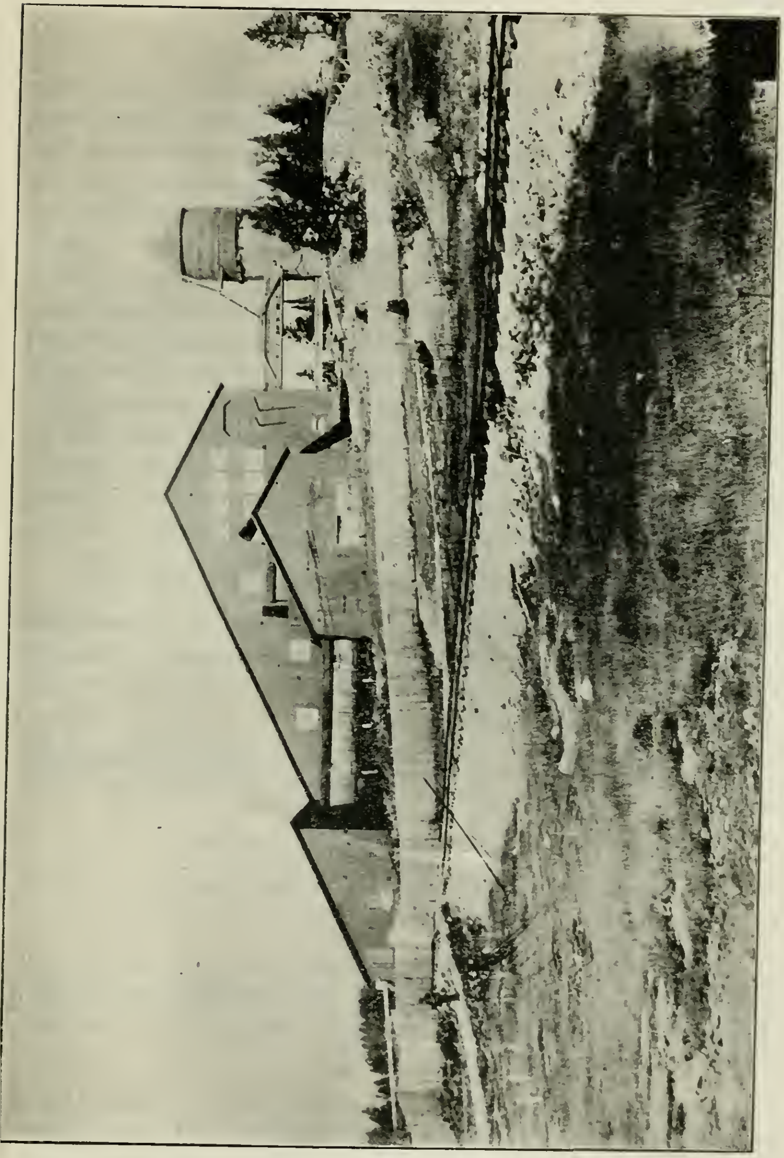


PLATE VII.—East End of 400-ton Mill. The Copper Mining and Smelting Co. of Ontario, Ltd., Bruce Mines, 1906.

DISCUSSION.

DR. BELL—I have often visited this property since 1860. At that time it was a very busy place. The works were conducted in the old-fashioned way. After concentrating the ore to about 20% it was shipped to England. I also saw the smelting works carried on by the late Mr. Hugh Fletcher, father of Mr. Hugh Fletcher of the Geological Survey. I took pains to collect statistics, some of which were embodied in the statement given by Mr. Williams, showing that notwithstanding the great waste, expense and losses in carrying on these operations, $3,300,000 worth of copper were taken out, and now and then there was a profit on its production. I believe the veins are sufficiently large and numerous to produce even more copper than ever in the past, and that we may now be on the eve of seeing a number of years of copper mining which may perhaps exceed anything that was done in the old time with which I was familiar.

MR. CIRKEL—What percentage of copper was taken out?

MR. WILLIAMS—There were 47,000 tons of concentrates averaging 20%. They had what they called prills or prill ore, which rich lumps were shipped in casks just as it came from the mine, and went from 20 to 25% copper.

MR. CIRKEL—Have you any records to show the proportion of clean ore to the lean ore?

MR. WILLIAMS—No, I cannot find any records.

MR. CIRKEL—You have no idea of how many tons it took to make one ton of concentrates?

MR. WILLIAMS—Supposing 400,000 tons were mined and 100,000 tons was waste, that would leave 300,000 tons treated, showing that it took rather more than 6 tons of ore to produce 1 ton of concentrates.

DR. BELL—I think in the old reports of Sir William Logan on the mines about 1848 and onwards, there is shown the percentage of copper pyrites and other ores to the whole mass. Also in the reports of the late Sir Hugh Allan, who was president of the mining company at that time, I think those details are given.

MR. WILLIAMS—All the books and everything have been destroyed. I have only found three books that give me any information. There are some points cannot ascertain to-day, and I wish anybody possessing data on the subject would allow me to see, especially any plans or sections.

MR. CIRKEL—I saw a report last week in the Montreal *Star* that silver had been found in your district. Did you hear that report?

MR. WILLIAMS—I saw a report referring to a discovery near Sault Ste. Marie. I have seen a very nice sample of cobalt. They produced one the other day that they claimed they got not far from Bruce. I would not like to say that they did.

DR. BELL—In some parts of the veins gold was found in sufficient quantity to detect it. It would probably never pay, but on making assays small quantities of gold are generally present. The lodes cut dark diorite, and on the surface there are considerable quantities of horse-flesh ore.

MR. WILLIAMS—We have samples in from 2 discovery on our property of $2\frac{1}{2}$ feet, assaying 62% of copper, then there is two feet of diabase separating the rich ore from seven feet six inches of sulphide ore running about $7\frac{1}{4}$%.

MR. MILLS—I was speaking yesterday to Prof. Willmott about that reported discovery of silver at the Soo, and he said there was no truth whatever in it.

THE GEOLOGY AND ORE DEPOSITS OF FRANKLIN CAMP, B.C.

By R. W. Brock, Ottawa, Ont.

(Toronto Meet ng, 1907).

The steady increase in the mineral production of British Columbia, which, last year, is estimated to have exceeded $26,000,000.00, the dividends now being paid, not by one concern but by a considerable percentage of the operating mines, the continued increase in the demand for copper and the corresponding great advance in its price, the opening up of new territory by railway construction, the general prosperity throughout the commercial world, have all contributed to a revival of outside interest in mining in this Province, and to restore that confidence which, since the collapse of the '97 boom had been withdrawn. This renewal of interest will find expression in the reopening of properties now lying dormant in the older districts and in the birth of new camps. Portents of this are not lacking. One of the first districts to benefit by this improvement in conditions is what may be termed the hinterland of Grand Forks.

The town of Grand Forks is situated in Yale district, at the Forks of the Kettle River, the Eastern entrance into the Boundary Creek District. Its chief industry is the large sme'ting works of the Granby Company which treats all the ores from their Phoenix mines, located on the mountains a few miles to the west of the town.

A short distance up the north fork of Kettle are several small mineralized areas that were partially developed some years ago, but which have been neglected the last few years. Farther up stream, on the East Branch of the North Fork, forty-three miles from Grand Forks, is Franklin Camp. It was located by Franklin MacFarlane, for many years a trapper on this stream. His discoveries and those of some friends, attracted prospectors and in 1900, a little colony of them were busy in this camp. During the same summer a reconnaissance survey, which included Franklin Camp, was made on behalf of the Geological Survey by the writer and Mr. W. W. Leach. The results of this survey were embodied in the West Kootenay map sheets published by the department.

But the camp had come into notice too late to be benefitted by the boom. Moreover, it was three days journey by pack train from Grand Forks, there was no immediate prospect of transportation facilities, and none was prepared under these conditions to buy surface showings at boom prices. During the last two seasons however, some attention has been paid to the district north of Grand Forks. Last summer a wagon road was constructed to the camp bringing it within eight hours stage journey from the railway, and work was begun on a branch railway from Grand Forks up the North Fork to Franklin. Several townsites had been platted, and hotel and store accommodation provided.

Some of the salient points in the geology and topography are shown on the map, taken from the West Kootenay Sheet of the Geological Survey. Many of the geological boundaries represented are only approximate as when the reconnaissance was made the country was to a large extent timbered. Since that time the district has been burnt over and the rocks and ledges are now much better exposed; but as my visit last summer was restricted to one day, nothing could be done toward revising the boundaries. The present paper is based largely on observations made during the reconnaissance.

The geology of the camp is somewhat complicated. The oldest recognized rocks are sedimentary, often greatly metamorphosed. Among these the most conspicuous when not too highly altered, is limestone. It is metamorphosed to crystalline limestone and lime silicate hornfelds. The latter is sometimes a green and sometimes a compact, broken up, light-colored, porcelain-like material, resembling a baked argillite. When alteration to silicates has been uneven and incomplete, a breccia-like or conglomerate-like rock results, with the green silicates sometimes as the matrix, with limestone rests and sometimes as the nodules, with an unaltered limestone matrix. The limestone and its alteration products occupy a larger area than represented by the limestone coloring on the map. Some argillites occur in this series, and closely associated are some greenstones. Large masses of gray Nelson granodiorite is intrusive in these basal rocks. Both these formations are intruded by small masses of a gabbro-like rock and a porphyritic syenite distinguished by its long reddish feldspar crystals. Towards the west, forming the West Branch divide is a light acid granite (Valhalla Granite) intrusive in the above series, and to the East a pink, alkali-syenite, also later than, and intrusive in the above formations. Numerous porphyry dykes from these intrusives traverse the older rocks.

At many points overlying the previous formations is a series of Tertiary rocks. These consist of quartzite-like, gritty tuffs with coarse conglomerate bands, conglomerates and ash beds, and overlying these again, lava flows with some inter-leaved ash rocks. The conglomerates hold pebbles and boulders of the older rocks particularly of the granodiorite, limestone, greenstone and an older, finer-grained conglomerate. These range in size from a half inch to two feet in diameter. The conglomerate appears to cover a greater area than represented on the map, reaching in places to the North Fork bottom. It is cut by dikes from the alkali syenite and from the volcanic rocks.

The lava beds, which occupy the higher levels, show in places basaltic jointing. Some beds are rich in gas pores, the latter often containing agate, calcite or zeolites. The intrusive rocks have profoundly altered the older formations over considerable areas, and incidentally ore-deposits have been developed in the latter.

The deposits so far uncovered present several more or less distinct types.

1. Those in which the gangue consists of country rock altered to green lime-silicates such as hornblende, epidote, garnet (generally reddish) with quartz and calcite. Such deposits, since they are especially apt to occur in the (altered) limestone may be, for convenience, called the limestone type.

Deposits of this class differ in the relative amounts of their metallic minerals and using this as a basis, may be sub-divided into—

(a) Pyritic Type,—The metallic minerals consist predominantly of pyrite and chalcopyrite.

(b) Magnetitic Type,—The metallic minerals consist predominantly of magnetite with some copper and iron sulphides.

(c) Galena Type,—The metallic minerals consist of galena, blende and chalcopyrite—This type occurs on the McKinley near types a and b; the silicate minerals are not prominent in the exposures on this lead, the crystalline limestone often abutting against the sulphides.

2. Chalcopyrite or pyrite deposits with molybdenite, calcite and quartz in crushed zones, fractures, fissures or near contacts. Replacements or substitution of the minerals of the country rock by ore is usually conspicuous. Grandiorite or porphyritic syenite formed the country rock in all deposits of this type seen by the writer. For convenience, then, these may be referred to as the granite type.

3. Quartz veins, in which quartz is the dominant mineral accompanied by galena, blende, pyrite, chalcopyrite, molybdenite arsenopyrite, etc.

The most extensively developed claim is the McKinley, on which approximately $30,000 has been expended in surface improvements, trenching, tunnelling and diamond drilling. On the north slope of McKinley Mountain in a band of crystalline limestone, running north across Franklin Creek to Franklin Mountain, four leads have been uncovered. The strike of the leads has not been definitely determined but they appear to be lying transversely to the direction of the limestone band—here about 300 feet wide. Along these leads the limestone is more or less changed to epidote, hornblende and garnet. The lowest lead, exposed by an open cut shows a heavy development of magnetite with some pyrite and chalcopyrite. The latter, while somewhat disseminated in small specks, show a tendency to accumulate in veinlets in the magnetite. Diamond drilling, which was in progress on this shewing, was said to be demonstrating a fair sized body of ore.

The second ledge outcrops for a width of about 30 feet but the dip is at a low angle southwest. It shews a heavy development of galena and blende as well as chalcopyrite. The lime silicates are only sparingly developed here, the crystalline limestone being often in direct contact with the galena. Only open cuts have been made in this lead. The grade of ore is stated to be high, particularly in silver. The third ledge, in which the chief work has been done, holds iron and copper pyrites with a considerable amount of the gangue minerals. It is supposed to be about 40 feet wide, dips 45° S, and has been traced for 300 feet.

The main working is a tunnel. About 100 feet in, a cross-cut has been run westward 104 feet, the last 80 feet of which is in ore. 214 feet in the tunnel 15 feet of ore is encountered (No. 4 lead). This ore is like that of No. 3, except that it contains less pyrite and more chalcopyrite.

Average assays of the largest ledge are said to run about 2.5% copper, and about $2.00 in gold and silver.

The McKinley Company was also testing the Banner claim on Franklin Mountain by diamond drilling. This claim has not been seen by the writer since 1900. At that time a strong, very wide lead of quartz, mineralized with galena blende and chalcopyrite was exposed.

On the Maple Leaf claim on the north-east slope of Franklin Mountain, copper ore occurs in the reddish porphyritic, syenite near and along its contact with the basal formation. The mineralization is confined almost exclusively to the intrusive rock. Fractures in this syenite are filled with seams of chalcopyrite and pyrite or with green malachite resulting from the alteration of the copper ore by atmospheric weathering or surface water, and in addition there is marked selective replacement of the minerals of the syenite by the sulphides. The colored constituents are more readily replaced, so that where the action has not been excessive the prominent feldspar crystals may be found lying in a sulphide base. Where the replacement has been more extensive, the feldspars are attacked, and finally the whole mass of rock becomes sulphides. At several points along the contact, which is generally covered with wash, wide stretches of the more or less mineralized syenite have been uncovered. About 400 feet back from the contact, an open cut has exposed a lode 4 feet wide of fairly well mineralized rock.

The Gloucester group, now being worked under bond by the Dominion Copper Company, was not visited. On the G. H. claim of this group is a ledge of magnetite, with a little pyrite and chalcopyrite. In places it is at least forty feet wide, and it has been traced several hundred feet. It seems to lie wholly in the grey granodiorite. On the Gloucester was a good showing of copper ore, with pyrite, molybdenite, calcite, and quartz, with grey granodiorite on one side at least, but the country rock is badly altered. Development here is made more difficult by some faults which have been encountered.

On the south slope of Tenderloin Mountain, several copper lodes were seen during the survey of the district. They occurred in the gray granodiorite, in fractures, or crushed zones. In the latter, the rock is sometimes crushed to a sort of nodular structure, the more highly triturated material of the rock wrapping round the ball-like rests of unbroken material. In these crushed zones, particularly along well marked fracture planes, the mineralization by copper and iron sulphides is quite heavy.

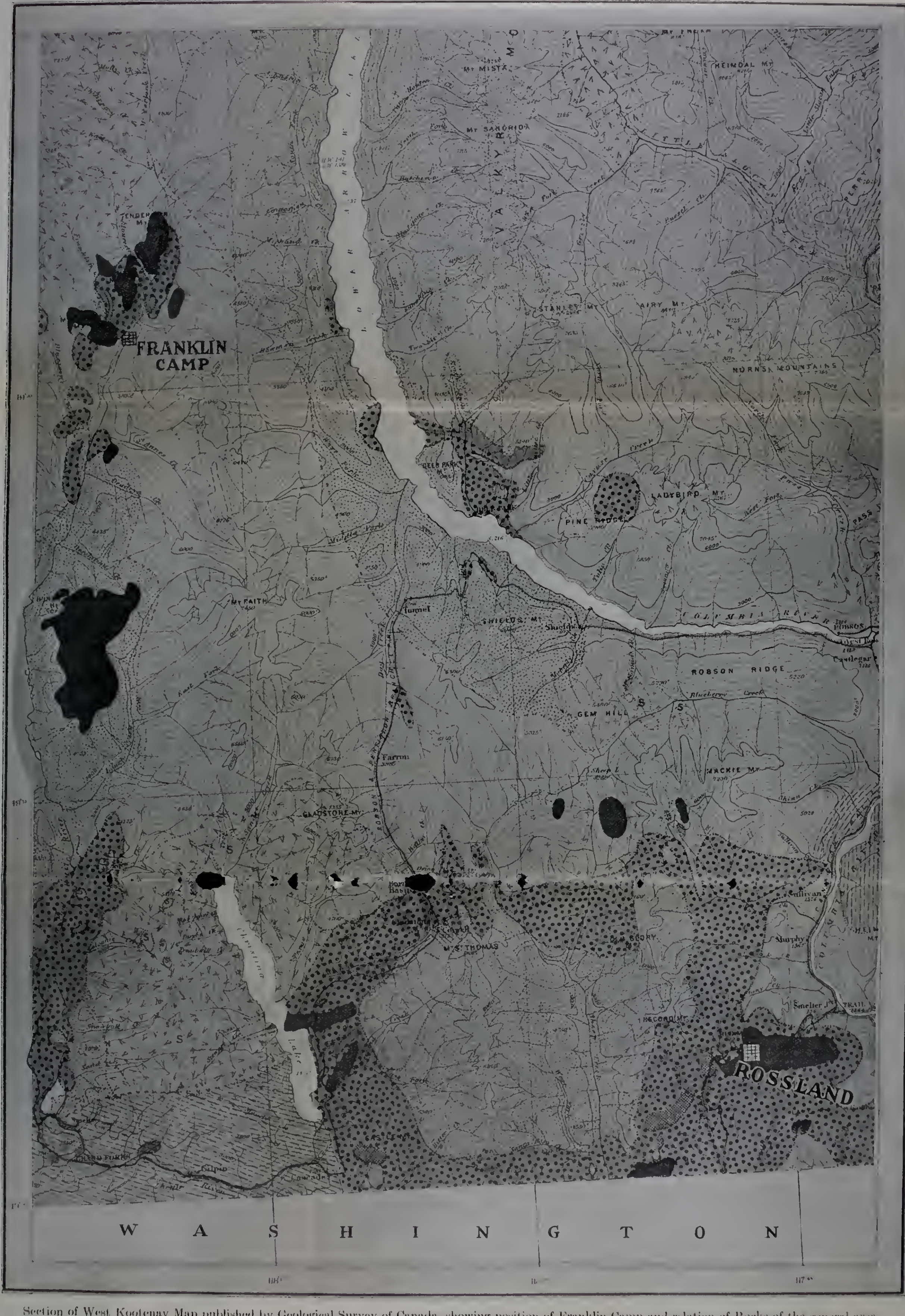
In addition to the claims mentioned, a large number are held, on which deposits of one or more of the types mentioned, have been discovered. Most of the claims spoken of lie within an area 3 x 1½ miles, and an area 8 miles long by 1 to 4 miles wide—covering both sides of the river, would embrace most of the discoveries so far made. There are possibilities, however, in this camp over a somewhat longer and a much broader area—all that ground lying within the encircling, recent acid or alkali eruption rocks, for all the older rocks of the camp, the altered basal rocks, the granodiorite, gabbro and porphyritic syenite are mineralized and lode bearing. Lodes of the first type are likely to occur in the continuation of the limestone band northward from the McKinley, and in other limestone or altered limestone areas. Contacts seem promising points for prospecting, and in addition to the contacts, shear or crush zones in the massive rocks. From what has been seen of the acid granite, and the pink alkali syenite (Rossland alkali syenite) and the Tertiary lavas, both here and elsewhere in this part of the Province, it is altogether unlikely that workable deposits, at all events of the described types, will be found in these rocks, but the older formations along their contacts, and along dykes from them is good ground to prospect.

In its geology and the nature of its ore deposits it bears a strong resemblance to the Boundary Creek district. The main rock formations are common to both, as are deposits of types I a and b, and 3, the main difference being that in the Boundary sulphur is less plentiful so that pyrrhotite is found in place of pyrite, and iron oxides are more prominent.

Deposits of Type 1 are connected with contact metamorphism by intrusive rocks—and are to be explained by the influence of heat, together with mineral-charged waters or vapors given off by the cooling intrusive magma upon the country rocks. Such emanations ascend as best they are able by all sorts of channels, among which fissures and fracture planes are likely to be important. The rock along these channels usually exhibits characteristic alteration produced by these mineralizers and is often replaced by the mineral matter carried by them for some distance on either side of the channel—especially when complex fractures enable the solutions to wander into the rock and expose a great number of surfaces to attack. It will be evident that contact metamorphic action will not be confined to the immediate contact of the intrusive rock (indeed may be absent there) but may be irregularly distributed, according to the physical and chemical characters of the neighboring country rock, the distance below the surface, temperature and other precipitating conditions. There may be expected to be transitions between contact metamorphic deposits and ordinary lodes or veins and such have been found in a number of places. Deposits of Type 2 ore probably to be regarded as such—as are also the deposits of the Rossland Camp now being mined. Deposits of the contact metamorphic type seem to be widespread in Southern British Columbia, not only in Boundary and Franklin, but in other districts as well, and will, no doubt, be recorded from a great many localities.

From descriptions of copper and magnetite deposits in the Similkameen, Kamloops and the coast, it would appear to the writer that examples occur in these localities. On the outskirts of the Rossland Camp the same type occurs, and transitional types to ordinary lodes and veins are widely distributed.

It has not been absolutely determined for Franklin Camp what intrusive rock has been responsible for the metamorphism and mineralization. The possibilities are the granodiorite, the alkali syenite, and the undiscovered or unrecognized plugs or dykes which gave vent to the lavas. The first is in closer proximity to the deposits in large exposed areas, but the second is well represented by large dykes; of the third, as no information is at hand, nothing may be said. The granodiorite is itself deformed and mineralized; the alkali syenite at certain points in this



Section of West Kootenay Map published by Geological Survey of Canada, showing position of Franklin Camp and relation of Rocks of the general area.

section is responsible for mineralization and seems to have been injected just prior to the great period of ore formation. Both these rocks are present in the districts in southern British Columbia visited by the writer, which are characterized by this class of deposits. At present, the balance of the evidence seems to be rather in favor of the alkali syenite as the metamorphosing rock. In the Boundary district the large syenite porphyry dykes seem to have been furnished the mineralizers.(1) In a recent monograph (2) Lindgren ascribes the origin of the Clifton-Morenci contact deposits to porphyry dykes.

The contact metamorphic deposits, while distinguished by Von Goddick in 1879, have only in recent years been recognized as an important type, found in a large number of copper gold districts, but an extensive literature on the subject is now being rapidly accumulated.(3)

Of the more important deposits of this class may be mentioned some of the Clifton-Morenci copper deposits, Arizona (4) the copper deposits of Cananea, Mexico (5), and the gold copper deposits of many other parts of Mexico. In Eastern Ontario, the writer has recognized examples of this type.

Since limestone has been found to be the country rock of most of the contact metamorphic deposits hitherto described and consequently seems to be the rock most susceptible to this mode of alteration, and since in its impurities it contains many of the elements necessary to form with the lime the observed gangue

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(1) Preliminary Report on the Boundary Creek Mining Dist. Summary Report G. S. C., 1902, p. 90-136.

(2) Prof. Paper, 43, U.S. G. S.

(3) As examples the following may be cited. The Character and Genesis of Certain Contact Deposits. W. Lindgren, Genesis of Ore Deposits, A. I. M. E., p. 716, T. A. I. M. E., Vol. XXXI.

Copper Ores and Garnet in Association, W. P. Blake, T. A. I. M. E., XXXIV, p. 886.

Limestone Granite Contact Deposits of Washington Camp, Arizona, W. O. Crosby, T. A. I. M. E., XXXVI, p. 626.

Ore Deposits at the Contacts of Igneous Rocks and Limestones, and their Significance as Regards the General Formation of Veins. J. F. Kemp, Economic Geologist, Vol. II, p. 1.

Die Kieslagerstatten Roros Sulitelma und Rammelsberg. J. H. L. Vogt, also Genesis of Ore Deposits, A.I.M.E., 1902, p. 648. Zeilschiep for Prak. Geologie, 1894, p. 177, 464, and 1895, p. 154.

(4) Lindgren, U. S. G. S., pp. 43; and T.A.I M. E., Vol. XXXV, p. 511.

(5) Ore Deposits near Igneous Contacts, Weed, T. A. I. M. E., Vol. XXXII., p. 715.

minerals, the inference has been widely drawn that such deposits are peculiar to limestone contacts. This fact has even been included in various definitions of this type of deposit. Many authorities (Rosenbusch, Barrell, Zirkel Klockmann) hold that the results are due to the alteration of impure limestones through heat alone and that there has been no addition of material, by waters and vapors, at all events none to go towards the formation of the typical gangue minerals. Others as Michel Levy, Vogt, Lindgren, Kemp and Blake bring forward facts to show that some of the material of these minerals has been introduced by emanations from the intrusive lava. In the Boundary Creek District the evidence is wholly in support of the latter view, (6) and the same seems to be true in Franklin Camp.

In many places the limestone is altered to marble, except in the mineral bearing zones. These mineralized zones have not the accordance in strike, nor the regularity in distribution that impure bands in a limestone formation would possess. The ores must certainly have been introduced, and there is good reason for believing that the iron and silica of the silicates have been as well. Moreover, these deposits are not confined in these districts to limestone as a country rock.(7) In the Boundary Creek District the writer has shewn that even the granodiorite is mineralized to some extent in this way and that in it garnet zones are developed. A fuller description of this formation of garnet in granodiorite will be given in a paper shortly to be published. Kemp in a recent paper (8) describes the formation of a similar mineral bearing garnet zone in granite porphyry at White Knob, Idaho. In Franklin Camp, the magnetite ore of the Gloucester Group, according to notes taken in 1900, occurs in the granodiorite, and some of the copper ores of the camp also have this as their country rock.

The development work already done in Franklin Camp is limited and shallow, so that it is not known how the values, particularly the copper values, will hold out in depth, nor is it yet

(6) Preliminary Report on the Boundary Creek District, R. W. Brock, Summary Report, G. S. C., 1902, p. 90,-136.

(7) Op. Cit., page 107, also Journal Can. Min. Inst., 1902, p. 369.

(8) Econ. Geol., Vol. II, p. 1.

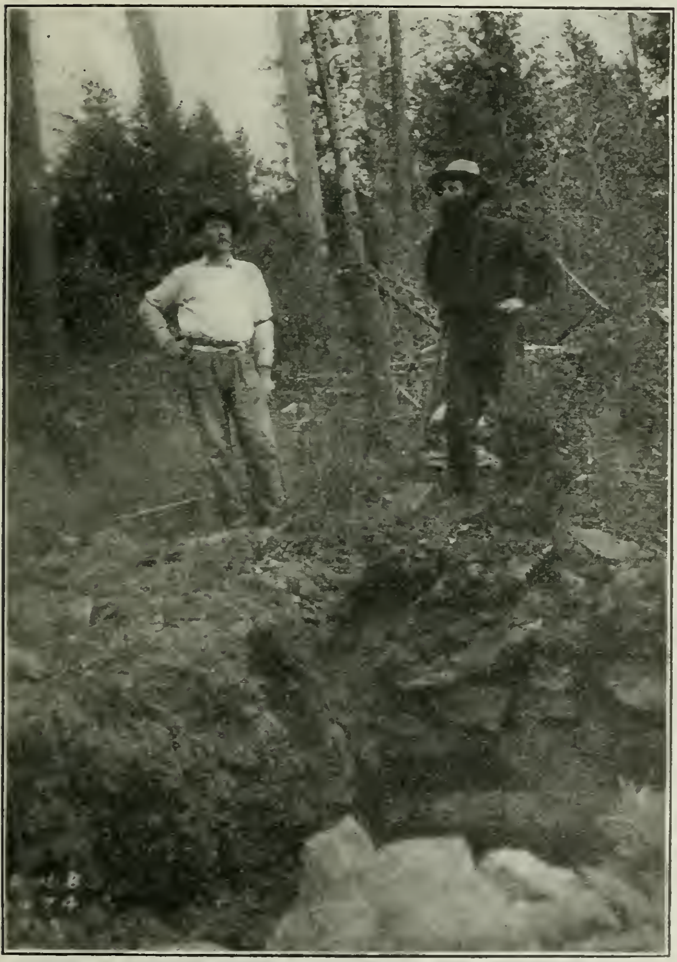
demonstrated that a large tonnage of low grade ore can be minatained. To prove these points requires extensive development and time. While good values have been found on some of the lodes it will probably be on low grade ore that the success of the Camp must depend. The results on the McKinley, so far, seem to be encouraging.

While nothing can yet be said of the extent and value of the mineralization, while it is yet too early to state that any one of the prospects is going to be a good mine, it may be said that the camp possesses many of the earmarks of a mineral-bearing district and that in kind, whether or not in degree, in the nature of its ores whether or not in extent, it takes its place in a goodly company of mining camps, among which its neighbor, the Boundary Creek District is not the least important.

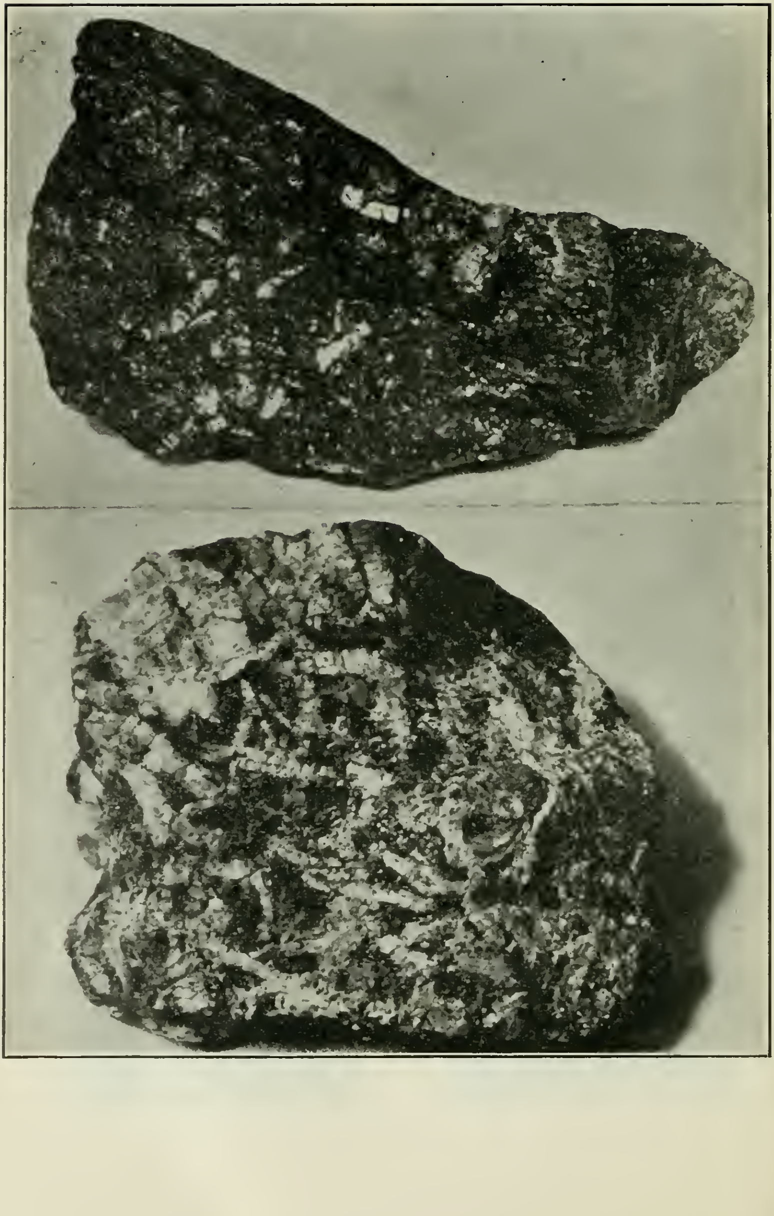
The expensive development work required in this camp will be greatly facilitated by the railway and when this reaches the camp, its possibilities will no doubt be tested as they deserve to be.

(1.) A Bunch-grass Hillside near Franklin Camp.

(2.) On the North Fork of Kettle River near Franklin Camp.



(3.) Prospect on the North Fork of Kettle River.



(4.) Ore in Porphyritic Syenite, Maple Leaf Claim, Franklin, B.C. The light crystals are original feldspars, the dark ground mass is largely secondary chalcopyrite, which has replaced minerals of the syenite.

REVIEW OF PROGRESS IN THE MINERAL PRODUCTION OF BRITISH COLUMBIA.

By E. Jacobs, *Victoria, B.C.

(Toronto Meeting, 1907.)

British Columbia's total mineral production to the end of 1906 is shown by official records to have been $273,643,000. This production was apportioned as follows:—

Placer gold		$68,721,000
Lode Metals—		
Gold	$41,016,000	
Silver	25,586,000	
Lead	17,626,000	
Copper	35,546,000	
Iron and zinc	270,000	120,044,000
Total metalliferous		$188,765,000
Coal and Coke—		
Coal	$72,815,000	
Coke	6,520,000	
	$79,335,000	
Building materials, etc	5,543,000	
Total non-metalliferous		$84,878,000
Grand total of production		$273,643,000

Reviewing several periods it is seen that from the time of commencement of mining operations in the Province to the end of 1886, the total value of production was $64,246,000, in the following proportions:—Placer gold, $53,797,000; coal, $10,449,-000. In the ten years, 1887-1896, a total of $37,809,000 was produced, this consisting of placer gold, $5,006,000; lode metals, $8,126,000; coal and coke, $23,537,000, and building materials, etc., $1,140,000. For the ten years, 1897-1906, the total was

* Editor *British Columbia Mining Record.*

$171,588,000, comprising placer gold, $9,917,000; lode metals, $111,979,000; coal and coke, $45,349,000, and building materials, etc., $4,343,000. Recapitulating, the production of the respective periods above-mentioned was as follows:—

To end of 1886.	$64,246,000
Ten years, 1887–1896.	37,809,000
Ten years, 1897–1906.	171,588,000
Total production, all years.	$273,643,000

The progress of British Columbia's mining industry is further indicated in the following summary:—

PLACER GOLD.

The production of placer gold dates back to 1858, in which year a total of $705,000 was recovered. The maximum production in any one year was that of 1863, with a value of $3,914,000, followed the next year by a total of $3,736,000. This was when placer mining was at its best in the Cariboo district. In the seventies there was a gradual reduction, while through the eighties the decrease was more marked, continuing into the early nineties. The minimum yearly total was reached in 1893 with a production for that year of only $356,000. Thenceforward there was a steady increase. The yearly average total recovery during ten years, 1897-1906, was about $991,700. The total production during 49 years has been in round figures:—

Period.	Value.
In nine years, 1858–1866.	$23,674,000
In ten years, 1867–1876.	19,787,000
In ten years, 1877–1886.	10,336,000
In ten years, 1887–1896.	5,007,000
In ten years, 1897–1906.	9,917,000
Total.	$68,721,000

LODE METALS.

The tables of production of lode mines, published yearly in the "Annual Report of the Minister of Mines for British Columbia," show that a commencement was made in 1887, in which year silver and lead to a total value of $26,500 was produced. The first official record of lode gold was a value of $23,400 for the year 1893, and of copper $16,200 for 1894.

Gold.—Out of a total of $41,016,000 of lode gold, only $2,178,000 was produced during four years, 1893-1896, but in five next following years, 1897-1901, there was an increase to $14,984,000 for that period, while still greater progress was made during the five years, 1902-1906, the total for which was $23,-854,000, or an average of rather more than $4,770,000 a year.

Silver.—Production of silver during ten years, 1887-1896, totalled $4,028,000, of which amount $2,100,000 was produced in 1896. For the ten years, 1897-1906, the total was $21,558,-000, with a maximum of $3,273,000 in 1897, and a minimum of $1,521,000 in 1903. The total for the whole period reviewed was $25,586,000.

Lead.—The production of lead during the ten-year period, 1887-1896, was small, having totalled only $1,581,000. During the next ten years, 1897-1906, an average yearly output of rather higher than $1,604,000 was maintained, with a maximum value in 1900 of nearly $2,692,000, and a minimum in 1903 of about $690,000. The total for this period was $16,045,000, and the aggregate of production for all years, $17,626,000.

Copper.—No copper was produced until 1894, in which year a beginning was made, with an output valued at $16,234. For the three years 1894-1896, a total of $254,802 is recorded. Thereafter the production for ten years, 1897-1906, totalled $35,292,000. The output of 1906, valued at $8,288,000, was by far the highest for any single year since production of this metal was begun in the Province.

Other Metals.—The production of other metals than the foregoing, placed at a total value for all years of about $270,000, may be subdivided, approximately, as follows: Zinc, $160,000; iron, $100,000; platinum, $10,000. Of these, both iron and zinc are expected to show increased production in the near future.

COAL AND COKE.

Coal mining appears to have been commenced in 1836, but production must have been small during 30 years to 1865, inclusive, official records showing a total value for the whole of that period of only $666,288. It was not until 1884 that the total for any single year reached $1,000,000; the recorded value for that year was $1,182,210. As already shown, the total value to the end of 1886 was $10,449,000. During the next period, 1887-1896, the production of $23,537,000 included $7,825 for coke, the manufacture of which was commenced at Union, Vancouver Island, in 1895. Of the total of $45,349,000 for coal and coke during the period 1897-1906, the production of the latter was $6,512,000, chiefly from the collieries of the Crow's Nest Pass Coal Company, in southeast Kootenay, at which coke-making was begun in 1898.

BUILDING MATERIALS, ETC.

Building stone and brick, fire-brick, lime, cement, and such earthenware as pipes and tiles, constitute practically all the non-metalliferous minerals included under this head. The output from Coast quarries of granite and sandstone for building purposes has considerably increased during the last two years. The production of brick and lime is also on the increase. Portland cement has been manufactured on Vancouver Island since 1904; the output for 1906 was of a value of between $200,000 and $300,000, while for the current year the outlook is favourable to a substantial increase. Oil and oilshales are still undeveloped so as yet are not of commercial importance in the Province.

PRODUCTION OF 1906.

Turning now to the mineral production of 1906, which was a record year in the history of mining in British Columbia, it is noteworthy that the total of nearly $25,000,000 is rather better than 11 per cent. higher than that of 1905, while it shows an increase of nearly 32 per cent. as compared with that of 1904, and nearly 43 per cent. over 1903. As regards tonnage of ore mined, which is of course exclusive of coal, the quantity was about 1,964,000 tons, an increase of 15 per cent. over that of 1905. The number of mines from which shipments were made was 154, but of these only one-half shipped more than 100 tons each, and but 41 in excess of 1,000 tons each. The number of men employed at the metalliferous mines was not quite 4,000, and at the coal mines a higher total, together giving an aggregate of between 8,000 and 9,000.

While the higher prices of silver, lead, and copper contributed in large measure to the considerable increase in value of the year's production over that of any other year, there was also an enlarged output of copper, coal, and building materials. Copper especially made a substantial gain in quantity—about 5,300,000 lb. more than was produced in 1905. Coal also showed an appreciably large increase over the production of 1905, and the year's output of 1,517,000 tons was the biggest tonnage ever reached in the Province in any single year.

The causes of decreased production of several of the minerals in 1906 as compared with 1905 were temporary and the reasonable expectation is that they will not similarly affect production in 1907.

As exhibiting the importance of mining in comparison with other staple industries of British Columbia, the following estimate of production in 1906, made at the close of that year, is submitted:—

Lumbering	$9,500,000
Agriculture	8,000,000
Fisheries	8,000,000
Together	$25,500,000
Minerals	26,000,000
Manufactures	11,000,000
Total	$62,500,000

It will be seen that the estimated total value of the mineral production was about $1,000,000 in excess of the actual amount shown in the revised figures based on the official returns, nevertheless the mineral industry came a long way first with a value of the year's production only about $520,000 short of that estimated as the total of the products of lumbering, agriculture and fisheries combined. While this is a decidedly creditable showing for the mining industry of the Province to have made, the immediate outlook is that when the time shall come for a corresponding comparison for 1907 to be made, the mineral production for that year will be found to have reached a still more favourable relative position.

THE EMMA MINE.

(By Frederic Keffer, Greenwood, B.C.)

(Toronto Meeting, 1907.)

Among the low grade mines of the Boundary District the Emma is in a way unique, in that the magnetite, which constitutes the main portion of the ore body, has persisted from the grass roots to at least the 250 level in a practically continuous vein or deposit; and also in that the vein stands vertically so far asexplored.

In the other low grade mines of the district magnetite is a frequent constituent of the ores, but its occurrence is most erratic, the deposits being irregular, varying in size from a few ounces to masses of thousands of tons, and frequently dipping (so far as any dip is observable) entirely at variance with the general dip of the ores with which they are associated.

A characteristic case was that of a body of magnetite of exceptionally good value found on the 300 level of the Mother Lode mine, which lay perfectly flat, being about 20 by 100 feet in area, but only 7 to 8 feet thick, and which was encased in barren eruptive rocks.

In the Emma (save in Quarry No. 1 where a slip has thrown the ore about 25 feet to the south east) the magnetite continues unbroken to a point some 200 feet below the surface, where diamond drilling has found what is seemingly another slip, throwing the ore again a short distance to the southeast. Diamond drilling on the 250 level has recently located the ore near the shaft.

The Emma ores are found along the contact of eruptive rocks and limestone, which limestone is here like an extensive "island" surrounded by eruptive flows. These latter rocks are of the general types characteristic of the Boundary District, analysis of which usually lie between the limits of:—

Silica	30 to 40 per cent.
Iron	15 to 25 per cent.
Lime	10 to 20 per cent.
Magnesia	0 to 5 per cent.
Alumina	5 to 15 per cent.
Alkalies	0.5 to 2 per cent.

To the east of this "island" of limestone are several pyrrhotite deposits, the most prominent of which is that occurring on the "Mountain Rose" mineral claim. This pyrrhotite is extensively mined for use as sulphur flux, it being sometimes essential in order to reduce the grade of copper matte, thereby avoiding unnecessary slag losses, which accompany matte running over 50% copper. This sulphur ore consists of pyrrhotite, together with varying proportions of lime, alumina and silica, but with little or often no magnetite, in striking contrast with the Emma ores, which contain little or no pyrrhotite.

On the Emma, to the south of the limestone "island," occurs a body of magnetite, which where mined was some 20 by 100 feet in area. This ore was followed to a depth of about 25 feet, where it was cut off by a slip, beyond which no further work has been done. But little pyrrhotite was found in this place.

To the west of the limestone island occurs the main ore body of the Emma mine, which ore has been developed by quarries and drifts for some 575 feet, shown in plan and section on the accompanying map.

Most of the ore next the east wall of the deposit (which here runs about 5 degrees east of north) is magnetite, but minor bands of garnetite also occur. Along the northwest wall, however, the magnetite for the most part is next a garnet zone, which (where crosscut by diamond drilling on the 150 level) passes into a bluish and very silicious rock beyond which the drill was not pushed.

In other places the magnetite stands directly against snowy white crystalline limestone, which latter rock, when near the ore, frequently carries masses of magnetite and chalcopyrite embedded within it, this mineralization extending sometimes several feet into the limestone in diminishing ratio. In other cases, however, the line between this limestone and the ore is clear cut. The garnet zone is about 20 to 25 feet thick and in places carries sufficient copper to pay for mining.

More or less epidote also occurs along both walls of the ore. The magnetite frequently includes masses of crystalline lime spar, which are almost always accompanied by enrichments of copper. The garnet zone includes considerable magnetite scattered through the rock in crystals and little patches.

On the surface to the north of the workings the magnetite gives place to garnet ore well mineralized with copper pyrites. Still further north (about 1000 feet) the garnet again crops for several hundred feet carrying good values in copper, but now dipping to the west about 70 degrees. The copper and gold contents of the ore show decided increase on the 150 level as compared with the ore mined in the quarries. Following are analyses and assays on two lots of several thousand tons each.

	Gold	Silver	Copper	Silica	Iron	Lime	Sulphur
Quarry	.007 oz.	.06 oz.	.52%	16.5%	43.6%	12.1%	1.1%
150 Level	.031	.06	1.28	14.9	40.7	14.4	1.7

So that this ore, which was at first mined solely as an iron flux, has, under the conditions obtaining in the Boundary, become intrinsically valuable as well.

The average thickness of the magnetite deposit in the upper workings is some 18 feet, but on the 150 foot level the ore widens materially, being in places 40 feet across exclusive of the garnet ore zone. A fair average thickness of the workable ores of the mine would be 25 feet. Below are given analyses of the garnet zone, the silicious bluish drill cores beyond the garnet, the general country and also the white crystalline limestones, the rock lying immediately east of the magnetite and an approximate average of the general eruptive rock of the district. Alkalies, magnesia and other constituents present in small quantities are not included:—

	Silica	Iron	Lime	Alumina	Sulphur
Garnet Zone	26.8	23.5	32.6	12.0	1.5
Bluish Drill Core beyond Garnet	63.6	5.3	4.5	16.9	.52
Limestone Country Rocks	18.3	2.3	43.9	5.6	.00
White Crystal. Limestone	7.6	.8	56.0	.3	.12
Rock next the Magnetite on the East	38.5	6.5	27.6	19.3	.47
Eruptives	35.0	20.0	18.0	15.0	

It is evident from these analyses that the limestone and eruptives contain in sufficient measure all the constituents necessary for the formation of the garnet and magnetite zones. That these latter rocks were produced by the hot water gases and water carrying dissolved mineral derived from the eruptives, reaching upon the adjacent limestones through replacement and recombination, can hardly be doubted.

It is seen from the analyses of the ore that the sulphur present is very small, barely more than sufficient to form the copper pyrites present.

Iron sulphides are of rare occurrence, and it seems certain that the magnetite was deposited as such, and did not result from the alteration of sulphides. This view is borne out by the fact that as a rule magnetite crystals and not iron sulphides are found in the garnet zone, however far removed from the main body of magnetite. The crystalline limestone found next the magnetite in the mine is considerably purer than the main portion of the limestone formation.

The accompanying photographs of rock sections from the Emma throw an interesting light on the formation of the deposit.

Fig 1.

Fig. 1 is a specimen of garnet ore, and shows a limestone in the course of alteration to a garnet rock. Some calcite remains, but it has mainly been replaced by garnet together with a little quartz. Copper pyrites run through the mass in irregular strings and bunches, and there are also some bits of magnetite.

Fig. 2 represents a rock from the 150 ft. level, in which all the original mineral has been replaced by plagioclase, feldspar and

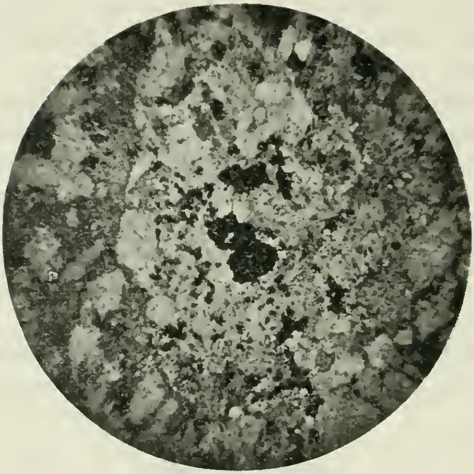
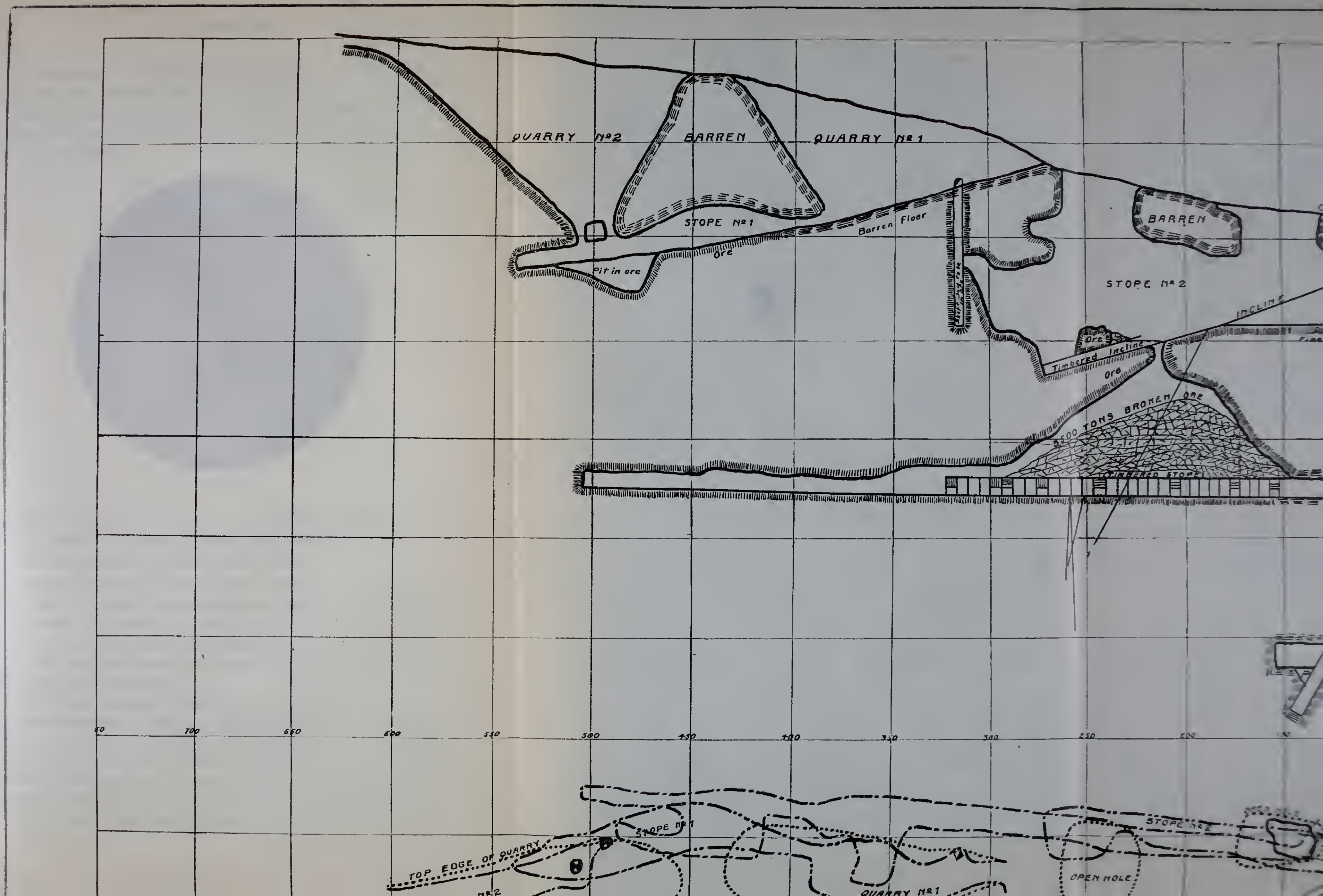


Fig. 2.

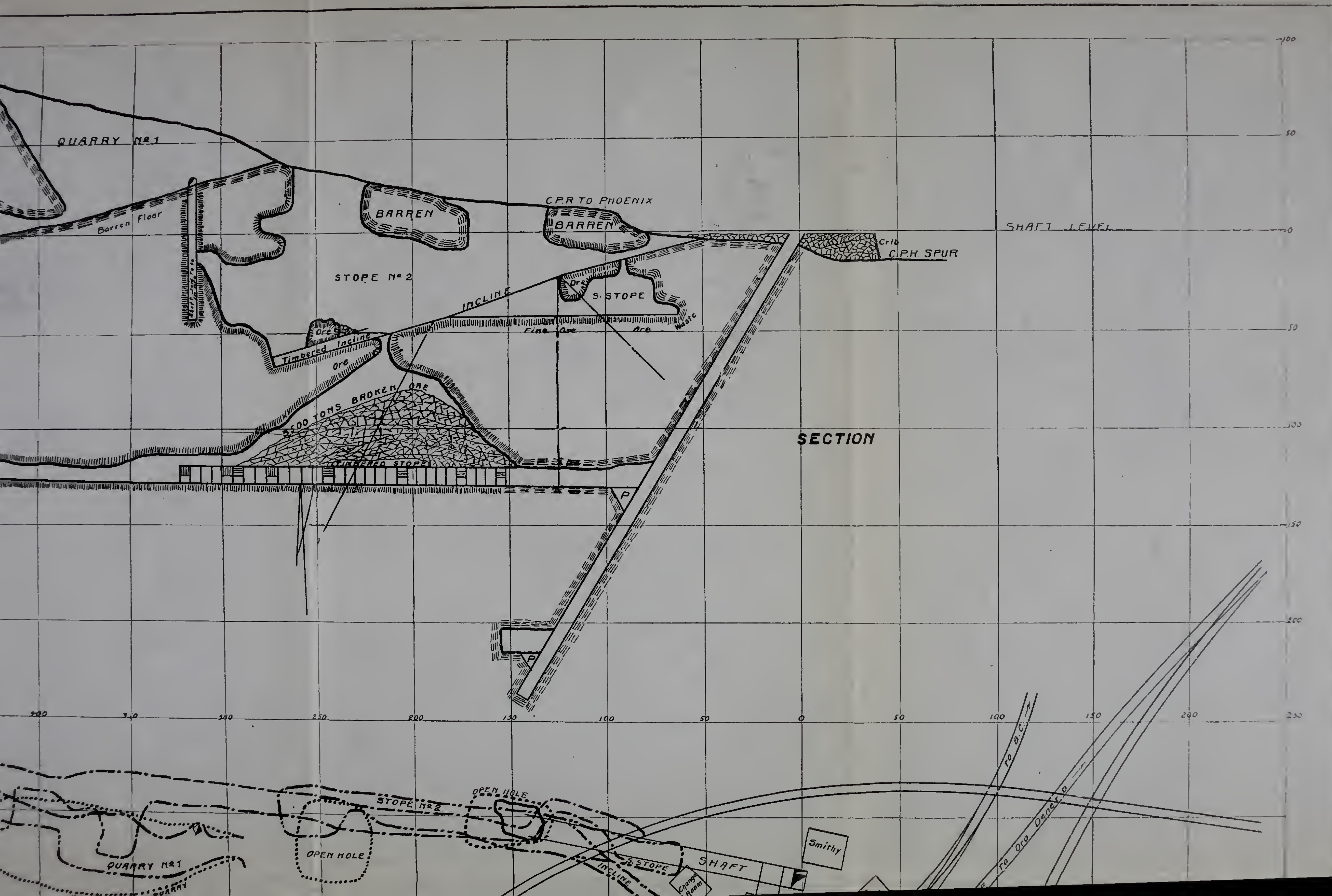
actinolite, together with some copper sulphides. This rock is probably an altered eruptive rather than a limestone replacement.

Fig. 3.

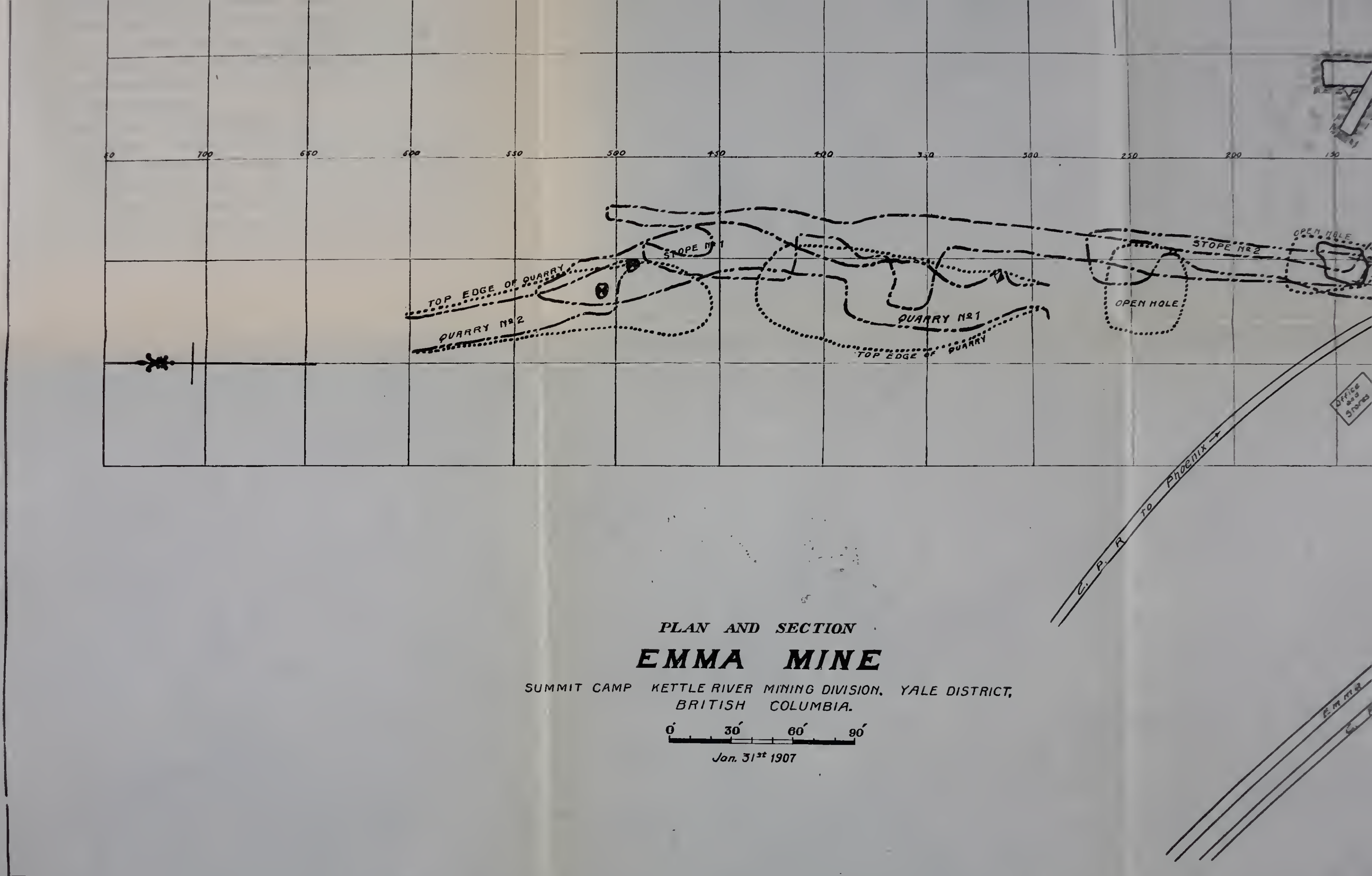
Fig. 3 is a section of the rock which cuts off the Emma deposit on the south. It is schistose through great pressure, and is



QUARRY Nº2
BARREN
QUARRY Nº1
STOPE Nº1
Barren Floor
Ore
Pit in ore
BARREN
STOPE Nº 2
INCLINE
Ore
Timbered Incline
Ore
5500 TONS BROKEN ORE
TIMBERED STOPE
700
650
600
550
500
450
400
350
300
250
STOPE Nº1
TOP EDGE OF QUARRY
STOPE Nº2
OPEN HOLE
QUARRY Nº1



QUARRY Nº 1
Barren Floor
BARREN
C.P.R TO PHOENIX
BARREN
SHAFT LEVEL
Crib
C.P.R. SPUR
STOPE Nº 2
INCLINE
Ore
S. STOPE
Ore
Timbered Incline
Fine Ore
Ore
Waste
Ore
3500 TONS BROKEN ORE
TIMBERED STOPE
P
P
SECTION
100
50
0
50
100
150
200
250
400
350
300
250
200
150
100
50
0
50
100
150
200
OPEN HOLE
STOPE Nº 2
OPEN HOLE
QUARRY Nº1
S. STOPE
INCLINE
SHAFT
Smithy
Change Room
TO B.C.
TO Oro Denero



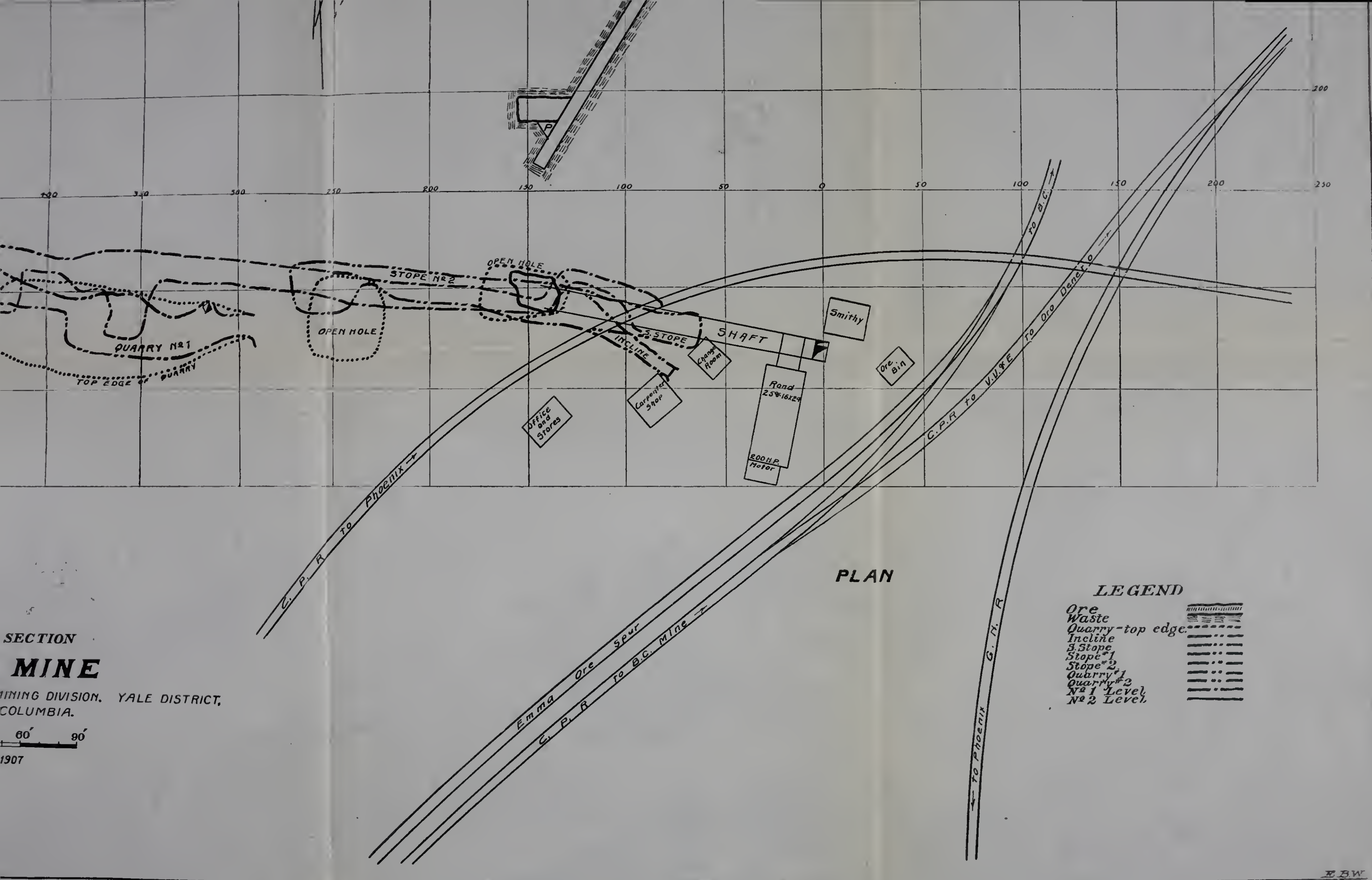
PLAN AND SECTION

EMMA MINE

SUMMIT CAMP KETTLE RIVER MINING DIVISION. YALE DISTRICT.
BRITISH COLUMBIA.

0′ 30′ 60′ 90′

Jan. 31st 1907



SECTION
MINE
MINING DIVISION. YALE DISTRICT,
COLUMBIA.
60′ 90′
1907
PLAN
LEGEND
Ore
Waste
Quarry-top edge
Incline
3. Stope
Stope #1
Stope #2
Quarry #1
Quarry #2
Nº 1 Level
Nº 2 Level
STOPE Nº 2
OPEN HOLE
OPEN HOLE
QUARRY Nº 1
TOP EDGE OF QUARRY
3. STOPE
INCLINE
SHAFT
Smithy
Change Room
Carpenter Shop
Office and Stores
Ore Bin
200 H.P. Motor
C.P.R. to Phoenix
Emma Ore Spur
C.P.R. to B.C. Mine
C.P.R. to V.V.&E. to Oro Denero
to B.C.
G.M.R. to Phoenix
E.B.W.

mainly composed of feldspar and hornblende. A few crystals of iron sulphide are also present.

Fig. 4 is from near the ore on 250 level, 40 feet north of the Emma shaft and like Fig. 1 shows limestone in the course of conversion to garnet.

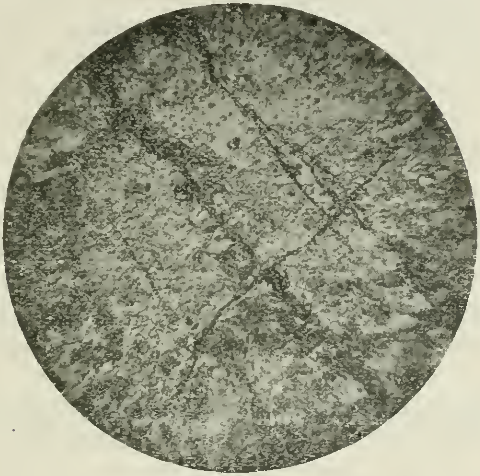


Fig. 4.

Some pyroxene is present in small grains, and all the calcite which remains is in minute lines running through the rock.

The sections are magnified 25 diameters.

Mining.—Owing to the vertical position of the deposit, mining here is a much simpler problem than in most of the Boundary mines. The shaft is a two compartment incline, angle 60 degrees. Across the drifts are placed heavy stulls supported by posts, the stulls and posts in the widest portions of the drift being often 30 inches in diameter.

The stulls are placed 5 feet apart, and are covered with 8 to 12 inch pole lagging. Chutes are provided at convenient intervals, they being at the opening 3½ to 4 feet wide by 2 to 2½ feet deep, so as to allow large rocks to pass. The ore is broken down on the timbers to the level above, only the swell being drawn from the chutes, which swell amounts to about 40%. After the level above is reached the stopes can be drawn at will, and, commencing at the point furthest from the shaft, the timbers can be removed if in condition to be used elsewhere. In commencing a stope it of course is necessary to first raise to the level above to secure ventilation. In portions of the work where bodies of crystalline limestone or poor garnet ore are found these are left as pillars to reduce the cost of timbering. The ore is so heavy, averaging from 8 to 8½ cubic feet to the ton when in place, that timbering must be of the heaviest description to bear the weight above, which weight owing to the vertical walls rests almost entirely on the timbers. Power is supplied from the Bonnington Falls electric plant some 85 miles distant, the machinery at the mine consisting of a 12 drill cross compound Rand compressor driven by a 200 H.P. motor, together with a hoist now driven by compressed air, but which will shortly be replaced by an electric hoist. There is also a steam driven X Ingersoll straight line Class A Compressor, capacity about 8 drills, which machine is held as a reserve.

There have been shipped from this mine to date some 93,500 tons of ore.

NOTE.—Rock sections were furnished through the courtesy of Dr. Frank D. Adams of McGill University, who also made a petrographic examination of them.

FURTHER OBSERVATIONS RELATIVE TO THE OCCURRENCE OF DEPOSITS OF COPPER ORE ON THE NORTH PACIFIC COAST AND ADJACENT ISLANDS, FROM THE SOUTHERN BOUNDARY OF BRITISH COLUMBIA TO THE ALASKAN PENINSULA.

By W. M. Brewer, Victoria, B.C.

(Toronto Meeting, 1907.)

Since the paper* submitted by the writer to the Institute and read at the Quebec Meeting, in March, 1906, the writer has had further opportunities of investigating this subject. The result of these observations has confirmed more fully the view that the classification of the various deposits of copper ore as noted in the previous paper, are substantially correct.

They are as follows:

1. Bornite ore accompanied by some carbonates, chalcocite, and at the deeper levels chalcopyrite, which occurs in contact deposits between crystalline limestone and igneous rocks, usually felsite associated with which is garnetite.

2. Chalcopyrite ore which occurs sometimes with magnetite but often in a quartz matrix in deposits of lenticular structure in fissures in the basic igneous rocks.

3. Chalcopyrite ore usually in a magnetite matrix which occurs as contact deposits between crystalline limestone, slate or schist, and igneous rocks.

4. Chalcopyrite ore occurring in association with iron pyrites, barite or heavy spar, and a small percentage of lime which has only been found up to date in a schist country rock.

5. Pyrrhotite ore carrying low copper values sometimes in a gangue composed of a high percentage of epidote, garnet amphibole and some calcspar, which occurs either in fissures in basic igneous rocks, or else at the contact of crystalline limestone and the igneous rocks.

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* Journal Canadian Mining Institute, Vol. IX, p. 39.

As the writer has already stated the examples of the first of this series were confined (so far as known at the time) to a portion of Texada Island, a few locations on Sidney Inlet on the west side of Vancouver Island, Gribbel Island, and the vicinity of White-horse in the Yukon, as well as a few points on Gardner Canal in the neighborhood of Gribbel Island. To these localities should now be added, it is believed, the Rainy Hollow Camp about forty miles northerly from Haines' Mission on Lynn Canal. These latter deposits the writer has not personally examined, but from descriptions afforded by men familiar therewith, they should clearly be classed under the first of the series referred to. Moreover, on the evidence of recent information, it seems that the copper deposits in the vicinity of Copper River and the head-waters of the White River should also be so classified.

In respect to the last mentioned copper belts, a reference to a map of that district will show that a line drawn in a northwesterly direction from the White-horse copper belt would pass through the head of the White River and thence into the heart of what is known as the Copper River copper belt. In fact, the same line would only pass a comparatively short distance north of the Rainy Hollow copper deposits. Consequently, without any very great stretch of imagination, it may be concluded that there is some relationship between the White-horse, Rainy Hollow, head of White River and Copper River copper deposits; but whether it will be discovered eventually that there is any actual connection between these various belts of copper bearing formations, or whether each one is distinctly isolated, is a question that can be settled only by further exploitation.

During the past summer quite serious effort was made in the development of copper bearing deposits on Hetta Inlet, on the west side of Prince of Wales Island, which undoubtedly belong to this first class; but like the examples of this class on Sidney Inlet on the west side of Vancouver Island, the occurrences are confined to a comparatively limited area, the formation covering possibly two miles square. The geology is practically identical with that on Texada Island, the only noticeable difference being that the granite is more closely associated with the ore bodies than is usually the case either on Texada Island or in the White-horse copper belt, but the structure of the ore bodies, the character of the ore, as well as the gangue material, are almost identical with the other examples belonging to this first class which have been already referred to.

The occurrences on Texada Island are more extensively developed than any of the other deposits of the same class. During the past year development work and shipment of ore has been carried on continuously, especially at the Marble Bay Mines, where the lowest depth reached is, to-day, about 900 feet, and the lowest level where stoping is being carried on is 760 feet. From reliable information the writer is of the opinion that further prospecting along the contact of the limestone and felsite on these deeper levels will demonstrate the occurrence of other ore bodies. In fact, on the 680 foot level of the Copper Queen Mine, on Texada Island, such has been the case, and at the Marble Bay the ore body shows every indication of trending more directly towards the ore body on the adjoining claim, the Copper Queen, than it did when an examination of both properties was made by the writer some four years ago.

In the White-horse copper belt, there has been considerable development work carried on during the past year, and some ore shipped, both from the Copper King claim and the Carlisle adjoining it to the east. The most extensive development work has been done, however, on the Pueblo mineral claim situated about a mile and one-half south-westerly from the "Copper King," and on the opposite side of an enormous mass of granite. This was one of the concessions located in 1899, and bonded, at that time to the British-America Corporation, one of the Whittaker Wright creations which also purchased the "Le Roi" mine in southern British Columbia.

Under that bond an incline shaft was sunk about 85 feet, and a drift driven from the bottom for something like 100 feet; but the showing from this work was poor; the material extracted from both the shaft and the drift being principally red hematite iron ore, which carried an average of possibly about 2 per cent. copper, although the material taken from the surface was of higher grade. Notwithstanding that the outcroppings covered an area of about 200 feet square, no other attempt was made to even prospect, and the property reverted to the original owners in the fall of 1900. From that time until last summer no attempt was made to work the property, although some shallow prospecting was done on an adjoining claim. However, in the spring of 1906 Mr. Byron White, who had been a successful operator in the Slocan silver-lead district of British Columbia, purchased this concession together with the "Carlisle" and "Tamarack," which, alone of the twenty concessions originally located and bonded to the British America Corporation, remained in good standing. Mr. White proceeded at once to thoroughly prospect the surface of these extensive outcroppings, and, within a short time, had demonstrated that the work done by the British America Corporation had been on the leanest portion of the entire outcrop; for from other portions he mined, by surface work, ore which yielded from sorted samples as high as 12 to 14 per cent. copper, and in September last, he had mined about 1,000 tons, which would yield an average, without sorting, of about 5 per cent. copper.

It is worthy of note that this capital, together with that furnished by the British-America Corporation in 1900, are the only instances on record where any outside investment has been made in the White-horse copper belt; but as a result of Mr. White's work on the "Pueblo" and "Carlisle," considerable activity was shown during the late fall, by the representatives of capital sent in to examine the belt. In short, until recently so little was known of the district abroad, that not long since reports were published in the eastern papers, in which appeared the statement that the Whitehorse copper belt had been discovered in the fall of 1906, notwithstanding that as early as the fall of 1901 the writer in an article contributed to the *Engineering and Mining Journal*, fully described the camp, together with the principal mining claims—notably the "Copper King," "Carlisle," "Pueblo," "Arctic Chief," "Grafter," and "Rabbit's Fo t." The views expressed in this article were based on observations made previously on Texada Island, the White-horse deposits at that time being merely undeveloped prospects; but the general correctness of the opinions then expressed have since been demonstrated.

The present high price of copper, in connection with the good showings exposed by development, are stimulating capitalists to carry on heavy operations in the districts. It is not to be anticipated, however, that any very big mines will be opened in any of the camps where this class of ore deposits occur, but when the grade of the ore is considered, together with its persistency in depth and continuity as well as regularity of structure, although lenticular, the writer is of the opinion, and the past records support that opinion, that such properties can be made commercial successes provided the operations are carried on with proper conservatism by experienced engineers who are not prejudiced or biased before commencing operations.

This last remark is particularly pertinent to this class of ore deposits, because, about five years ago, no less than four prominent mining engineers advised the then owner of the Marble Bay Mine, on Texada Island, to stope the ore from above the 140 foot level, which at that time was the deepest attained, and abandon the property. He subsequently sold the mine for $150,-000.00, and the present owners realized this sum from the net returns on ore mined,and made their full payments twelve months before they were due; in addition to purchasing and installing an entirely new machinery equipment capable of carrying the work to 2,000 feet or deeper, and the mine is now paying regular dividends.

Referring to the second class of ore deposit (that in which the chalcopyrite ore occurs sometimes with magnetite but often in a quartz matrix in deposits of lenticular structure in fissures in the basic igneous rocks) there is little to add to the remarks contained in the paper submitted to this Institute a year ago, for no development work of consequence has been performed on any of these occurrences.

However, in addition to the districts already mentioned, namely, those of Vancouver and Prince of Wales Islands, this class of ore deposits is found in south-western Alaska, in the Prince William Sound district—especially in the mountains surrounding Landlocked Bay and on Knight's Island. In the first mentioned camp several veins filling fissures in basic igneous rocks, generally described as greenstone, may be noted. The ore in these veins occurs as lenses sometimes having quite considerable lengths and at other times of inconsiderable lengths, with the lenses separated by sheared and brecciated material, which for a better name, may be termed "ledge matter," but which, rarely, if ever, carries commercial value, although usually showing low copper values.

The development on these occurrences had, up to the time of the writer's visit last summer, been confined to open cut work and shallow prospect holes, to represent "assessment" work. In some instances, however, notably on a property known as the "Putz, Steinmetz & Egan," where the ore in the fissure apparently maintained continuity for a distance of 400 feet along the line of strike, which fact had been partially proven by open cuts and surface stripping made at irregular intervals for that distance; and on another property—the "Montezuma," owned by Dickey and associates—as well as on an adjoining group of claims owned by Hemple and associates, indication was found that the ore bearing fissure maintained continuity for a considerable distance along the line of strike.

The factor, though, referred to in the author's former paper, as being doubtful in this class of ore bodies, i.e., the maintenance of continuity with depth, is equally doubtful in respect to Landlocked Bay and Knight's Island occurrences of copper bearing ore, as, also, in reference to the same class of ore deposits along the coast to the South, and until more development work shall have been done, an opinion, in either direction, is not justifiable. Nevertheless during the present year this question of maintenance with depth on this class of ore bodies will have been, at least, to some extent solved in the Prince William Sound District, where active operations will doubtless be carried on at properties recently acquired under bond. Prospects, meanwhile on Knight's Island have, during the winter of 1906-07, been bonded by Seattle, Pittsburg, and even New York speculators; although it will not be possible for an examination to be made of these claims until next summer.

During the past season the writer's attention has been called to some occurrences of highly silicious copper ore, located in the mountains bordering Portland Canal, on the British side of that canal. These occurrences, although no magnetite is found as the matrix of the ore, should be classed with the second of the series. The ore is a combination of iron and chalcopyrite in a quartz gangue occurring as filling well-defined veins in the greenstone country rock. These veins are very persistent and can be easily traced for several hundred feet. The grade of the ore is so comparatively low that previous to the advance in the price of copper, it is doubtful if successful operations could have been carried on, except by using the ore as a flux for the treatment of heavy irony ores, such as are found on the Prince of Wales Island.

The width of these ore bodies is quite a variable quantity and ranges from two to seventeen feet of quartz ledge matter with grains and kidneys of pyrite scattered through the quartz; but only forming a small proportion of the entire vein filling.

Of the third class of ore bodies, that in which chalcopyrite ore occurs usually in a magnetite matrix as contact deposits between crystalline limestone, slate or schist, and igneous rocks, there is much more known to-day than a year ago, as a result of development work; and the largest tonnage of ore shipped during the past year has been from this class of mines.

In British Columbia, along the coast and adjacent islands, but little has been done to properly develop this class of occurrence, but on Prince of Wales Island in Alaska, also in the Prince Williams Sound district, the efforts made to develop such properties have been earnest and attended with gratifying results in some instances, especially so on La Touche Island, where this class of ore occurs at the contact between a graphitic slate and an igneous rock resembling an andesite, but which has never been microscopically examined, and consequently is known locally by several different designations, often even being called quartzite, due to the fact that the rock is extremely quartzose in character and the crystals of hornblende so minute, to be recognized only with difficulty by the aid of an ordinary lens.

The main cross-cut on this ore body has proved it to be 205 feet in width, averaging about 5 per cent. in copper, of which 55 feet will produce ore carrying an average of 10 per cent. in copper. Drifting on the same level has opened up the body along the strike for a length of about 240 feet,with high grade ore in the face of the drift towards the north, and with a fault in the formation shown in the face of the drift towards the south. This ore body has not yet been developed to any great depth for the reason that the outcroppings form a high bluff, from which ore has been quarried to a depth of 85 feet, below grass roots, and shipments are confined to the product from this bluff, while the main crosscut is on a level about forty feet below the floor of the quarry. Another cross-cut adit is being driven 100 feet lower, and it is recently reported that the ore body was encountered at a point about 40 feet further to the westward than in the upper adit. It was expected that by the action of erosion, which had caused a considerable portion of the face of the bluff to be carried off, the adit on the lower level, which is below the zone to which erosion has acted, would demonstrate that the ore body was of considerable greater width than was shown in the upper adit.

La Touche Island, although only about 15 miles in length, and an average of about six miles in width, promises to be one of the greatest producers of copper ore on the Pacific Coast. There is here a zone carrying mineral and showing contact between the graphitic slate and igneous rock almost the entire length of the Island. Apparently this mineralized zone has attained its maximum extent on the Robertson-Beatson property, which is described above; and it is doubtful whether any such extensive body of copper ore of good average grade will be found anywhere along the Pacific Coast. Another property which belongs to this same class is the Ellamar on the coast of Prince Williams Sound, where the country rock formation is very similar to that on La Touche Island, but the ore body itself occurs between slate walls, and the outcrop shows below the high tide mark on the beach. This fact would prevent an examination to determine whether or no the same contact exists as on La Touche Island.

In developing this property a depth of 600 feet has been attained, but the length of the ore body is comparatively short and until last year no serious efforts to prospect along the line of strike of the copper ore bearing formation had been made. This mine has been a producer of high grade copper ore since 1902, as also has been the Robertson-Beatson mine; but on the former stoping has been carried on from each level, while on the latter shipments have been made from the surface quarry work only.

More extensive exploration, than has been done so far in the Prince-Williams Sound district, is necessary before a comprehensive description of the occurrences of copper bearing ore, and the relationship, if any, that they bear to each other can be made.

The ore bodies of this class on Prince of Wales Island,—and these have been most thoroughly exploited during the past season, —are the Stevenstown, Mamie, and Mt. Andrew, on Kasaan Peninsula, from each of which a considerable tonnage of ore has been shipped. The deepest work done on any of these mines has been on the Mamie, where a depth of some 300 feet has been attained, and this work has demonstrated that the lenticular structure so general along the line of strike of this class of ore bodies is also apparently the rule when they are considered perpendicularly.

The theory, sometimes advanced, that there is a relationship between the length and depth of ore bodies of lenticular structure does not hold good, so far as the writer's observations go, in the occurrences of copper bearing ore on this coast. Hence, although as in the case of the Mamie Mine, a deeper development has shown that the lenses of ore, which outcropped on the surface, may be, and in many cases will be, repeated at variable depth below, even though the surface lense should be apparently cut off entirely at the bottom,—no theory can be advanced regarding the tonnage of ore contained in a lense, unless the four sides are exposed.

The presence of garnetite having a dyke structure is especially noticeable on the Mamie property, and regarding this there is a very interesting problem which has not yet been solved. This is in respect to the origin of the garnetite, which is usually associated with a rock locally designated as felsite, and classified by some petrographists as augite-porphyrite. Another opinion has been advanced with regard to this rock, that it is not an igneous rock, but only a formation evolved from the contact of limestone and granite. Doubtless the members of the United States Geological Survey, who have taken specimens of the various classes of the country rocks, will have these properly classified within a short time, and if that classification corresponds with the classification of similar rocks made by the geologists of the Geological Survey of Canada, then a scientific question will have been settled definitely.

There is one feature connected with all the contact occurrences of copper ore, where limestone is one of the contact rocks. No ore occurs except associated with more or less garnetiferous felsite (the local designation) and, so far as observed, there is apparently no association between the granite and the deposition of the ore.

The development at depth on the Mamie Mine has demonstrated to some extent how difficult is the development of this class of property, at depth; for the reason, that little if any connection can be shown between the different lenses of ore, and also it is noticeable that the lines of contact are so irregular that it is difficult to follow them, even where a thoroughly systematic method of development is being followed.

The future of this class of ore occurrences depends almost entirely on the extent and grade of the lense that outcrops at the surface; because in a case where this is of sufficient importance from a commercial standpoint for ore to be mined and treated at such cost as will leave a substantial margin to pay the expense of prosecuting further exploitation, then a systematic and thorough method of prospecting at deeper levels can be carried out. On the other hand, if the surface lense is limited in tonnage, and the ore comparatively low grade in value, there would be little encouragement for an operator to attempt such thorough exploitation at deeper levels.

The other properties belonging to this same class (the third in the series) situated on Prince of Wales Island, on which development has proceeded during the past year are the Rush and Brown on the Coast of Kartar Bay; the Mammoth, near the head of Kasaan Bay; the Cymru on the shore of the north arm of Moyra Sound, and some prospects near the south end of Prince of Wales Island; but on none of these properties has development been carried to as great a depth as on the Mamie.

So far as the fourth class of ore bodies is concerned, that in which chalcopyrite ore occurs in association with iron pyrite, barite or heavy spar, and a small percentage of lime, it is noticeable that this class of ore has not yet been discovered anywhere on the Coast, except on Mt. Sicker, where mining operations on several claims have been conducted since 1899. The principal mines that have been opened being the Tyee, from which about 200,000 tons of ore have been mined and treated; the Lenora, from which some fifty or sixty thousand tons of ore have been mined and treated and the Richard III, which is during the present season being actively operated after having remained idle for about two years past.

Of these mines the Tyee has been the most important. It has been in continuous operation since 1900, and the development has been carried on to a depth of 1,250 feet.

The occurrences of ore on Mt. Sicker in the schist country rock afford an interesting study to the geologist, as well as to the metallurgist. To the former, because notwithstanding the large extent of the ore bodies, especially on the Tyee Mine above the 300 foot level, no ore was discovered until the 1,000 foot level was reached so far as exploitation has shown, and this has been carried on very thoroughly between that level and the 1,250 foot level; to metallurgists, because of the high percentage of barium sulphate (about 40%) that occurs in the gangue.

Below the thousand foot level on the Tyee mine, ore of practically the same character, but of lower grade than in the upper levels was exposed, and this body has also been exposed to the 1,250 foot level. At present development work is being carried on at these levels, while the main shaft is being sunk to the 1,400 level and ore mined from above the 300.

The development of the Richard III mine is now being prosecuted vigorously, work on the Tyee having shown that the ore body maintained continuity along the line of strike into the Richard III ground.

The Lenora mine has been closed down for the past three years, development at deep levels resulting unsatisfactorily.

One very noticeable feature of the Mt. Sicker ore bodies is that the outcroppings are of comparatively limited extent; in fact the major portion of the ore bodies do not outcrop at all along the line of strike. The country rock, in which the ore bodies occur, is a schist; but whether of aqueous or igneous origin has never been definitely settled. Owing to the presence of graphite and from the general appearance, the writer has always been of the opinion that this schist is sedimentary, having become more or less metamorphosed by reason of the intrusion of masses and dykes of volcanic rocks of the diorite class; but some geologists, who have visited the district, are inclined to the opinion that the schist is merely an alteration of the volcanic rocks caused by the shearing movement, which has produced a zone where the schistosity is extremely marked. The fact that the schist, even where closely associated with the ore, carries no barium sulphate, and again, that the line of demarkation between the schist walls and the ore is so well defined,—in mining the transition from barren country rock to ore of shipping grade is sudden and complete—precludes the theory that the origin of the ore is from lateral secretion. In fact from a consideration of all the conditions surrounding these ore bodies it would appear as though the ascension theory would best explan their origin.

Class number six, refers to pyrrhotite ore carrying low copper values, sometimes in a gangue composed of a high percentage of epidote, garnet, amphibole and some calcspar, either in fissures in basic igneous rocks, or else at the contact of crystalline limestone or igneous rocks.

Examples of this class of ore deposits are relatively numerous, and, apparently, the ore bodies are of much greater extent, although lenticular in structure, than those belonging to any other class in the series under discussion in this paper. Whether any of these ore bodies will prove to be of commercial value has yet to be determined. The values contained in the pyrrhotite at or near the surface have almost invariably been so low that operators have hesitated to carry on developments to any extent; and the writer is not aware of any ore body of this class on the Coast or the Islands adjacent thereto, on which the development has been carried to a point to demonstrate commercial value. The old theory that values improve with depth has been so thoroughly exploded, especially with regard to the occurrences of copper ore, that, at the present day, capitalists will scarcely consider a property unless the outcroppings carry fair values. The writer does not wish to be included among those who hold to the theory that ore bodies increase in value at depth, when this hypothesis is advanced to establish a rule, but there are occurrences, and one of those is the Robertson-Beatson property on La Touche Island, where a zone of secondary enrichment occurs at a depth of about 70 feet below the apex of the outcroppings, and this zone is known to extend to over a hundred feet deeper.

There is one rule noticeable in all the occurrences of pyrrhotite outcroppings. This is that surface waters percolate through the pyrrhotite very freely and where this ore carries even low copper values on the surface, it does not require any great stretch of imagination, to conclude that values have leached out and been carried downward with the percolating waters.

Extensive bodies of this class of ore are known to occur on the west coast of Vancouver Island; on the main land near the head of Jarvis Inlet, British Columbia; as well as on the mainland along the Alaskan Coast; on Prince of Wales Island and Knights Island and Prince Williams Sound. The same condition in respect to lack of development is applicable to all these localities; but the time is not distant when a market will be created for this ore by the smelters for fluxing purposes, and possibly by powder works for the manufacture of sulphuric acid. This should result in a settlement of the question whether the copper values in this class of ore will increase at some depth below the zone to which the surface waters percolate.

One feature in connection with pyrrhotite ore on the Pacific Coast is worthy of note. This is that unlike the pyrrhotite found in the Sudbury district, Ontario, it carries no nickel values, and unlike the pyrrhotite ore in the Rossland district, British Columbia, it carries no appreciable gold values. Owing to these deficiences and the low copper contents carried by the outcroppings, it is not surprising that so little development has been attempted on this class of ore bodies, notwithstanding their apparent great extent.

There are meanwhile certain characteristics general to all the occurrences of copper bearing ore along the Pacific Coast. These are as follows: Garnets and epidote are almost always found associated with the copper ore and the presence of these minerals in the gangue is a sure indication of an occurrence of copper bearing ore. It is not intended, however, to intimate that wherever garnet and epidote occur copper ore will be found, but that the writer has observed that wherever copper ore is found these minerals accompany it, especially is this the rule in the case of bornite and chalcocite ores.

Another characteristic, that is very general with regard to occurrences, is the lenticular structure of the deposits and the absence of what may be termed "true leads." Even where copper ore occurs in veins, it is almost always found that the solid ore is in lenses in the vein matter. Of course, there are exceptions to this latter rule, in fact an occurrence at Maple Bay on Portland Canal, in British Columbia, may be taken as an exception, the chalcopyrite being disseminated through the quartz ledge matter in small grains and crystals. About the same condition also occurs on a portion of the Britannia Mine on Howe's Sound, British Columbia, but there the mass of quartz that carries the mineral has itself lenticular structure.

NOTE.—The author regrets that the statement published in the Advance Proof of this paper, wherein it was alleged that in an interview Mr. D. D. Cairnes, of the Geological Survey of Canada, is reported as having said that the White Horse Copper deposits were not discovered until 1906, is incorrect. Mr. Cairnes informs the author that he was not interviewed by any newspaper on the subject and made no statement as was attributed to him. The author takes pleasure in making this correction.

RECENT DEVELOPMENTS IN MINING IN THE SOUTHERN YUKON.

By D. D. Cairnes, B.Sc., M.E., Geological Survey, Ottawa.

(Toronto Meeting, 1907).

By permission of the Director of the Geological Survey.

In introducing this subject it may not be entirely amiss to mention some of the conditions under which mining operations must be conducted in this somewhat northerly portion of Canada. Until very recently the common idea of this district was that it was one of perpetual snow and ice and one very difficult of access. Pictures and newspaper accounts of the Chilcoot Pass and the building of the W. P. & Y. Ry. are mostly accountable for this opinion. Now a person can travel to Whitehorse or Dawson with the same comfort as to any of the ordinary popular summer resorts of the West.

Steamers ply regularly between Seattle and Vancouver and Skagway—distances respectively of about 1,000 and 867 miles. From here Whitehorse is reached by the W. P. & Y. Ry., a distance of 111 miles, hence steamers run to Dawson—460 miles.

The placers for which the Yukon is so well known occur chiefly in the northern portion of the territory—the richest being within a few miles of Dawson, on the creeks running into the Klondyke and Indian rivers. The only places where quartz mining has been done are just west of Whitehorse and along Windy Arm to the south, and it is with quartz and coal mining that this paper has to deal.

In actual mining there are few more difficulties to contend with than in B.C. or many other northerly parts of the world where mining is carried on so extensively. At least six months are suitable for surface working and for the necessary outside operations and during several months of this time work can be carried on almost as well by night as by day without artificial light; and although the frost extends to considerable depths, in places, this does not interfere to any great extent except on the very surface, when working in soil and loose material. The current wage paid to miners in the Windy Arm mines this last season was $3.50 per shift of 8 hours, with board and lodging included.

With the exception of the Whitehorse copper district little or no quartz mining, except assessment work in a few scattered places by a few prospectors, had been done in the Yukon until the latter part of season of 1905, when Col. J. H. Conrad commenced to develop some properties on the west side of Windy Arm, and since then much has been accomplished in a short time. In consequence the little town of Conrad has sprung into existence; a great many men have been employed; a waggon road has been built from Caribou Crossing along the beach to Conrad, about 11 miles; Government trails have been built up to the mines and connecting several of them; three aerial tramways have been built to carry supplies, &c., to the mines and to carry ore down to the beach; and a foundation has been laid for what appears to be a permanent industry in the Yukon. Moreover, men have been encouraged to prospect further with the results mentioned below. A new mining district was also created this season with a mining recorder's office at Conrad, called the Conrad Mining District, embracing the Windy Arm district and extending north to include the Watson and Wheaton rivers districts.

It is not the purpose of this paper to go into details in regards to the different properties of this district—a full account of which will be published in the writer's detailed report for the Geological Survey, but merely to give the general characteristics of the district.

Topographically the country is very rugged, the summits rising as high as 5,200 feet above Windy Arm, or about 7,360 feet above sea level. No timber exists, except in some of the valleys and part way up some of the hillsides, ceasing, however, entirely at about 2,000 feet above the valleys. Most of the Windy Arm properties are situated high up on the bleak mountain sides, and all wood, timber, supplies, machinery, &c.,

had to be packed or pulled up by mules or horses—now replaced largely by aerial tramway systems—so that prospecting and opening up the properties was both difficult and expensive. The district is, however, very accessible. The ore having arrived at the beach of Windy Arm is loaded on boats and carried to the railway at Caribou Crossing. There is also a good grade for a railway from Conrad along the beach to Caribou Crossing, or a spur could be run from Log Cabin direct to Conrad.

The minerals in this locality are in quartz veins, in true fissures, and the values are chiefly gold and silver. The Big Thing veins are in granite; all the others are in a formation I have called the Windy Arm formation. This consists of a somewhat complex series of porphyrites, diorites, gabbros, &c., which apparently represent rocks from the same magma, but which differ considerably on account of segregation and cooling under different conditions. These rocks are generally fresh looking, fine grained, and greenish in colour. Towards the edge of the series, in places, is a porphyry presenting somewhat the appearance of a conglomerate, due to portions of one porphyry being included in another.

The veins vary considerably in width, but in most cases are noticeably persistent in length. Argentiferous galena is the common mineral of value. There are also found some native silver, argentite, stephanite, pyrargyrite, tetrahedrite, chalcopyrite, jamesonite, stibnite, lead carbonate, malachite, azurite, pyrite, arsenopyrite, pyrrhotite, and sphalerite.

The principal vein on the Big Thing group was struck this summer at the end of an 80 foot drift. A crosscut was then run 60 feet on the vein and a winze was sunk, which, when seen in October, was about 55 feet deep. The vein was widening rapidly and becoming almost flat, and was, in the bottom of the winze, about 10 feet wide. This vein appears to be of the elongated lense type. The ore is chiefly secondary quartz, and is very porous, near the surface, due to leaching action. The minerals are chiefly oxides and carbonates which will give place to the sulphides in a short distance. Some stibnite, arsenopyrite, and pyrite were found near the bottom. High assays running into the hundreds have been obtained in gold and silver, and it is claimed the ore body will average close to 30 dollars per ton.

On the Montana, a drift was run in on the vein about 700 feet, the vein being from 2 to 5 feet in width, with a streak of rich ore 8 inches to 18 inches wide next the hanging wall, which assays about $90.00. The rest of the vein may run $20.00. An incline had also been sunk on the vein which at a depth of 320 feet was about 8 feet in width, from wall to wall, with over 4 feet near the centre of almost barren, leached, and somewhat decomposed, porphyry with quartz stringers running through it. The values are chiefly in silver, the chief mineral being galena.

When seen in October, the Vault which had a drift run in on the vein over 300 feet, was probably the most promising looking property in the district. This is the same vein, in all probability, as the Venus No. 1 and can be traced over 4,000 feet. It is, in places, 20 to 30 feet in width, being nearly all well mineralized quartz. In places there are 4 to 6 feet of almost solid galena. The lead here, as on the Venus, varies greatly in width, and at times is only a foot or so wide. So far, however, the vein on the Vault has been much more uniform in width than on the Venus.

On the Venus, a crosscut tunnel was run about 100 feet to the vein, and drifts were run about the same distance each way, from which a number of stopes were raised, the vein being from 18 inches to 16 feet in width. In the stopes there are from 4 to 8 feet of good ore which will probably average over $20.00 in gold and silver. A lower crosscut has also been run 544 feet to the vein, and drifts have been run each way, but where opened up here, it is narrower and leaner than in the upper tunnel, but this feature is likely only of limited extent, as the property looks well both to the north and of this place on the surface. The chief minerals are galena, lead carbonate, arsenopyrite, chalcopyrite, malachite, pyrite, and also considerable jamesonite and antimony ochre. The ore is chiefly argentiferous galena. Where the vein is wide it consists of alternating bands of quartz and more or less mineralized country rock. A 50 h.p. gasoline engine operates a compressor here to run the machine drills used in tunnels, but piping and the necessary machinery is being installed to utilize some of the water power of Pooley Canon and replace the use of gasoline.

On the Humper No. 1, only about 70 feet of work had been done, when last seen, mostly in the form of drifts, but the property looked very promising indeed. The vein which can be traced for 1,700 to 1,800 feet, at least, is from 18 inches to 4 feet in width, and carries considerable argentite, ruby silver, and stephanite, and also some native silver, galena, and pyrite. About 8 inches of the vein will average over 300 ozs. in silver, and a narrow streak of argentite ½ to ¾ of an inch in width, which is quite persistent, runs 3,000 ozs. in silver.

There are also several properties such as the M. and M. and the Ruby Silver, on which are veins only a few inches in width, often less than a foot, but which contain very high grade ore.

In the above description of claims seen, no attempt has been made to describe all the promising looking properties or to give many details in regard to those mentioned, but merely to give a somewhat general idea of the character of the deposits and of their values. The properties are all as yet in the prospect stage and only small shipments of ore have been made from time to time; but the work done has at least proved this belt to be very highly mineralized. Reports of numerous discoveries came in at different times during the season from different directions, chiefly from along Taku Arm, and the ores shown looked very well indeed.

The success met with in this district encouraged men to do more prospecting than in previous seasons, with the result that a number of valuable discoveries were made. On June 21st, the Gold Reef claim, on which was discovered quartz carrying free gold and telluride minerals, was staked on Gold Hill about 16 or 17 miles south west from Robinson, and in the next 90 days 700 claims were located on the same belt. This belt or belts of schists, approximately ½ mile wide, outcrops in a northwesterly and southeasterly direction near the eastern edge of the granites, which often become porphyritic. Dykes of greenish porphyry and porphyrite occur in the granites, also near their eastern edge and it is in this disturbed belt that the quartz veins occur. They are often quite well mineralized, the chief minerals being galena with sometimes grey copper, chalcopyrite, pyrite, malaconite, and malachite and, as a rule, are very persistent and can be traced in some instances, for several miles. Outcrops of quartz very much resembling each other are seen in almost straight lines, at short intervals, and with the same general strike from the Watson river to about 8 or 10 miles south of the Wheaton river, a distance of nearly 20 miles, and although most of the veins found were in this belt, about 2 miles wide, towards the end of the season Mr. Porter and others discovered some large deposits of quite pure stibnite, and other minerals, at a considerable distance west of this belt.

Only a small amount of the rich telluride minerals which were sylvanite, hessite, and telluric ochre was found, but no work had been done on any of the claims, when last seen, except a limited amount on the Gold Reef. A government wagon road was built from Robinson to Gold Hill immediately after the discoveries were made. Assays as high as $300.00 and over, here and there, and a number of fairly average assays from $20.00 to $60.00 were obtained. Recently the writer has been informed by several disinterested parties that the Tally-ho Mining Co., whose property is situated on the north side of the Wheaton river, in the line of this Gold Hill mineral belt, has over 2 feet of quartz at the end of a 70 foot tunnel averaging over $200.00. The rest of the vein is lower grade. The property is still working and the ore is being freighted out to Robinson to ship to the Tacoma Smelting Works.

The copper deposits just west of the town of Whitehorse have been known for some years and considerable work has been done on some of the properties. However, for several reasons these have not developed as rapidly as might have been expected. Freight rates were high, either for getting in supplies or shipping out ores and to treat the ore on the ground, coke was required, and no coking coal was known to exist in the country; and to bring in coke made treatment very expensive. Also one of the first reports written on the district was one by R. H. Stretch, prepared for the W. P. & Y. Ry., but which was afterwards published in the *Engineering and Mining Journal*, in Sept. 1900, and which may also have had a tendency to keep capital out. In this report Mr. Stretch claimed the granites would be found underlying the limestones, felsites, and diabase dykes and the ore bodies were only superficial and would not extend down more than a few feet. The writer saw no reasons for adopting this theory.

Mr. Wm. M. Brewer in an article in the *Engineering and Mining Journal* of Feb. 1st, 1902, and also in a paper read before the Canadian Mining Institute in 1905, has given a very concise and clear description of the district and a number of the properties, drawing attention in particular to the striking resemblances between these deposits and those on Texada Island. Recent work in both places has further proved the similarity of the deposits in these two localities; and as those on Texada Island have improved from the surface to their present depths there is every reason to believe that the Whitehorse deposits will do the same. For recent information regarding the Texada Island deposits the writer is indebted to Mr. O. E. LeRoy of the Geological Survey who examined them this last season.

The writer agrees with Mr. Brewer in regards to the Whitehorse deposits, except as regards their origin. Only a very casual examination was made this summer, but from what was seen in the field and from examinations of specimens here since, it seems almost certain that the felsite rocks in which the ore occurs are of secondary contact origin and not intrusives and that the granites are directly the cause of the deposits and are connected genitically with them. A thin section of a typical specimen of the felsite shows it to be a mosaic of spinel with some pyroxene and to be clearly of secondary contact origin.

This season Byron N. White of Spokane has been working the Pueblo nearly all summer and is still continuing, and when seen in October this property presented an enormous surface showing. A body of ore, approximately 225 feet by 250 feet, was uncovered and a shaft had been sunk over 100 feet on it and no walls had as yet been encountered. The ore on the Pueblo is hematite strongly impregnated with the copper minerals, chalcopyrite, bornite, malachite, cuprite, and even some native copper. Aside from the copper values in the ore, the hematite itself will be valuable for fluxing, when smelting operations commence in this district. On most of the properties magnetite takes the place of the hematite. Ore is at present being shipped from the Pueblo to the Britannia smelter at Crofton, B.C.

The Carlisle shaft has been sunk over 115 feet and 100 tons of ore were shipped from this property this summer. The Arctic Chief is working at present and is reported to be steadily improving.

So in this district from the British Columbia and Yukon boundary to Whitehorse, a distance of approximately 100 miles, there are a considerable variety of mineral deposits which extend over a considerable portion of the district showing how widely mineralized this section is. Added to this is the fact that there is a considerable amount of good available coal in the Yukon.

Just south of the Whitehorse copper deposits and between them and Gold Hill, is a belt of anthracitic coal which has been worked to some slight extent, about 12 miles in a southwesterly direction from Dugdale on the W. P. & Y. Ry. The general strike of the measures is about true 74° west. A 60 foot tunnel has been run in on one of the seams. Here the strike is true 63° west with a 42° dip to the northeast. Three seams were seen being respectively 9 feet 6 inches, 10 feet 4 inches, and 2 feet 6 inches wide, and others may be covered by the heavy wash in the valley. The samples tested were surface samples, and consequently ran very high in ash. The coal should make a good fuel and, as there is a good grade from the railway to the coal claims, and as the coal is close to the copper deposits, the Watson and Wheaton rivers deposits, and the town of Whitehorse, this coal should be of considerable value to the district.

Down the river from Whitehorse about 190 miles, or somewhat less than halfway to Dawson, is the Tantalus Coal Mine. As the coal outcrops here on the river banks it is well situated to work economically. Most of the river steamers burn this coal and about 7,000 tons will be loaded this season. There are three workable seams opened up, only the lower two of which are being worked at present. Other seams may be found as the formation is heavily covered in most places. The coal is worked by the stall and pillar method from two tunnels which were in about 700 feet when visited in October. The wages paid was $5.00 per day with board and lodging for underground and $4.00 for surface work. The measures are quite regular and can be traced over 20 miles down the Nordenskiol river to the south, and for over 10 miles to the north, showing that there is an enormous amount of coal in this district, and when the measures have been prospected more closely it is hoped that they may be found in some accessible points much closer to Whitehorse, because, as the coal gives good coking results in the laboratory, it probably will make a metallurgical coke and, in that case, a smelter seems a probability in the vicinity of Whitehorse, where there is the ore, flux, and the water power.

The following section was measured near the end of the tunnels at the Tantalus Mine:—

Bottom seam	Coal	2 feet	4 inches.
	Shale	0 "	7 "
	Coal	2 "	0 "
	Shale	0 "	8 "
	Coal	2 "	11 "
	Shale	4 "	0 "
Middle seam	Coal	2 "	3 "
	Shale	0 "	2 "
	Coal	0 "	7 "
	Shale	0 "	2 "
	Coal	2 "	0 "
	Shale	0 "	2 "
	Coal	1 "	8 "
	Shale	7 "	0 "
Top seam	Coal	3 "	0 "
	Shale		

Analyses of coal from these three seams are:—

Water	0.75	0.76	0.82
Volatile combustible matter	23.61	24.74	25.12
Fixed carbon	55.21	58.60	66.03
Ash	20.43	15.90	8.03
	100.00	100.00	100.00
Coke per cent	75.64	74.50	74.06

These coals yield in the laboratory a firm coherent coke.

SOME NOTES ON THE ECONOMIC GEOLOGY OF THE SKEENA RIVER.

By W. W. Leach, Ottawa, Ontario.

(Toronto Meeting, 1907.)

By Permission of the Director of the Geological Survey of Canada.

Since the Grand Trunk Pacific scheme was first projected, a great deal of interest has been aroused in the potentialities of the country through which this road will pass. Up to the present, however, the attention of the public has been turned chiefly to the eastern and prairie sections, the uncertainty of the route through the mountainous districts of British Columbia having deterred many from exploring that part of the country in the hope of locating valuable minerals, lands and timber in advance of the railroad.

At the present time it seems fairly definitely settled that the road will pass down at least part of the Skeena valley, and during the past two seasons a number of prospectors have found their way into that district, many coal and mineral claims have been staked, and a great deal of the available arable land taken up.

Although this was one of the first parts of British Columbia to be traversed by the earlier explorers, Sir Alexander Mackenzie having crossed from the Peace River to Bella Coola on the Pacific (passing a short distance south of the Skeena waters) as early as 1793, very little is yet known of the economic geology of the region. The only official reports, known to the writer, dealing with this subject are those by Dr. Dawson, contained in the Report of Progress of the Geological Survey for the years 1879-80, and by Mr. Wm. Fleet Robertson, the British Columbia Provincial Mineralogist (see Report of Minister of Mines, B.C., 1905). Dr. Dawson's work consisted of a hurried exploration from Port Simpson to Edmonton, following the main travelled trails and, with the map accompanying it, affords the only reliable information of much of this country to-day. Mr. Robertson's report, as far as geology is concerned, deals chiefly with a number of prospects in and adjacent to the Bulkley valley.

Up to the last few years little or no prospecting has been done in this great district, if we except the placer miners, who have over-run the greater part of it pretty thoroughly but without any very startling results.

The rocks of the Skeena river may be roughly divided into four main divisions to which, in their southern continuation in the neighbourhood of Francois Lake, Dr. Dawson has applied the following nomenclature beginning at the oldest:—1st, The Cascade Crystalline Series; 2nd, The Cache Creek Group; 3rd, The Porphyrite Group; and, 4th, Rocks of Tertiary Age.

The Cascade Crystalline Series extends in a belt along the coast and is crossed, more or less at right angles, by the river, and has here a width of 50 to 60 miles. These rocks consist chiefly of gneisses, granitic rocks and micaceous schists, generally much disturbed and usually found dipping at high angles; they are supposed to be of Palæozoic age probably Carboniferous or older. Up to the present they have not been found to contain many large or valuable mineral deposits, although various minerals of economic value have been reported as occurring in these rocks at different localities in this neighbourhood, notably, pyrrhotite and chalcopyrite on the Tshimpsian Peninsula back of Port Simpson, galena and copper pyrites at the head of Kitamat arm and iron ore on the Ecstall river near Port Essington. It is highly probable, however, that future prospecting will bring to light other occurrences of valuable minerals, as the extremely wet climate of the coast region, with the resultant rank growth of underbrush and heavy covering of moss has deterred many from prospecting this part of the district with any degree of thoroughness. The mountains here, besides, are high and rugged with few trails and less feed, so that the more open country and better climate of the interior has up to the present gained most of the attention.

Of the Cache Creek series little can be said; the rocks composing it are chiefly quartzites, dark highly-altered argillites and crystalline limestone and are supposed to be Carboniferous, though no fossils have been found in them in this region, and this classification must be regarded as only provisional. Their extent is very doubtful and they do not appear to outcrop in the Skeena valley itself, at least as far up as Kispyox; the only locality in the lower part of the Skeena watershed where these rocks were noted being on the Kitsequecla river, a few miles above its mouth. On the Upper Skeena they appear to be more largely represented as they crop continuously along the river from near the fourth telegraph cabin to the mouth of Bear river and beyond. The writer is not aware of any claims having been located in these rocks.

The third of these divisions, the Porphyrite group, covers by far the most extensive area, and is also of most interest to mining men, inasmuch as practically all the recent discoveries of mineral occur in this formation, while the coal-measures may, for the present at least, be also included. These rocks are probably of Cretaceous age and vary greatly in composition and appearance throughout the district. While named by Dr. Dawson the "Porphyrite Group" on account of the preponderance of that rock in the Francois Lake district, to the south of the part in question at present, still rocks of volcanic origin are by no means the only ones represented, there apparently having been a gradual change from south to north from beds mainly of volcanic materials to those of purely aqueous deposition.

In and adjacent to the Bulkley valley these rocks cover a great area, and have been studied in more detail than elsewhere, having been prospected more or less thoroughly and numerous claims located on them. Here volcanic rocks are much in evidence, consisting of porphyrites (andesites), tuffs, agglomerates, etc., often highly amagdaloidal with inclusions of calcite, zeolites, epidote, etc., more often occurring in sheets as volcanic flows, but frequently showing evidences of deposition under water, and all more or less regularly bedded. They vary greatly in texture and appearance, in colour ranging from light greenish greys to dark purplish reds. Dr. Dawson has estimated their thickness, south of Francois Lake, at about 10,000 feet, and while of necessity this will vary greatly, in the neighbourhood of the Bulkley valley it will probably not fall far short of this.

These volcanics have been cut in various places by intrusive granitic areas which have shattered and metamorphosed them to a great extent. It is along the contacts of these intrusive rocks and the numerous dikes from them with the porphyrites that mineralization has most frequently taken place. The granitic rocks themselves are somewhat variable in appearance, two distinct facies having been noted on the Telkwa river, one consisting of a coarse light coloured biotite granite shading off into a granite porphyry near its edges, and the other of a pinkish syenite porphyry; both, however, seem to have had the same effect in regard to mineralization. The dikes from them show an indefinite number of types.

In the vicinity of the Bulkley there would appear to be, so far as is now known, three main mineral-bearing belts, the most important so far being situated on the Telkwa river near its head, crossing over into the headwaters of the Morice river. The other two have not been visited by the writer, but from description of prospectors and others conditions there must be very similar to those on the Telkwa. One of these lies at the head of the Zymoetze or Copper river including Hudson Bay Mountain, and the other is located on the Babine range between the Bulkley and Babine Lake, near the headwaters of Driftwood Creek. These two latter districts differ from the first-named inasmuch as a number of galena leads have been located in them, whereas on the Telkwa district that mineral is seldom seen.

On the Telkwa river the ores consist chiefly of copper, and occur in a variety of ways. At times they are found occupying fissures where the country rock has been shattered near the intrusive granitic rocks; this is particularly noticeable in Hunter's basin at the head of Goat Creek. Replacement along crushed zones is another common form of ore deposition, and again in places the later dikes themselves are mineralized, and in other cases although the dikes appear to be barren, the porphyrites along their contacts are mineralized; one such case, that of the Black Jack and Dominion claims in Dominion basin, which came under the writer's notice showed a strong dike about 45 feet wide cutting nearly vertically the porphyrites, themselves dipping at low angles. The brown trap of the dike seemed to be quite barren, but in certain beds of the volcanics, which were more readily decomposed than others, the country rock had been replaced by quartz, calcite, epidote and ore, which alteration appears to have followed the bedding planes, reaching its maximum intensity near the walls of the dike and gradually decreasing laterally from them.

It will be seen from the above that uniformity in the manner of ore deposition is not to be looked for; probably the most common form is when the large dikes are themselves mineralized, especially along their walls, in such instances the adjacent porphyrites are in most cases themselves decomposed in part and more or less mineral-bearing.

Practically no work has been done on any of the Telkwa river properties beyond mere surface prospecting, and that to a very limited extent only, so that it is much too early to prophecy as to their continuity and ultimate value. In some of the small fissures high grade ore is found with values chiefly in silver and copper (the gold contents as a rule being small), the ore consisting of a variable mixture of chalcopyrite, chalcocite, copper carbonates, bornite and specular iron, the latter at times being highly micaceous. This micaceous iron seems in places to be associated with silver, as a sample of it, carefully separated from the other materials, gave by assay 8 ounces of silver to the ton. The gangue is usually quartz. The following are a few of the most typical claims of this class, the Rainbow, King, Waresco, Idaho, and Russell, all in Hunter's basin.

It is, however, mainly on the larger and lower grade properties that the future of the district depends; the most common ore in these is a mixture of chalcopyrite, a little chalcocite, specular iron and iron pyrites in a gangue consisting of quartz, altered country rock, epidote, calcite, etc., which should make a nearly self-fluxing ore. Among the principal claims of this description may be mentioned the Duchess group, the Evening group, and the Anna-Eva group, all on Howson creek, and the Dominion and Black Jack claims of Dominion basin.

As a general rule it may be said that, although the greater part of this district is underlain by rocks of the Porphyrite group, no important discoveries of mineral have been made except in the immediate vicinity of the granitic intrusions and the dikes from them, and it would therefore appear conclusive that they were instrumental in the deposition of such ore as has so far been found.

Coal.

Coal has been reported from many widely separated localities in the Skeena watershed, in fact it was known and locations taken up some time before the existence of the metalliferous deposits were noted. To give an idea of the wide-spread distribution of coal the following localities may be mentioned where it has been found; the lower part of the Telkwa river and its tributaries, the headwaters of the northern branches of the Morice river, the Bulkley river from near its junction with the Morice river to the mouth of Sharp creek, about twelve miles below Moricetown, Driftwood creek, the Kitsequecla river near its mouth, the lower end of the Kispyox river, Tzesatzakwa river, the head of Copper river, and near the head of the Skeena river itself.

In not all of these localities have workable seams been found, but it is of interest to note the presence of the coal-bearing rocks with the possibility of future work showing up other and better seams in some places at least.

It seems probable that all these coals are at about the same geological horizon, and are of Cretaceous age, though, towards the south, Tertiary coals may be represented contemporaneous with some of the volcanic flow rocks there found, which are in all probability younger than those of the Porphyrite series.

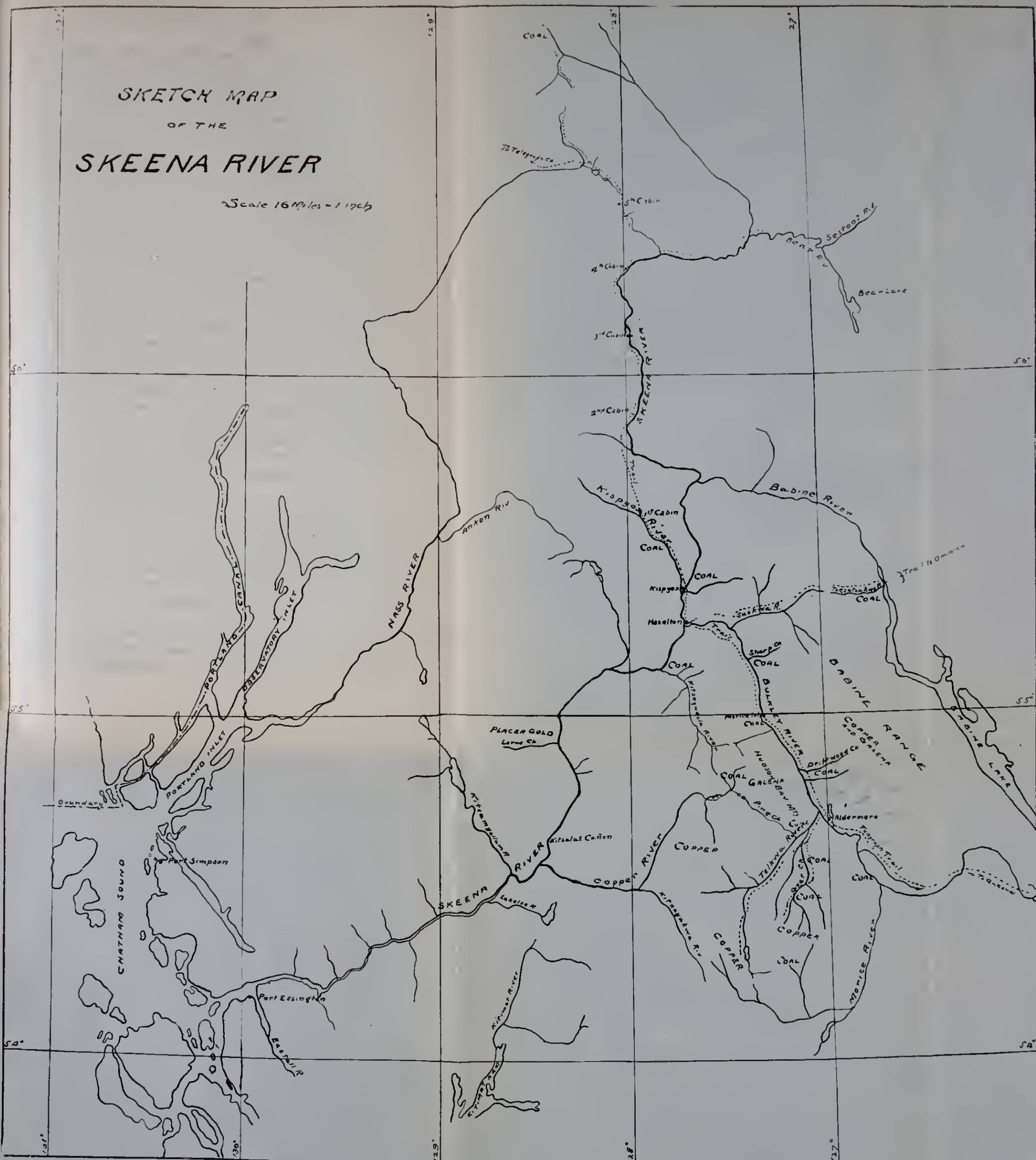
Besides being widely distributed throughout the district, coals differing greatly in quality have been found, as a glance at the following analyses will show:—

No.	Remarks.	Moisture.	Volatile Combustible Matter.	Fixed Carbon.	Ash.
1	2 foot seam, Driftwood C'k., does not coke...........	7.90	36.64	42.06	13.40
2	2 foot seam, Bulkley river near mouth of Sharp C'k., cokes well	1.02	25.70	52.96	20.32
3	Top seam, 10 feet, Cassiar Coal Co., Goat Creek, non coking; sulphur 0.52% ..	3.40	28.80	62.00	5.80
4	6 foot seam, Transcontinental Exploration Syndicate, Goat C'k, non-coking, sulphur 0.52%	0.90	9.90	75.80	13.40
5	6 foot seam, Western Development Co., Head of Skeena river, non-coking	5.75	7.34	75.26	11.65
6	4 foot seam, Telkwa Mining, Milling and Development Co., head of Morice river, non-coking	0.58	10.82	82.70	5.90

Of these coals Nos. 1 and 2 are not likely to be of much economic importance for some time occurring as they do so close to others of better quality; No. 3 is typical of most of the coal on the lower Telkwa and should make a most excellent fuel for steaming, while Nos. 4, 5 and 6 may be classed as semi-anthracites, they are all strong bright coals and should stand transportation well and may some day supply the greater part of the domestic fuel of the Pacific Coast cities.

It is to be regretted that none of these coals make a good coke, No. 2 being the only one that coked well in the laboratory, and it is too high in ash for commercial purposes. In view of the proximity of smelting ores a good coking coal would be of great value, and it is to be hoped that further exploration will bring to light some suitable seams.

It will be seen from the above analyses that the condition of the coal differs widely at points comparatively near together, and it would appear that the proximity of areas of eruptive


SKETCH MAP
OF THE
SKEENA RIVER
Scale 16 Miles = 1 inch
SKEENA RIVER
Babine River
Kispyox River
Kispyox
Hazelton
BABINE RANGE
BABINE LAKE
BULKLEY RIVER
Aldermere
Telkwa River
Morice River
Copper River
Kitsalas Cañon
Port Essington
Port Simpson
CHATHAM SOUND
PORTLAND CANAL
PORTLAND INLET
OBSERVATORY INLET
NASS RIVER
Ankon Riv
Bear Lake
Bear Rv
PLACER GOLD
Lorne Ck
Boundary
Kitimat River
COAL
COPPER
GALENA
Telegraph Trail
Trail
Sharp Ck
Driftwood Ck
Suskwa R
5th Cabin
4th Cabin
3rd Cabin
2nd Cabin
1st Cabin
55°
54°
56°
129°
128°
127°
130°
131°

rocks younger than the coal-measures has been the chief factor in altering it from a lignitic coal to a semi-anthracite.

Among the better known localities the Telkwa river field may be mentioned in more detail. Here the coal-bearing rocks overlie those of the Porphyrite group with probably a slight unconformity, but, as they have subsequently been much folded and disturbed, their relationship to one and other is not entirely clear. The coal-measures are the highest horizon represented, being themselves overlain by glacial debris. In a total thickness of not more than 300 feet of measures, four at least, good, workable seams have been uncovered; the intervening beds consisting of clay shales, often highly nodular with much ironstone, a few beds of soft, crumbly sandstone towards the bottom, and finally a basal bed of coarse loosely-cemented conglomerate composed chiefly of pebbles from the underlying volcanics.

These rocks must have originally covered a much more extensive area than at present, but their soft nature and consequent inability to resist erosion has resulted in detached remnants only remaining in the valleys. As the valleys are wide, and almost invariably heavily drift-covered, the coal is exposed only where the streams have, in a few places, cut through the deep mantle of gravel to the bed rock; elsewhere no natural exposures are to be found until the higher ridges are reached consisting of volcanics, the actual contact being everywhere masked. The strata, in addition to this, are much flexed and very subject to faulting, so that it will be readily seen that the task of delimiting the areas and prospecting generally is one of extreme difficulty.

The very small thickness of rocks overlying the coal, and the fact that they are folded in a series of short rather sharp flexures and subsequently been subject to denudation, has resulted at times in the formation of a number of small basins where the seams at no time gain any great depth. It might be possible in such cases to work the coal in a series of open cuts or by stripping the overlying gravel and shales in favorable localities.

Small faults are numerous, and the seams are likewise cut by a number of dikes, usually accompanied by faulting, from the nearby granitic areas.

In regard to the size of the individual seams the following section was measured at the Cassiar Coal Co's property on Goat Creek; this is the most complete section to be found anywhere in the district.

		Feet.
Clay Shales		
Top Seam	Coal with a few small clay partings	12.0
	Clean coal	7.7
	Clay	2.0
	Gray sandy shale and covered, about	30.0
Middle Seam	Coal	1.5
	Clay shale	2.7
	Coal with a few irregular clay partings	14.5
	Shale with ironstone nodules	3.3
	Coal	2.0
	Gray clay shale with nodular ironstone bands, about	50.0
Bottom Seam	Carbonaceous shale and coal	2.0
	Coal	1.5
	Shale	0.5
	Coal with small irregular clay partings	9.0
	Clay shale	——

Several small seams overlie these. A short distance up the creek beyond these exposures, the two upper large seams have been burned leaving thin beds of slaggy material; the overlying clay shales are burned to a brick red forming a very noticeable feature in the landscape where exposed in a high cut bank. The burnt area, however, does not appear to be of any great extent.

In the Transcontinental Syndicate's openings, a few miles higher up Goat Creek, five seams 4 ft., 3 ft. 3 in., 4 ft., 6 ft., and 4 ft. respectively in thickness were cut in about 130 feet of measures; while on the property of the Telkwa Mining, Milling and Development Co. on the head of the Morice river at least four seams of the following thicknesses, 4 ft. 2 in., 4½ ft., 4 ft. and 7 ft. 3 in., have been stripped.

Practically all the coal land in this vicinity is controlled by four companies, the three above mentioned and the Kitamat Development Co.

On the Bulkley river, from a short distance above Moricetown to Sharp creek (about 12 miles), coal outcrops at intervals, but no workable seams have as yet been uncovered. At Sharp Creek nine small seams were stripped varying from 15 to 40 inches thick, but they all proved too high in ash to be of value (an analysis of one of these is given above).

Near the head of the Skeena, about 150 miles north of Hazelton, another important coal field is situated which has been prospected in some detail by the Western Development Company who control about sixteen square miles of coal lands here. In this field the coal measures occur near the top of a great thickness of sedimentary rocks which probably represent the porphyrites to the south. The rocks here are not so highly disturbed, and there is apparently a greater thickness of overlying strata than at the Telkwa areas. The coal-bearing rocks occupy the trough of a syncline with gentle dips on either side, the Skeena cutting diagonally across it. At the southern edge of the basin, however, the strata are much more disturbed, being often tilted at high angles. At least one seam of good coal, from 5½ to 6 feet thick, has been opened up at several places, an analysis of which has already been quoted; other smaller seams are known to exist and it is quite possible that the larger one does not represent all the workable coal in this area. The physical qualities of this coal are all that could be desired, it being extremely hard, resists weathering well and is bright and lustrous in appearance. Although no recent volcanic rocks are known of in this neighbourhood, still evidences of volcanic action are not wanting, as the rocks of the coal measures and the coal itself are found in places to be cut by small quartz veins sometimes more or less mineralized with iron pyrites.

In most of the other coal districts mentioned no workable seams have as yet been found, the coal being either too thin or too highly disturbed to be economically worked. Taking into consideration, however, the difficulties of prospecting already alluded to, there is no reason to suppose that larger and more favourably situated seams do not exist, at least in some of the localities in question.

Although placer miners were the first to prospect the Skeena country, the results so far have not been encouraging, Lorne Creek being to-day about the only producing locality. This creek has afforded annually a small output of gold since about 1884.

The Omineca country to the east, and reached via the Skeena and Hazelton, has long been a producer of placer gold. The old diggings are now nearly all abandoned to Chinamen, but there is said to be a large amount of ground there which can be profitably hydrauliced when transportation facilities have been improved and the cost of working lessened correspondingly. The presence of argentiferous galena in that district has also been known for some years as well as that somewhat rare mineral arquerite, a native amalgam of silver, which has been found in the creek gravels.

In the neighbourhood of Kitsalas Canon, a number of quartz claims holding gold and copper have been located, but the writer is ignorant as to the conditions prevailing there.

In conclusion, it may be said that lack of transportation facilities has prevented the exploitation of a country rich in possibilities, and until the advent of the railway, nothing can be done to open up and develop its latest resources. The present means of communication are highly unsatisfactory, Hazelton, the distributing point, being reached either by pack trail, 400 miles from Quesnel on the Cariboo road, or by river steamer from Port Essington, and as the Skeena is navigable only at certain stages, and then only with difficulty, this route cannot always be depended on. Away from the river, trails are few and bad, and much trail and bridge building will have to be done before even the best known camps are made easily accessible.

THE COALS AND COAL FIELDS OF ALBERTA, SASKATCHEWAN AND MANITOBA.

By D. B. Dowling.

(By permission of the Director of the Geological Survey.)

(Toronto Meeting, 1907.)

Any description of the coal fields of the three prairie provinces to be complete would necessarily be lengthy, but the present paper is an attempt at a resume of the extent and character of the coals to be found there

The rocks in which these coals are found all belong to the sediments of the Cretaceous sea and the coal horizons are in three successive portions of the period. Each one marks a time when the surface was not very much above the sea but high enough to support a luxuriant flora. The history of the period seems to be as follows:—At the beginning of the Cretaceous time the land surface consisted of limestone beds which extended westward to the Selkirks. This began to sink along its western margin, concurrently with an elevation in the Selkirk region. This sinking went on to below sea level but the subsidence was made up by a heavy deposit of sand and mud derived mostly from the elevated land to the west. This then gradually spread eastward but was very intermittent, so that large land areas were formed and covered by vegetation. A great submergence beneath a muddy sea next occupied a long portion of the Cretaceous time, but again the crust was sufficiently elevated to bring the muddy bottom to sea level. The western portion did come to the sea level or even above it and coal deposits were formed; but it is not definitely known how far east they extended. One total submergence succeeded another, but for shorter time, before this new muddy surface rose above the sea for the last time; and again in its transition period coal beds were formed.

This threefold coal forming period gives us three horizons in which to look for coal:—At the base; above the middle; and at the top of the Cretaceous sea deposits.

The first we call the Kootanie; the second the Belly River; and the third the Edmonton or Laramie.

In the three formations the quality of the coal varies under two fairly good rules. The first is that in the same district coals of the lower horizons, owing to age and pressure of the beds above them, should show a greater percentage of fixed carbon and also be more compact. The second is a general tendency to increase both the fuel ratio and the compactness in going toward the mountains, mainly on account of the increase in the thickness of all the deposits in that direction and thus the load over the seams. The fuel ratio is the fixed carbon divided by the volatile combustible matter and the term porosity is here taken to mean the percentage of water absorbed by the coal.

KOOTANIE MEASURES.

The lowest horizon is exposed in the raised and tilted blocks of the crust shown in, and in the neighbourhood of, the Rocky Mountains. The quality of the coal, as given by the fuel ratio, varies considerably; and from a number of analyses the following notes will show the general range.

In the Elk River region the variation shown at Morrissey ranges from 3.2 to 6.12. At Fernie the ratio increases from 3.22 to 4.60 in the lower seams. At Michel two seams differ slightly the ratios being 3.5 and 3.7. The eastern outcrop of some of these seams on Marten Creek evidently show less change in the physical structure as the ratio falls from 2.08 to 1.86. In order to bring all the areas under notice lists are added giving full rate and thickness of seams arranged in order of hardness. The areas within the mountains may briefly be outlined as

(1) the Elk River basin with 22 workable seams containing 216 ft. of coal. This, with a slight gap, extends north to the head of Elk River.

(2) Crowsnest areas, several narrow blocks known as the Coleman-Blairmore areas, with 21 seams and 125 ft. of coal and

extending north ending with the Sheep Creek area in front of Mount Rae.

(3) Moose Mountain area, south of Morley, with 2 seams, 7 and 8 ft. respectively.

(4) The Cascade area, running from the mountains north of the Elbow River northward to near the Saskatchewan, having mines at Canmore and Bankhead. In the vicinity of the Bow River there are 10 to 14 workable seams and 75 to over 100 feet of coal. Its extension north of Red Deer River has 15 workable seams with 114 ft. of coal.

(5) Palliser area on Panther Creek, east of Cascade coal basin, several seams known. Area not extensive.

(6) Costigan area on Panther Creek, five seams known with 27 feet of coal.

(7) Bighorn area running from Saskatchewan River north to past Brazeau River, only about 5 seams yet located, largest 16 feet.

(8) Other areas in foot-hills, or farther north, not yet discovered

The Kootanie coals are all so well compacted that less than 2% of water, as a rule, is absorbed by any. Their porosity is not considered in the list which here follows but they are given in order of hardness.

LIST OF KOOTANIE COALS BY FUEL RATIO.

Locality	Fuel ratio	Thickness of seams examined ft	in.
Anthracite, Alta., seam A	11.59*	7	0
Marsh mine, lowest seam	8.79	4	0
Bankhead mine, seam No. 2	7.98	8	0
Cascade River, old workings	7.50	4	0
Palliser area, Panther River	7.89	5	0
" " "	7.30*	2	0
Marsh mine, from old tunnel	7.23	12	0
Canmore, seam No. 3	7.10	5	0
Costigan area, 2nd from top	6.97	4	0
Marsh mine, seam above tunnel	6.92	4	0
Sheep Creek, 1st seam opened	6.92	8	0
Canmore, Alta., seam No. 1	6.61	5	0
Sheep Creek, higher seam	6.49	8	8
Marsh mine, upper seam	6.54	10	0
Morrissey, lower seam	6.12	18	0
Canmore, seam No. 4	6.00 to 5.35	3	0
Marsh mine, highest seam	5.95	15.	0
Costigan, seam eastern outcrop	5.84	4	9
Costigan area, lowest seam, west outcrop	5.79	11	0
Sheep Creek	5.76	10	4
Coxcomb, Mt. Jumping pound Creek	5.75	3	0
Canmore, Alta., seam No. 2	5.37	4	0
" " " " 5	5.34	5	0
Thorne mine. Moose Mountain	5.15	7	6
Canmore, seam No. 6	5.06	4	6
Costigan seam, western outcrop	4.89	4	9
Costigan area, 3rd seam from top	4.85	3	9
" " 4th " "	4.83	3	6
Fernie, B.C., lowest seam	4.60	22	0
Moose Mountain, outcrop of seam	4.05	5	0
Sheep Creek, Moose Mt. seams	3.65	3	0
Snow Creek, Panther River, Cascade area	5.36	5	0
Michel, B.C., lowest seam	3.70	10	0
" " highest "	3.50	15	0
Fernie, Mine, No. 3	3.49	6	0
" " No. 1	3.41	9	0
" " No. 1	3.22	8	0
Morrissey, B.C., highest seam	3.20	18	0
Elbow River, branch west of Moose Mt	3.12	5	4
Oldman River, 1½ miles east of gap	2.92	5	0
Saskatchewan River, opp. Bighorn Range	2.79	5	0
Elk River, head of	2.71	13	0
Oldman River, N.W. br., North Fork	2.70	8	0
" " south fork	2.47	9	9
Branch of Brazeau, Bighorn Range	2.37	16	0
Marten Creek, Jubilee seam	2.08	30	0
Oldman River, near gap	1.90	5	7
Marten Creek, B.C. Peter seam	1.86	14	0
" " small seam	1.61	2	0

Belly River Measures.

The middle horizon is exposed in the foot-hills where it is brought up by a general rise toward the mountains. This part is known only in small portions and provides a good grade of very compact lignitic coal.

Under the surface of the plains it is disclosed along the deep excavation or trough through which the branches of the south Saskatchewan flow. A slight roll in the measures, running in the general direction of the Coteau, exposes these measures north of the surface depression of the South Saskatchewan, and beds are recognized to near the Vermilion lakes, a short distance south of the North Saskatchewan. In this northern extension little coal has yet been found, and eastward the measures are covered by higher beds, due to a slight depression of the beds in that direction. The interesting feature of the eastern extension of the formation, is its possibility of carrying coal into the central portion of Saskatchewan. Such occurrences of loose lignite near Prince Albert, and a seam reported on the face of the hills between Montreal Lake and Lake la Ronde, as well as in the bed of the Saskatchewan, above Saskatoon, appear to be encouraging. The fact that boreholes near Carlton and the Elbow of the Saskatchewan have not revealed seams, may mean only, that the drilling began below the coal bed. The seams of the Lethbridge area are not numerous. The ore mined there being only about 5½ feet. At other places near by the thickness does not appear so great. Near Medicine Hat a 5 ft. seam was worked but the coal appears to be very porous and carries a high percentage of water.

The horizon containing most of the coal is in the upper part of the formation, and thus separated by about 1,000 feet of shales from the lowest coals of the highest horizon. So that the border of the recognized areas of Belly River rocks are marked by coal seams.

Comparisons of the fuel ratios in the Kootanie coals give us what might be called a scale of their hardness. The same comparison in the fuels of the upper horizons show only the degree of alteration that has taken place in them during their change from vegetable matter toward the more stable condition as coals.

They all show, in a marked manner, that their substance has not been so compactly pressed, as they all absorb much greater percentages of water. The Belly River coals are slightly denser than the Edmonton coals of the same district, but it is not until the seams outcrop near the mountains that this character is well marked.

In the western upturn they carry less than 3 per cent. of water while the Edmonton coals run from 3 to 7 per cent. For the Lethbridge area the difference is not so strongly marked except at one or two localities.

COALS OF BELLY RIVER FORMATION IN WESTERN UPTURN OR FOOT-HILLS.

Localities	Fuel ratio	Porosity per cent.	Thickness of seam ft.	in.
Head of Mill and Pincher Creeks....	2.96	1.99	8	0
Mill Creek, 4 miles above mill......	2.02	1.63	8	0
Sheep Creek, Tp. 19, R. 4 west of S.	1.62	2.16	5	0
" " " " "	1.57	2.50	7	0
Morley, on Indian Reserve.........	1.18	1.26	6	0

COALS OF BELLY RIVER FORMATION IN LETHBRIDGE AREA.

Localities	Fuel ratio	Porosity per cent.	Thickness of seam ft.	in.
Taber Coal Co....................	1.83	10.8	3	3
McPhee mine near Taber...........	1.72	11.35	2	7
10¼ miles above Medicine Hat......	1.62	17.70	4	0
Belly River, Driftwood Bend.......	1.40	9.18	3	3
St.Mary River, 7 miles from mouth .	1.38	7.02	3	8
10 miles above Medicine Hat.......	1.38	16.82	4	0
Bow River, Grassy Island..........	1.34	11.96	4	6
Red Deer River, 9½ m. below Bull pd.	1.30	13.06	3	6
Milk River Ridge, north side.......	1.32	5.58	3	0
Lethbridge, main seam.............	1.26	6.50	5	6
Stair, main seam..................	1.25	20.54	5	0
Red Deer River, 4½ m. below Bull pd.	1.15	13.63	1	6
" " 2 "	1.19	12.62	1	3

LARAMIE—EDMONTON COAL AREAS.

The larger coal areas of both Alberta and Saskatchewan are of the above formations and are practically on one and the same horizon which occupies the dividing line between sea deposits below and fresh water and land deposits above. Some of the coal seams are in the upper fresh water stage—the top of the Laramie; but the majority are in beds separated by sands and clays, holding remains of organisms which lived in brackish water—the Edmonton or lower Laramie. In Saskatchewan the divisional lines between these deposits are not worked out; but in Alberta, the beginning of fresh water stage is drawn at about the horizon of the Big Coal Seam on the Saskatchewan. The formation originally probably covered a very large area, but the uplift of the western edge and the subsequent denudation of a great part of the plateau formed of these soft beds, has left remnants only of the upper coal rocks. In Saskatchewan these remnants occupy the high lands in the Cypress Hills and Wood Mountain and a triangular area eastward from the Coteau.

A great excavated depression running outward from the mountains, branching to north and south of the Cypress Hills, separates them from the plateau running north and south and sloping eastward from the foot of the mountains. The western coal area occupies a belt near the eastern edge of this slope, narrow at the south but widening northward reaching its maximum in the latitude of Edmonton The coal rocks are then covered farther up the slope by heavy beds of sandstone, but emerge from under them along a narrower band just in front of the foot-hills in some parts and in others, generally in the south, nearer the mountains. There is thus one part of the field which has suffered much pressure and in this the coals show the effect of the compression. The thickness of the seams in this area appear to increase to the north. Thus in the vicinity of Bow River, seams of 4½, 6 and 9 feet are the best that are known; but in the vicinity of the Saskatchewan, seams of 8, 18, 4 and 6 feet occur near Edmonton and at the Pembina River, the horizon of the Big Seam shows 3 seams, 13, 13 and 6 feet or 32 feet of coal

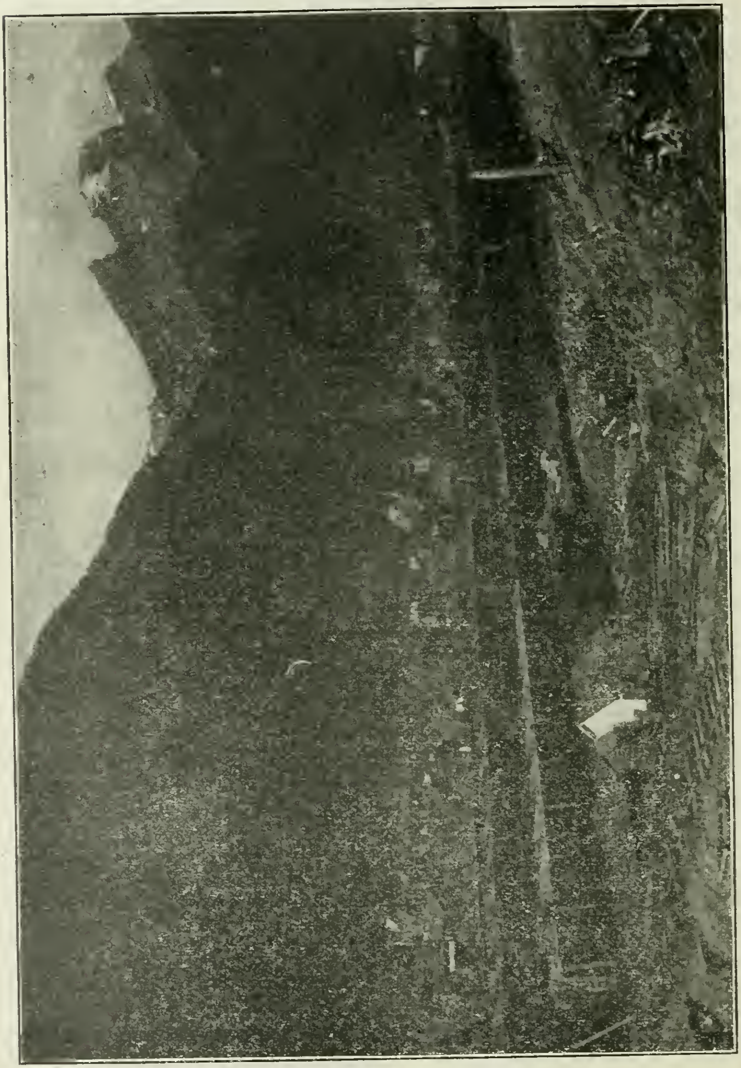
In the Saskatchewan areas, the coal seams of the Cypress Hills and eastward to Wood Mountain, are all thin; but a 4 ft. seam south of Cypress Hills may prove fairly persistent. In Wood Mountain two seams of 6 and 8 feet respectively will probably be utilized. On the eastern side of the Coteau at the Dirt Hills three seams, 7, 3, and 6 ft., are reported. In the Souris district seams of 5 and 8 feet are being mined, the latter reported as thickening to 15 feet toward the east.

In the following list which is here, for uniformity, arranged as the others in order of fuel ratio, the porosity runs somewhat at variance with this scheme; but if the arrangement had been by porosity only a regular progression from west to east would have been nearer secured, since all the coals absorbing water from 3 to 7.1 per cent. actually come from the beds in the disturbed western part of the field. All those absorbing from 8 to 14 per cent. are from the eastern portion of the Edmonton field, while all with a porosity of from 14 to 22 per cent. are from the Saskatchewan areas.

LIST OF LARAMIE AND EDMONTON COALS IN ORDER OF THEIR FUEL RATIOS.

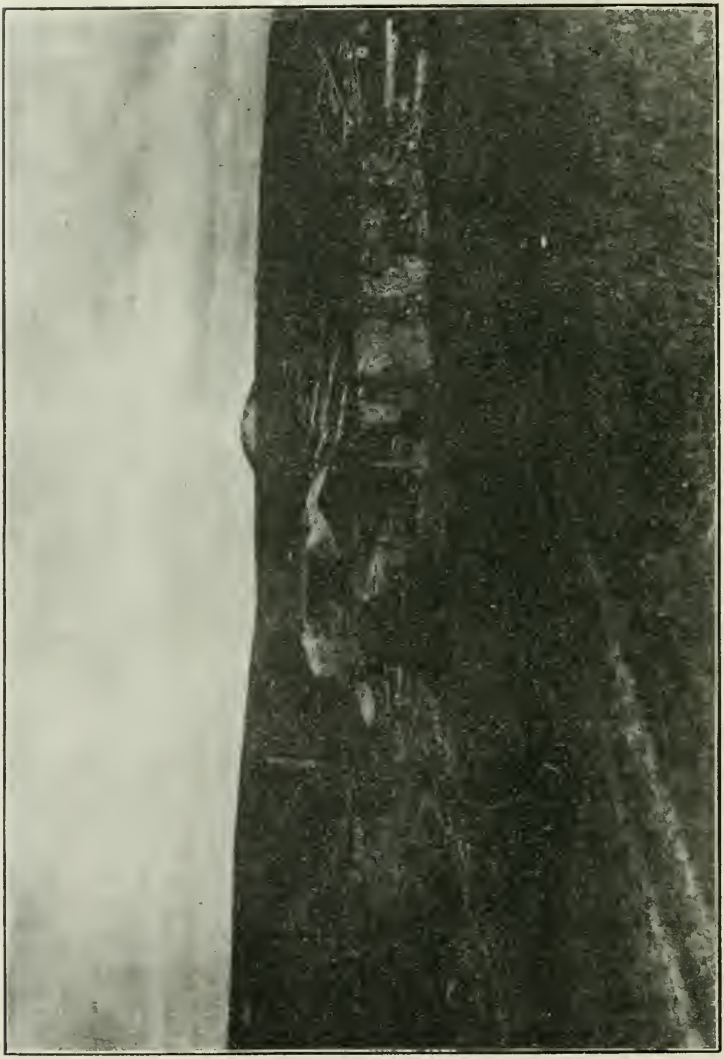
Localities	Fuel ratio	Porosity per cent.	Thickness of seam ft.	in.
Shaws Coal mine, Fish Creek.	1.66	3.76	2	0
Blackfoot Reserve, 6½ miles below Crossing.	1.6 to 1.5	12.31	4	8
Big seam, Saskatchewan River	1.6 to 1.3	11.14	18	0
Indian Farm, Pincher Creek.	1.58	5.38	3	0
North Fork, Highwood River.	1.56	6.12	1	6
Athabaska River above McLeod River.	1.53	10.58	3	0
Athabaska River above McLeod River.	1.49	11.47	10	0
Edmonton, just below town.	1.49	12.89	6	0
Pembina River Tp. 53 R. 7 west of 5th lowest.	1.48	13.07	6	0
Pembina River Tp. 53 R. 7 west of 5th highest	1.47	13.78	13	0
Red Deer River in foot-hills.	1.46	4.97	9	0
Rocky Mountain House seam.	1.45	7.01	2	0
Red Deer River 4 miles below Tail Creek.	1.41	10.02	5	11
Red Deer River, mouth of Rosebud	1.40	13.08	6	0
Battle River, Meeting Creek.	1.39	11.68	4	6
Sheep Creek Coal mine, Lineham P.O.	1.38	3.08	4	0
Coal Creek, west of Cochrane, Alta. .	1.38	4.93	4	6
Edmonton, The Ross seam.	1.34	11.47	4	0
Red Deer River, 12 miles above Tail Creek.	1.33	7.66	7	0
Knee Hills Creek.	1.33	9.86	4	0
Crowfoot Creek, 4 miles from Bow River.	1.33	11.25	6	0

Localities	Fuel ratio	Porosity per cent.	Thickness of seam ft.	in.
Bow River, 4 miles below Blackfoot Crossing	1.31	10.72	8	11
Big Island, 12 miles above Edmonton	1.30	8.92	3	8
Egg Creek, near Victoria, Alta.	1.24	11.91	1	1
Borehole on Souris River, east of mines	1.26	17.78	6	0
Dirt Hills, upper seam	1.24	14.80	7	0
Dirt Hills, lowest seam	1.24	15.50	6	0
Dirt Hills, middle seam	1.11	17.53	3	0
Souris River, mouth of Short Creek.	1.10	21.84	5	0
Long Creek, 1 mile north of Wood End	1.08	15.11	7	0
Bow River, three miles south of Horseshoe Bend	1.06	11.13	4	6
Poplar River Tp. 1, R. 28 west of 2nd	1.01	12.05	18	0
Willow Creek, south of Cypress Hills	1.05	16.37	4	0
Wood Mountain, lowest seam	1.04	12.26	8	0
" " Hay flat	.99	13.73	6	0
" " Upper seam	.96	18.61	8	0
Turtle Mountain, from locality in Dakota	.90	13.98	——	——
Long Creek, opposite Estevan	.63	17.97	6	6
Long Creek, near Wood End	.70	14.73	7	0
Big Muddy Creek, south of Willow Bunch	.58	16.28	5	0
Big Muddy Creek, south of Willow Bunch	.55	15.51	4	0
Big Muddy Creek, south of Upper seam	.54	15.20	3	0

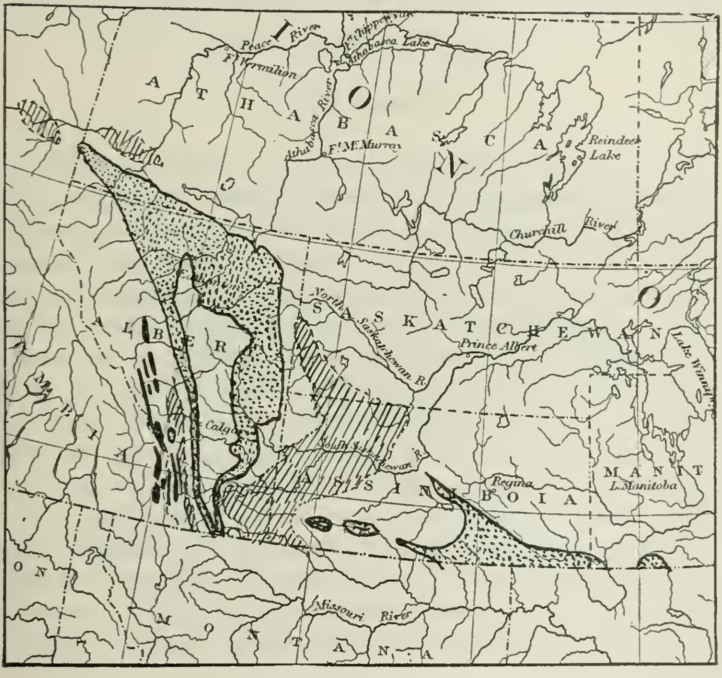


Coke Ovens at Fernie, B.C.

A Coal Mine in the Mountains, Coal Creek, Fernie, B.C.



A Coal Mine on the Prairie, Mine at Estevan, Sas.



Sketch Map showing distribution of Coal areas.

THE MARBLE BAY COPPER DEPOSIT.

By O. E. LeRoy.

(By permission of the Director, Geological Survey of Canada.)
(Toronto Meeting, 1907.)

Introduction.

During a reconnaissance survey of part of the southern coast of British Columbia, in the summer of 1906, the writer had an opportunity of examining briefly the ore deposits occurring on Texada Island. One type of deposit is of particular interest, both on account of its being in a contact metamorphic zone and of its economic importance in containing valuable ores of copper. These deposits have previously been described in the reports of the Provincial Mineralogist, and in several papers by Mr. W. M. Brewer. In his later papers Mr. Brewer has drawn attention to certain deposits occurring on Gribbel Island, and in the White Horse District, Yukon Territory,* and shows that in mode of occurrence they are very similar to those on Texada Island.

The object of this paper in describing an example of this type is to again emphasize the economic importance of these deposits lying in widely separated areas, and to show that they are worthy of the careful consideration of those interested in mining.

Geographical Position.

Texada Island, named by Elsa in 1791, lies in the Strait of Georgia, its south-east end being about 80 miles north of Victoria, and 47 miles from Vancouver. (See Fig. 1, Inset Map.) The town of Van Anda, where the chief mines are situated, is about

* Jour. Can. Min. Inst., Vol. IX, p. 39; Eng. and Min. Jour., 1902, Vol. 73, p. 167.

75 miles from Vancouver and is a port of call of the Union Steam Ship Company. The island has a length of 30 miles with a maximum width of 6½ miles. High and mountainous throughout especially in the eastern half where Mount Shepherd attains a height of 2,900 feet, it presents to the observer when viewed at a distance the appearance of part of a submerged mountain chain. The shores are very rugged with bold cliffs fringed in part with narrow boulder beaches. Sand and gravel beaches are few and there are only three harbors, Marble, Gillies and Blubber Bays, the two latter being somewhat exposed in certain winds.

GENERAL GEOLOGY.

The island is underlain by the Vancouver series of Dawson, part of which has been referred to the Triassic. There seems, however, to be an entire absence of fossils in the associated limestones, and part if not all of the series may belong to the Paleozoic era. The series admits of two divisions. The lower is composed of chlorite and hornblende schists, tuffs, amygdaloidal lavas, porphyrites and agglomerates which show over small areas obscure bedding. The upper division consists of limestone, which varies from a massive thick bedded unaltered rock to a fine grained pure white marble.

Subsequent to the deposition of the limestone there was considerable volcanic activity, and the whole of the Vancouver series was much disturbed by intrusions of diorite, gabbro, hornblende and augite porphyrites and diabases. The relations of these rocks with the limestones are well seen where they have intruded as dykes, sills and irregular masses faulting, and marbelizing the latter.

These igneous rocks, both older and younger than the limestones, have been much altered, and a large proportion of their present mineral content consists of secondary epidote, magnetite, chlorite, pyrite and calcite. They are widely developed and underlie the greater part of the island. The limestone, with the exception of a few small outliers, appears only at the north-west end where the exposure has a length of 7½ miles, with a maximum width of 2. In upper Jurassic times extensions of the great Coast Range batholith, consisting of granites and syenites, penetrated this older series and had a profound effect on them, producing schistose structure and shear zones in many of the igneous rocks, and converting the limestone to various crystalline types along with wide spread faulting as the discordant strikes and dips now show.

The coast batholith was followed by a great series of basic dykes, principally diabases and all the older rocks have been cut by them.

The Cretaceous has a limited exposure at Gillies Bay, consisting of feldspathic sandstones with calcite cement. The beds are probably basal, and are but slightly disturbed with low dips to seaward.

During the Glacial Period the island was eroded by the Strait of Georgia Glacier. A thin mantle of drift covers certain areas composed of sandy boulder clay, the boulders being principally varieties of granite from the main coast.

In the general depression which followed the island was much reduced in size, being some 400 feet lower with respect to sea-level than at present.

Economic Geology.

In the early nineties attention was first called to the occurrence of free gold in quartz veins, and later, deposits of rich copper sulphides were found in the limestone. These latter were not considered of any great importance at the time, but subsequent development has proved the contrary. Both divisions of the Vancouver series contain valuable ore bodies, which are found in the eruptive rocks, at their contact with the limestone, and in the limestone.

In the eruptive rocks, the ores occur in shear and fracture zones with quartz and country rock gangue. Much movement is shown by the slickensided walls, and later cross fractures are filled with calcite. The ores are galena, zinc blende, copper and iron pyrites carrying as a rule low values in gold and silver. The ore is also very pockety, and solid ore alternates with barren zones. The width of the veins varies from 2 to 4 feet, and one mine only, the Surprise, has been proved to a depth of 360 feet. Other veins contain pyrite chiefly and have been noted for the rich showings of free gold in quartz. These, unfortunately, were only surface enrichments and had no depth, the pyrite immediately below being practically barren.

Contact deposits between the various igneous rocks and the limestone, include the large and important bodies of magnetite situated on the south side of the island and owned by the Puget Sound Iron Company. On this property there is also a series of copper deposits,—chalcopyrite and carbonates—along the contact of the limestone with the altered porphyrites or the magnetite. The ore occurs in rudely lenticular bodies lying at various angles from vertical to horizontal, the limestone being almost invariably the hanging wall or roof.

The important deposits of bornite and chalcopyrite, to which particular reference will be made, are found wholly in the limestone. At present two mines are being worked the Marble Bay and Cornell. The Copper Queen, which was the pioneer mine of the district, is lying idle. (Fig. 1).

THE MARBLE BAY MINE.

In 1897, an insignificant outcrop of copper and iron pyrites with some bornite was found a quarter of a mile east of Sturt Bay, on a crown granted lot owned by Messrs. Christie and Palmer, of Toronto. A shaft was sunk on the ore and drifts run, but it was not until the 260-foot level was reached that the ore body assumed a definite character.

In 1902, the property was purchased by the Tacoma Steel Company for $150,000, and it was extremely gratifying to the company to have been able to pay the whole of the purchase price in three years out of the profits earned by the mine. The mine is now 760 feet deep and 715 feet below high tide. The ore body from the 260-foot level to the present workings has varied in length from 75 to 115 feet, and in width from a few inches to 45 feet. On the first floor of the 760 level, it is 87 feet long with a maximum width of 32 feet.

From the 140 to the 560 level the ore body pitched north at a high angle, but from there to the 760 it is practically vertical.

From the data collected this deposit may be described as an ore chute, occurring in a zone of brecciation in the crystalline

Plan showing Marble Bay, Copper Queen and Cornell Mines, Texada Island.

Limestone
Granite
Porphyrites, tuffs etc
Dykes

SCALE
One Mile

limestone, this zone being approximately parallel to the strike· Divided into subordinate chutes above the 360 level, it has, below that, been continuous. The borders are broadly irregular, and small stringers are given off which run a few inches into the country rock. In the upper levels the walls were brecciated and weak, but in the lower they are firm, and very little work is necessary in the way of lagging. The ore is bornite with subordinate chalcopyrite, and a little pyrite, pyrrhotite and molybdenite. These occur in a gangue made up largely of pale green pyroxene—"green-felsite",—and reddish brown garnet —"bull-felsite,"—with calcite. The ore is either finely disseminated through the pyroxene, or occurs in large rather pure masses between the pyroxene and the limestone. Very little is found in the garnet. A considerable proportion of the pyroxene gangue is partially altered, and disintegrates rapidly on exposure to the air. There are also large areas of the pyroxene which are practically barren. A microscopic examination of a few prepared sections of the gangue shows that the pyroxene (variety omphacite) occurs in mosaics of clear individuals with turbid borders. The garnet, which shows zonary structure, and optical anomalies, is traversed by numerous cracks which are filled with turbid material in part calcite. Towards the calcite, the garnet has a tendency to develop crystal outline. Bornite and chalcopyrite occur in small grains, solitary, or connected in groups by narrow stringers between the pyroxene individuals, inter-grown with them, or along cracks in them and the garnet. Calcite with the larger grains of the sulphides, well formed garnets-andradite,—and vesuvianite were the last to crystallize out and filled all the interstitial spaces.

Subsequent to the formation of the ore body it was cut by one of the later dykes of basic porphyrite. Between the seventh and eighth levels it varied in width from 4 to 6 feet with ore on both sides. This dyke dipped to the south, and in its downward extension became much reduced in size. On the 760 level it is only 7 inches wide and crosses the drift some distance south of the ore body. It is highly altered with a development of numerous fissures now filled with epidote, and pyrite. This intrusion caused considerable movement in parts of the ore body, and many small fissures were formed and subsequently filled with chlorite, pyrite and calcite. Some beautiful examples of slickensided surfaces are seen especially where molybdenite occurs. The pyroxene and garnet have both been fractured and under microscopic examination the former showed strain shadows, incipient and complete granulation, with considerable alteration. Bornite has been redeposited along these lines of fracture, between individual grains, and along cleavage planes. It occurs in solitary and connected grains and parallel bands. Calcite of the first generation shows strain shadows, and the last phase in the formation of the deposit was the filling up of all the small interstitial spaces with calcite. The order of crystallization was pyroxene and garnet, simultaneously, along with the greater part of the bornite, then the remainder of the bornite in larger masses associated with well formed garnets, vesuvianite and calcite.

ORIGIN.

This deposit is closely connected with the intrusion of the coast granite, and is clearly of pneumatolytic origin being an example of the Kristania type.*

It is well known that molten magmas give off enormous quantities of aqueous vapors which in this case would have a profound effect on the limestone through which they would pass along zones of brecciation or bedding planes. The limestone has here been replaced by silicates rich in lime, and by sulphide ores with the consequent liberation of carbonic acid gas. With the exception of the lime and a small amount of magnesia, all the other constituents are foreign to the limestone and must have been brought up from below with the aqueous vapors.

An approximate analysis of the pyroxene gangue resulted as follows:—SiO_2 55.25, Fe_2O_3 and Al_2O_3 6.50, CaO 25.00, MgO 14.50.

Garnet (andradite) averages about 31% and vesuvianite about 35% of lime oxide.

The deposition of ore and gangue went on simultaneously with the cooling of the granite magma, and the ore body was

* Gensis of Ore Deposits—Prof. J. H. L. Vogt, p. 648 et seq.; Waldemar Lindgren, p. 725 et seq.
Trans. Amer. Inst. Min. Eng.—W. H. Weed, Ore Deposits near Igneous Contacts, Vol. XXXIII, p. 720.

formed before the intrusion of the aplite dykes. These dykes have not been found as yet in the Marble Bay mine, but they have been noted in two instances in the neighboring deposits.

ORE VALUES.

The ore throughout is essentially high grade and carries good values in gold and silver. The ore which is finely disseminated through the pyroxene gangue carries much higher values in gold and silver, than the purer and more massive bornite and chalcopyrite. It has also been found that the percentage of copper has steadily increased with depth.

As it is necessary to mine considerable barren gangue which is intimately mixed with the productive, the ore is hand sorted before shipping and graded into coarse and fines. The waste, on account of its fluxing properties, is shipped in large part and sold to the smelter. At present the total production is sent to the Tacoma smelter for treatment.

In order to ascertain the average value of the ore, the smelter returns for the year beginning in June, 1905, and ending June, 1906, were examined with the following result.

Grade.	Gold oz. per ton.	Silver oz. per ton.	Copper per cent. (dry)	Net value per ton.
Coarse	0.498	4.138	6.765	$28.77
Fines	0.1673	1.569	1.602	$6.88
Waste	Tr.–.08	0.15–0.9	0.22–0.8	$0.50
Coarse	1.006	5.73	11.25	

The last entry of coarse grade refers to a shipment of 116 tons made in July, 1906.

About 13,000 tons are mined annually, and approximately for every ton of coarse, two tons of fines and two of waste are shipped. Through the courtesy of Mr. F. C. Robinson, of the Sheffield Smelting Works, I am enabled to publish a few interesting assays which he made of the ore and gangue. The samples were taken from a stope on the 660 level, and the gold and silver values are stated in ounces per long ton.

Assays			Analyses	I	II
Number.	Gold	Silver.			
I.	0.40	18.60	Insoluble. . . .	31.60	43.10
II.	1.05	7.85	Copper	34.00	13.60
III	0.008	0.04	Iron.	10.30	9.90
IV	0.025	0.07	Lime	Trace	. . . . .

I. Bornite and chalcopyrite, (massive ore).

II. Pyroxene and garnet gangue with finely disseminated bornite.

III. Calcite after removing mineralized portions.

IV. Calcite and garnet after removing mineralized portions.

Numbers III and IV are interesting in showing the occurrence of gold and silver in what was apparently barren gangue. Free gold in distinguishable leaves and grains has been found occasionally, but it is not a common occurrence.

SIMILAR DEPOSITS.

The ore chutes of the Copper Queen and Cornell mines adjacent to the Marble Bay are associated with basic dykes, some of which are older than the ore bodies. These are very much decomposed and in places have altered to a serpentine which carries ore, and is occasionally traversed by small veins of greenish white asbestus. The former mine has been noted for certain occurrences of free gold and argentiferous tetrahedrite. The deposits in the White Horse District, Yukon Territory, differ from the above, in that they carry low values in gold and silver, and higher values in copper. Their mode of occurrence, however, seems to be identical.

CONCLUSION.

The past development of these mines on Texada Island has proved the ore bodies to a considerable depth, the Copper Queen being 740 feet deep, while a winze is now being sunk to the 860 level in the Marble Bay. As regards the permanence of these deposits, there seems to be very little doubt but that they will continue until the limestone granite contact is reached.

SOME NEW POINTS IN THE GEOLOGY OF COPPER ORES.

By James F. Kemp, D. Sc., etc., Columbia University, New York.

(Toronto Meeting, 1907.)

During the past year or two cobalt and silver have been the metals most prominently in the foreground in Ontario; but south of the national boundary and in other parts of the world, copper has occupied the centre of the stage. The growth of electrical applications and the increasing consumption of brass have made the market well-nigh insatiable. Copper mining has greatly increased and with the growth of new districts and with widening experience, we have found it necessary to modify some of our old-time conceptions.

Twenty-five years ago when the classes in the mining schools were taught the mineralogy of the ores of copper, it was chalcopyrite that was esteemed the principal mineral. Of course the importance of the native metal on Keweenaw point was appreciated, but we used to define an ore as "the compound of a metal and mineralizer such as sulphur or oxygen"—and the native form, even though abundant in one locality, was thus ruled out. Experience with the lenticular beds or veins, in the slates and schists along the Appalachian belt from Sherbrooke, Quebec, to Ducktown, Tennessee, and the historic ore bodies of the Rio Tinto district in Spain, whose geological relations are similar, gave good ground for the esteem in which chalcopyrite was held. It was considered, moreover, to be the original mineral from which the others were generally believed to have been derived. Observers of those days were perfectly familiar with the oxidized zone, and with the zone of enrichment, at the level of the ground-water. At the latter horizon the Ducktown mines had taught all of us in America that rich black ores were precipitated, but the dark mineral was for many years believed to be the oxide, tenorite or melaconite, until W. H. Weed proved it to be chalcocite. Chalcocite was esteemed to be rather uncommon and when we students saw it at all, it was chiefly in crystals from the old copper mine at Bristol, Connecticut, an enterprise that had impressed its shareholders rather by the lack of copper than by its abundance.

To-day, on the contrary, in the United States and Mexico, chalcocite furnishes much the largest part of the copper produced, and for some years to come its relative importance bids fair to increase rather than diminish. Butte, Morenci, Bisbee, Globe, and Cananea derive most of their output from it, while Bingham and Ely will soon be concentrating the glance from the porphyries on an enormous scale.

So far is chalcopyrite from being the principal and original mineral at Butte, that on the one hand it is rather uncommon and on the other it is one of the latest of the secondary minerals, since we find it in veinlets cutting covellite. Alike at Butte and in Arizona the original mineral appears to be a lean copper-bearing iron pyrite, which is then, by secondary enrichment, oxidized in one place and deprived of its copper, only to gain the latter elsewhere in the form of chalcocite, which brings the lean original up to grade.

In later years, and for a period lasting well up to the present, we have laid great and just emphasis on the processes of secondary enrichment by the descending surface waters. We believed that the new chalcocite and other minerals were deposited at the level of the ground-water and for a limited distance below it. That is, we gradually grew to recognize the necessity of a greater diffusion of the descending copper solution throughout the quiet ground-water than we had at first thought either necessary or probable. But in the issue of the *Mining and Scientific Press*, for February 23rd, 1907, page 236, we learned that a cross-cut in the Berlin claim at Butte had cut a great body of glance, at 1,800 ft. from the surface, and that in the Neversweat, at 2,400 ft., a similar occurrence had been noted. Even before this it was generally reported that a cross-cut from the shaft at 2,000 ft. in the Speculator claim had intercepted these rich ores in a still different lode.

Various suggestions tending to reorganize our old views either have been made or may be made in consequence of these discoveries. The hillside on which the copper mines are situated at Butte rises gradually to the north from the valley of Silver Bow

Creek, or more steeply to the west from the same creek at Meaderville. In the latter area shafts are said to have found the bed-rock under 600 ft. of overlying loose material. Obviously, as the valley was excavated by erosion, and as the former representative of Silver Bow Creek established the low point of the ground-water upon its bed-rock, the subterranean water-level must have risen from this point, in the hill, roughly following the surface, but at a flatter slope. The present outcrops of the copper veins are from 500 to 700 ft. above the present valley, or from 1,100 to 1,300 ft. above the bed-rock. To estimate the ancient level of the groundwater, we must diminish 1,100 to 1,300 by such figures as will allow for its rise, roughly parallel with the surface. Whatever assumptions we may make, moreover, regarding wall-rock and vein-matter removed by erosion, will operate to further raise the ground-water level. It certainly can scarcely have been lower than 800 to 1,000 ft. below the collars of the present shafts. The recently discovered bonanzas are from 1,000 to 1,500 ft. below this level, and according to our old ideas of the diffusion of the descending copper-bearing solutions, they must have penetrated at least 1,000 to 1,500 ft. of standing water. This seems unlikely.

On the other hand we may raise the question, could the ground-water have been so irregular in its distribution that no standing body of it intervened to stagnate the descending water? This seems unlikely. Again, is chalcocite necessarily a secondary mineral? May it not be of original deposition? Experience thus far leads us to think that the presumption of its secondary nature is well grounded.

Most reasonable of all would appear to be W. H. Weed's suggestion of secondary enrichment by uprising solutions of copper, set in action perhaps by the late rhyolite. From these no lean pyrite of primary deposition thus far observed would be too deep to escape, although solutions of oxidized copper salts, such as bring about enrichment by descending surface waters, are not what we associate with waters uprising from the depths. Mr. Weed applies his conclusions especially to the enargite at Butte, but as the glance is being found deeper and deeper we may at least raise the question whether its lower deposits may not also have been introduced from the depths.

Ten years ago, or even less, great apprehension was felt about the persistence of ore in depth. The newly appreciated doctrines of secondary enrichment from above had emphasized and increased the misgivings, and much experience corroborated them. Rio Tinto was most often cited, where in the San Domingo vein or lense, 4 to 5% of copper had been obtained at the surface; 2% at 260 ft.; 1½ to 1¼% at 325, and 1¼% at 425 ft. In the Dionisio, there was 4% at the surface; 2% at 650, and 2½% at 1,500 ft. In the last citation there was a ray of comfort, but the general result was decidedly discouraging. At Butte too, the general yield of the ores has gone down. A few years ago it was 5 to 6%; now it is 3 to 4%. In Arizona, 15 to 20% was not uncommon twenty years ago. The ores run 6 to 7% now, and the glance in the porphyries 3% as it goes to the mill. Improved transportation and milling processes are responsible for bringing lower and lower ores within the range of profit, and, as we must realize, there is the tendency steadily to reduce the general average; but if, at Butte, 40% ore occurs in great stopes at 1,800 ft., and 60% ore at 2,400 ft., we may raise the question as to whether the old-time generalization is as sweeping as we formerly thought.

Reverting again to the time-honored conceptions of the lenticular ore bodies or *Kieslager* of the slate and schist of the Appalachian belt and of Rio Tinto, many of us will recall that these were esteemed our typical deposits. But in later years developments in the southwestern United States, in Mexico, and in Queensland, have proved the frequent occurrence and great importance of garnet zones produced by contact metamorphism in limestone along intrusive rocks. Bisbee and Morenci, in Arizona; San Pedro, New Mexico; Aranzazu and San José, Mexico; Chillagoe, Queensland; and many more have shown the importance and wide distribution of this type. Garnet, vesuvianite, wollastonite, and diopside, are the associated minerals, and the ore bodies are of irregular shape. They often need secondary enrichment to bring them up to grade. They are not lenses, as are the ores at Thedford and Rio Tinto; nor veins as at Butte; nor beds as at Mansfeld; nor impregnations of shattered rock as at Nacosari; but are a new type when compared with our old conceptions.

One of our tendencies in earlier years was to connect ore bodies, especially of copper, with basic eruptives. Keweenaw Point and

Sudbury gave good support to these inferences. It was also natural to infer that as iron and the other bases increased in rocks, therefore copper, lead, and other metals would do the same in less degree. But recent experience is just the opposite in the case of copper. Globe, Arizona, with its diabase, and the Nikolai and other greenstones of the northwest coast are almost the only basic ones that appear in the newer districts. On the contrary, we find quartz-bearing rocks of various kinds and more especially a fairly acidic variety midway between syenite and diorite, called monzonite. Bingham, Ely, Bisbee, Morenci, Nacosari, and the granite at Butte, all afford a similar experience. The great deposits of northern California are in rhyolite porphyries. We cannot but reflect that the acidic magmas are richest in dissolved vapors, that they probably in cooling yield relatively abundant magmatic waters; and that being at the outset copper-bearing, the ore bodies are perhaps due to these characteristics.

But the most striking feature of the last year or two is the tendency of mines first worked for other metals to yield copper in depth. From Butte we learn that the silver mines along the Rainbow lode, in which, in the upper workings, no copper was found, are now showing as much as 3% at 1,000 ft. The old Black Rock claim, once a silver mine and a participant in the famous Black Rock-Niagara apex suit, is being revived and deepened for copper; and others are actually yielding the red metal. The Cable gold mines, farther west in Montana, now supply 3% ore to the Washoe smelter. Bingham, once a lead-silver camp, has changed to copper. From Leadville the same report has been coming for some years, that much copper was found with the unchanged sulphides in depth. At Red Mountain, where, near the surface, lead-silver was formerly the yield of the ore, now, in the 1,100 ft. adit into the mountain, copper has been found. In North Carolina, some gold mines of former years have become copper mines to-day. Most striking of all, at the great Mt. Morgan gold mine of Queensland, the diamond drill, at 725 ft., has shown great bodies of copper-bearing sulphides, which now go to the furnace, as the earlier gold ores went to the mill.

We have for years known that lead above often passed into zinc below. We may perhaps now add a still deeper copper zone, when, in the uprising waters that brought in the ore, copper was present with the other two. Gold above may also change to copper below, or be associated with it, and apparently not always because copper once general throughout the vein has passed downward with the atmospheric waters.

An interesting corroboration is thus afforded of views advanced by W. H. Weed in the paper already cited, of which one of the closing paragraphs is: "Ascending hot-spring waters, if metalliferous, may deposit different ores with an orderly vertical distribution. Existing veins now mined often show this arrangement of metallic sulphides."*

* Trans. Amer. Inst. Min. Eng. Vol. XXXIII, p. 754, 1903.

THE GENESIS OF THE COPPER DEPOSITS OF YERINGTON, NEV.

By E. P. JENNINGS, Salt Lake City, Utah.
(Toronto Meeting, 1907).

The Yerington Copper deposits in Lyon County, Nevada, 40 miles southeast of the famous Comstock Lode, present many interesting features both from commercial and geological view points.

The Mason Valley Mountains in which the mines are located are a small north-south range about 25 miles long and 3 to 6 miles wide with a maximum elevation of 6,500 feet above sea level and 2,000 feet above the valley of the Walker River.

The core of this range is intrusive granite, exposed in the higher peaks and in the deeper canyons where the erosion has been greatest, but covered by metamorphosed sedimentary strata on both the eastern and western slopes. Late rhyolite flows occur along the eastern base of the mountain.

The intrusive granite is a coarse grained mixture of feldspar, quartz, hornblende and biotite, becoming porphyritic in structure near the contacts.

Resting on this granite are beds of rock several hundred feet in thickness composed of the lime-alumina garnet, grossularite, graduating into andradite by the partial replacement of the alumina and lime by iron.

A partial analysis gave the following results:—

SiO_2	36.2
Fe_2O_3	27.2
Al_2O_3	12.7
CaO	22.7
MgO	.4

This rock varies in texture from a compact mass to a coarse crystalline aggregate of a cinnamon-brown color.

Thick beds of white to gray crystalline limestones cover portions of the garnet rock, but their original area has been greatly reduced by erosion.

An extensive series of metamorphic rocks also occur, whose greatest development is on the west side of the range where they have a nearby vertical dip and a thickness of 3,000 feet. This series is unconformable with the garnet and limestone on the western slope and separated from them by a fault which has dropped this later series into its present position. These rocks are not as well developed on the eastern side and their relation to the garnet-lime series is obscure.

In composition they range from silicified limes to microscopic aggregates of tremolite, lime-silicates and biotite, and probably were lime shales and slates originally.

The eastern foot-hills are covered by late flows of rhyolite that have no connection with the ore deposition.

The structure is complicated by a system of folding and faulting older than the granite intrusion, also by faulting after the mineralization. The effects of this faulting will be considered later.

Copper ore occurs in the garnet rock as an impregnation throughout portions of its mass and as richer concentrations in fractures and shear zones; also as bedded veins in the marbleized limestones.

The effect of the folding and fracturing of the strata previous to the granite intrusion has been to localize, in a degree, the deposition of the ore in the garnet rock along these fracture zones, giving the deposits the appearance of fissure veins filled with chalcopyrite disseminated in a garnet or garnet-epidote gangue, which has a laminated structure parallel to the boundaries of the fractured zone.

On either side of these fissures the garnet rock is more or less impregnated with chalcopyrite, but separated in some cases by a narrow rib of barren epidote 2 to 3 feet thick.

The lower boundary of the ore is the granite as shown in the Bluestone Mine on the eastern side of the range where the contact is well exposed; chalcopyrite in a garnet-epidote gangue resting directly on the barren intrusive rock.

The marbleized limestone which, in places, covers the garnet rock, contains bedded veins filled with oxidized copper ore in a quartz and calcite gangue.

At water level, which in one case occurs at a depth of 600 feet, pyrite and chalcopyrite begin to appear, replacing the oxidized ore.

The mines have not been sufficiently developed to show the relation of the ore in the limestone with the ore of the garnet shear zones, but that there is some connection is very probable.

The original minerals of the ore deposits are chalcopyrite and pyrite which have been oxidized and partly leached, forming in the upper enrichment zone, malachite, azurite and chrysocolla, and covellite as a coating, or chalcopyrite in the upper sulphide zone. Bornite and chalcocite occur as secondary sulphides in a few instances.

These ore occurrences can be classed as contact-metamorphic deposits, but differing from the ordinary type in which the ore occurs as irregular masses near the contact; this difference being due to the preexisting fissures which confined the ore-bearing waters in channels of great vertical extent, aside from these local concentrations the garnet is impregnated with a low grade copper ore.

Where the fissures were more open they were filled by the molten magma, forming dikes of granite-porphyry.

As mentioned before the mine developments are not of sufficient extent to connect the limestone ore bodies with those contained in the garnet, but it is difficult to avoid the conclusion that in depth the two classes of ore bodies will connect, forming a continuous lode, whose lower boundary is the granite and with its apex in the limestone.

If this view is confirmed by later work, the deposits will be of great interest as illustrating the genesis of ore bodies due to the action of intrusive rock masses, the magmatic waters of which have mineralized certain preexisting fissures, and, together with the heat derived from the molten magma, has converted certain sedimentary beds into garnet rock containing more or less disseminated ore and other beds, in a higher horizon, into marble, and also filling fractures parallel to the bedding of this marbleized limestone with copper ore.

It is not possible at the present time to determine how much of the rock metamorphism is due to the heating effects of the intrusive and how much to the introduction of new compounds by the waters of the molten magma, but we can assume that the ore is due to these waters and that the rock metamorphism was largely caused by the action of heat, supplemented by the chemical action of the water, as the garnet is more or less impregnated with ore, showing its permeability to these solutions which undoubtedly contained other mineralizers that contributed to the formation of the garnet.

The limestones, which occur at a higher horizon, have probably been altered by the action of heat alone, as they contain no ore, except in the fissures.

The District is being developed rapidly; one mine having a million tons of ore in sight, and in two years time it is expected to become a copper producer on a large scale.

MAGNETIC CONCENTRATION OF IRON ORES BY THE GRÖNDAL PROCESS.

By P. McN. Bennie, FitzGerald & Bennie Laboratories, Niagara Falls.

(Toronto Meeting, 1907).

The writer had the pleasure of attending the Toronto Meeting of the Canadian Mining Institute, in March, 1904, when a very interesting paper on Magnetic Separation was presented by Mr. F. T. Snyder. The technics of the magnetic separation of various materials were well covered in Mr. Snyder's paper, so that those features need hardly be again referred to.

In the present paper it is proposed to give an account of progress in magnetic separation with a specific process; and to draw some conclusions as to its possible bearing on the utilization of certain Canadian iron ores to the economic benefit of the Dominion.

It is not the intention to enter closely into mechanical details of the various forms of apparatus used in the Gröndal Processes for grinding, separating and briquetting iron ores. The results obtained in actual practice are probably of superior interest, and for this purpose a typical series of products may be taken, as follows:—

1st—Ore from Herräng, Sweden, ground in the Gröndal Ball Mill, as prepared for subsequent magnetic separation by the Gröndal Process.

2nd—Tailing from this Herräng ore, after passing through the Gröndal Magnetic Separator.

3rd—Concentrate from Herräng ore, showing the perfection of the separation.

4th—Briquette made from such concentrates by the Gröndal Briquetting Process.

The composition of these various materials, with reference to iron, sulphur and phosphorus content, is as follows:—

TABLE I.

RESULTS OF TREATMENT OF HERRANG ORE.

	Crude Ore per cent.	Concentrate per cent.	Slimes per cent.	Briquettes per cent.
Iron.	40.00	65.20	9.6	63.01
Sulphur.	1.20	0.17	...	0.003
Phosphorus	0.003	0.0025	...	0.0025

POROSITY: Per cent. of volume of briquettes = 23.9.

DEVELOPMENT OF THE GRÖNDAL PROCESS.

About 20 years ago the question of iron ore supplies became serious, and at that time magnetic separation received considerable attention from Conkling, Ball and Norton, and others, with the idea of utilizing large bodies of magnetic iron ore which could only be made available by means of magnetic concentration.

Then came the rapid development of the immense bodies of Lake ore, of a quality which could advantageously be used in the blast furnace, and except in certain restricted districts, interest in magnetic ores was lost. About the same time there was some hope that the magnetic iron ore deposits in Ontario would receive serious development, and indeed a number of fairly large shipments were made to the United States. But the development of the Lake ore bodies practically closed that market, and work on the Ontario mines declined to insignificance. In fact the discovery of those same Lake Superior ore bodies has had an influence upon the metallurgical life of both Canada and the United States but little appreciated nowadays.

In European countries, however, especially in Sweden, conditions were different. The supply of suitable ores ready for blast furnace use in their natural condition was limited and low grade; in many cases highly phosphatic and sulphurous ores had to be used; consequently great efforts have been made to perfect concentrating methods. The attention of many prominent engineers and metallurgists has been turned, with more or less success, towards the solution of the difficult problems involved in turning to account these ore supplies.

Mr. Gustaf Gröndal's efforts in this direction, extending over a number of years, have been more successful, the appliances and machinery invented by him for crushing, concentrating and briquetting low grade and impure iron ores being now so perfected as to constitute a complete commercial process. By these methods a great many hitherto practically valueless iron ores can be turned to excellent account by reason of the richness and purity of the concentrates and briquettes produced, and the comparatively low cost of production.

Primarily the Gröndal processes permit of the economic use of the many, in some cases immense, deposits of iron ore which are found in various places throughout the world, and which are unsuitable in their native state, owing to some objectionable characteristic, for economic blast furnace practice, and the production of good quality pig iron. Usually, the objection to their use will be found to be one of the following:—

1st—That the ore is too low in iron content.

2nd—That it contains impurities which cannot be eliminated in the blast furnace.

3rd—That it occurs in a mechanical condition unsuitable for blast furnace use, except to a limited extent; such as iron sands and small ores generally.

Among the ores which may be commercially utilized by the Gröndal Processes may be instanced:—

1—Magnetites of all kinds, including magnetic iron sands, containing as low as 25 per cent. iron.

2—Magnetites containing a high percentage of phosphrous and copper not chemically combined with the iron.

3—Purple ore and pyrites residues.

4—Nearly all kinds of iron ores containing a high percentage of sulphur.

5—Flue dust.

The Gröndal Concentrating Process.

The scheme of treatment is briefly as follows:—

1st—The ore is crushed dry to about ½ inch cube or thereabouts.

2nd—Wet treatment in a Gröndal Ball Mill, which reduces the ore from the crushed size to 10 to 100 mesh as may be found necessary.

3rd—The ground pulp is passed through a Gröndal Magnetic Separator where the non-magnetic particles are removed.

4th—The concentrates are pressed into briquettes and heated in the Gröndal Briquetting Kiln, from which they issue as hard, porous, easily reducible, ferric oxide briquettes, with a minimum percentage of sulphur.

To take each operation in detail:—

Any good type of commercial crusher may be used in the preliminary crushing of the ore. Usually either a Gates or Blake crusher is employed.

The broken ore is conveyed and distributed to the feed hoppers of the Gröndal Ball Mills. The feeding arrangement consists of an ordinary roller feeder driven at a uniform speed and so constructed as to admit of accurate adjustment of feed. The ball mill consists of a hollow cylinder, 4 feet in diameter and varying in width from 4 to 8 feet. It is reinforced with steel ribs and lined with manganese steel, or other steel alloy of good wearing quality. The mill is charged with about two tons of chilled cast iron balls, of about 6 inches diameter.

The ends are of cast iron with suitable openings provided with a screen at the discharge end. The degree of fineness of the ore is regulated by varying the amount of water introduced into the mill.

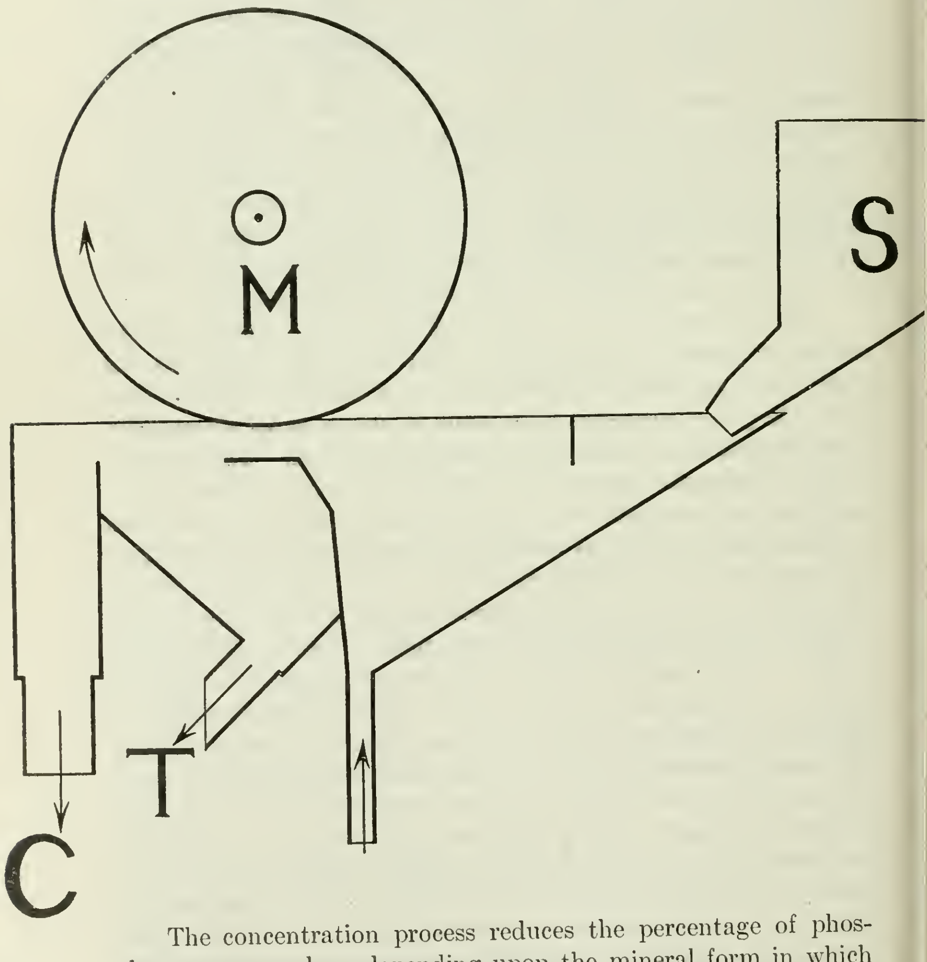
It is found that working with ores of average hardness the consumption of iron, represented mainly by the wear on the balls, amounts to about 2 pounds per ton of ore treated.

The mills require from 20 to 25 horse-power each, make from 25 to 30 revolutions per minute, and grind from 50 to 100 tons of ore per 24 hours, from ½ inch down to from 10 to 100 mesh in fineness.

In order to free the pulp from the bulk of the non-magnetic slimes, it is often advisable to pass the pulp coming from the ball mill through a slime box before charging it into the separator proper. The slime box consists of a V-shaped box, the pulp entering at the top and a stream of water at the bottom. The slime boxes are usually built in pairs and between each pair is placed an electro-magnet with a hatchet-shaped pole piece. This electro-magnet is of such strength as just not to lift any magnetic particles out of the water. The velocities of the pulp and clear water are so arranged that the heavier particles settle at the bottom, from whence they are drawn off to the separator. The function of the magnet is to arrest magnetic particles in the fine slimes which collect on the surface of the water immediately under the pole piece in masses and from time to time drop to the bottom whence they are carried off with the main pulp to the separators.

The accompanying diagram shows the principle of the separator proper. The pulp feed from slimes now passes to this part of the apparatus. This consists of a series of magnets with flat pole pieces arranged with their N and S poles alternately. The magnets are enclosed in a plain brass drum. This drum is made to rotate at a speed of from 80 to 100 revolutions per minute, and about one inch above the surface of the pulp, which traverses a pyramidal box divided into two compartments by a partition reaching nearly to the top of the box. The pulp enters at the top of the box, and a stream of water, entering at the bottom and rising up on the same side of the partition, carries all the pulp well over the edge of the latter and thus immediately under the drum. The magnets within the drum powerfully attract and bring the magnetic particles out of the stream of pulp and against the revolving brass drum. The remainder of the pulp drops down on the other side of the partition, and is carried off by the water through the waste outlet. The magnetic particles are lifted by the drum to the very edge of the magnetic field, where they are thrown off centrifugally. The capacity of the double-drum separator (which is the form commonly used) is from 70 to 100 tons of ore per 24 hours; it requires about 6 amperes at 120 volts, or say one horse-power, while less than $\frac{1}{4}$ horse-power will drive the drums.

A plant consisting of four ball mills, four double-drum separators, and having a capacity of fully 200 tons of concentrates per 24 hours, would require approximately 180 gallons of water per minute, and a power plant generating 150 E.H.P. would be ample for all the motive power required.



The concentration process reduces the percentage of phosphorus more or less, depending upon the mineral form in which it occurs in the ore. In most magnetites it is found in the form of apatite, in which case the phosphorus can be almost entirely eliminated. For example at Gellivare, Sweden, the phosphorus is reduced from 1.29 in the crude ore to 0.005 in the concentrates, and 0.006 in the briquettes. The percentage of iron is raised to a high figure, and at the same time the amount of slag-forming minerals is lowered. As a result the ore is more easily reduced in the furnace, and requires less fuel per ton of iron. The quality of the pig iron will be materially improved when using purer ore and less fuel than ordinarily.

Sometimes the ore mined is a mixture of magnetite and hematite. The dry magnetic concentrating methods hitherto employed give rather unsatisfactory results as regards the iron content of the tailing. With the Gröndal concentrating process, where the ore is already slimed up in water, a retreatment of the tailings on jigs or slime tables can be carried out with advantage, thus increasing the output of the plant without crushing or grinding any additional tonnage of ore.

The Gröndal concentrating process can be regarded as practically the only existing method for the economic treatment of low grade ores in which the magnetite is so finely and intimately mixed with the gangue that the ore has to be crushed down to less than say 20 mesh before it can be separated. Take the case of the banded jasper ore in the Temagami district, which would require very fine grinding to effect an economic recovery of iron; the Gröndal Process could do this, where no other could. But it is also obvious that such fine ores must be briquetted.

The Gröndal Briquetting Process.

Concentrates produced by this process, iron sands, pyrites residues, small ores generally, as well as ores containing a high percentage of sulphur, which are unsuited for use in the blast furnace, are next briquetted.

The material is conveyed to the briquetting presses. These are drop presses—the height of the drop being from 6½ to 7½ inches, and the briquettes receive three blows, the falling weight being about 1,800 pounds. The briquettes may be of various sizes, but are usually made 6 in. x 6 in. x 3 in., weighing from 8 to 10 pounds each. Each press requires 3 E.H.P., and will make from 500 to 750 briquettes per hour. The pulverized ore is pressed into briquettes without any binding material whatever, the moisture in the ore being so adjusted as to obtain briquettes sufficiently firm to be removed from this press to the cars used in the furnace.

The briquettes are taken from the press and placed on the furnace cars. These are made of iron and covered with fire brick. Along each side of the car is a deep flange which dips into a channel filled with sand placed along the sides of the furnace, thus forming a gas-tight seal. The ends of adjacent cars are fitted with a groove and projecting rib respectively. By this means the surface of the cars forms a gas-tight partition and thus prevents the lower portion of the cars, frame, wheels, etc., from becoming heated. The cars measure 3 ft. 6 in., and hold from 15 to 16 hundredweight of briquettes arranged on edge in two tiers.

THE FURNACE.

The furnace is fired by gas derived preferably from gas producers, although blast furnace gas can be used. The combustion chamber is situated about one third of the length from the intake end. The air needed for combustion is introduced below and traverses the row of cars, thus helping to keep the wheels and framework cool, and at the end of the furnace is diverted to the top of the row of cars, traversing the burnt briquettes, cooling them, and becoming itself heated before reaching the combustion chamber. The products of combustion pass over the entering cars, assist in drying and heating the briquettes, and finally escape through a stack at a temperature of only 150 deg. Centigrade. The furnace being thus constructed on the regenerative principle, has a very good thermal efficiency, radiation is small, and the chief loss of heat is due to the evaporation of the water contained in the briquettes (5 to 7 per cent.). A car of finished briquettes is drawn about every half hour, depending somewhat on the degree of desulphurization required. Recently, furnaces have been arranged so as to give a continuous movement to the cars, increasing the capacity of the furnace considerably.

The temperature in the combustion chamber of the briquetting furnace reaches 1,300 deg. to 1,400 deg. C. At this heat the particles agglutinate sufficiently to form a firm, hard briquette, able to stand rough handling and long transport. The briquettes, though hard, are very porous, and are consequently far more easily reduced in the blast furnace than ordinary lump ore. The briquette made from Herräng ore, previously mentioned, has a porosity of 23.9 per cent. of its volume.

When briquetting iron ore concentrates and using producer gas for fuel, the consumption of coal has been found to average 7 per cent. of the weight of briquettes burnt.

Gröndal Briquettes.

The Gröndal Briquette is unique in that it does not contain an added binder, and, therefore, there is no foreign material such as lime, to be heated, and slagged off. In the case of magnetic oxide concentrates the particles are completely peroxidised, owing to the very free supply of air given to the furnace during the process of burning the briquettes. Such peroxidised ore is very easily reduced in the furnace, thus introducing a certain fuel economy.

Treatment of Pyrites Residues.

Briquettes made by this process from pyrites residues and purple ore have proved to be entirely satisfactory in the open hearth steel furnace. At Cwmavon, ores containing 2 to 4 per cent. sulphur, and sometimes more, are being successfully treated by this process.

Capacity of Furnace.

The output of one furnace varies from 30 to 80 tons in 24 hours, according to the class of ore used, and the degree of desulphurisation required; for in addition to its mechanical action this furnace acts as an exceptionally efficient calciner for removing practically all of the sulphur.

The following analyses of crude ore, concentrates and briquettes will give an idea of the results obtained by the use of the Gröndal Processes:—

TABLE II.

RESULTS OF GRONDAL TREATMENT.

	Iron	Sulphur	Phosphorus
HERRANG, Sweden. (Shown in Table I.)			
GELLIVARE, Sweden.			
Crude Ore	58.96	0.036	1.29
Concentrates	72.38	0.003	0.005
Briquettes	69.49	0.002	0.006
SALENGEN, Norway.			
Crude Ore	36.43	0.021	0.318
Concentrates	71.76	0.015	0.008
Briquettes	.....	.....	.....
PITKARANTA, Finland.			
Crude Ore	28.40	2.60	0.260
Concentrates	69.59	0.132	0.007
Briquettes	67.98	0.011	0.008
CORNWALL, Penna.			
Crude Ore	30.65	1.603	0.012
Concentrates	69.95	0.036	0.003
Briquettes	69.90	0.010	0.005

The results from Cornwall ore were obtained with a ten ton sample sent to Herräng about a year ago, as there is not yet a plant available on this side of the Atlantic.

SEPARATION OF TITANIUM.

At the FitzGerald & Bennie Laboratories, Niagara Falls, Ontario, a small separator of the Gröndal type was installed in June of last year, and some tests were made on the separation of titanium from ore, working with what are known as Moise Beach sands, from the St. Lawrence River. The following results were obtained:—

Original ore	16.57 pct.	TiO_2
Concentrate	4.21	"
Middling	19.48	"

It should be remarked that the concentrates were obtained by a single passage through the separator. Doubtless even better results could be obtained from finer grinding, and repassing through the separator.

Cost of Plant.

It is impossible to give anything but bare approximations as to cost of plant, which varies considerably with the local situation and conditions. The figures quoted are based upon cost of materials, and cost of erection, in the United States:—

Concentrating plant for 400–500 tons of crude ore per day	$45,000
Briquetting plant for 200 tons of concentrates in 24 hours.	65,000
	$110,000

For 100 tons of concentrate per day these figures would be about $27,000 and $39,000 respectively, a total of $66,000.

Cost of Concentrating.

The cost of concentrating will naturally vary with the character of the ore treated, and the amount of iron contained in same. Assuming the treatment of an average magnetic iron ore, containing 40 per cent. iron, and the production of a concentrate carrying about 63 per cent. iron, the cost of concentrating varies from 30 to 45 cents per ton of concentrates. These figures refer to the mechanical treatment only, and exclude the cost of ore.

Cost of Briquetting.

The cost of briquetting is also an item varying with local conditions. A briquetting plant of 200 tons daily capacity would consist of four to seven furnaces, depending upon the ore, and to a large extent on the amount of sulphur to be removed. The cost per ton for briquetting can be taken, under normal conditions, as varying between 45 and 85 cents per ton.

At a small plant consisting of one furnace, producing 25 to 30 tons per day, the actual cost including labor, coal, rent and taxes, but exclusive of depreciation and royalty, amounts to 85 cents. This plant is working on pyrites residues, and owing to its small size, and nature of the work, the cost is high.

On the other hand, at a typical plant in Sweden, turning out 120 tons of briquettes daily, the cost of briquetting amounts to 77 cents per ton. At one of the Swedish plants of recent construction the cost has been reduced to 67 cents per ton.

Recently the briquetting furnace has been simplified and improved so as to materially decrease the cost of installation, and at the same time to lower the cost of briquetting.

TREATMENT OF CANADIAN ORES.

The present situation in Canada, and particularly in the Province of Ontario, is similar to that in the Scandinavian countries, in many ways. Not over blessed with ready fuel, and with iron ores that in many instances require concentration, yet it is well known that certain qualities of iron (Swedish pig, for example) are produced, which bring a premium on the market. There is no reason why Canada should not largely augment its production of high-grade pig iron, and have as great a demand for it as for the Swedish article.

There are many bodies of magnetic iron ore in Ontario, running from 35 to 50 per cent. iron, that would be so improved by proper treatment as to produce premium ores, for which there is now and probably will continue to be a brisk demand.

For ores that demand fine grinding to recover an economical percentage of iron content, the Gröndal briquette affords a means of converting unsalable ores into an article that will actually bring a premium, thus helping to pay for the cost of treatment. Only recently a blast furnace manager told me he would be glad to get 200 tons a day of such briquettes. Gröndal briquettes are now being shipped in considerable quantities from Sweden to Great Britain, where they command an instant market at prices above the average.

ELECTRO-THERMIC PROCESSES.

Another feature certain to be of considerable economic value to Canada is the application of electro-thermic processes for producing high-grade pig iron and steel. Broadly speaking, the use of sufficient electrical energy to produce one ton of pig iron in the electric furnace means the displacement of about 1,600 pounds of fuel. Coal once used is gone forever, while water powers maintain themselves by a natural process, a fact of great economic importance to Canada. The fortunate existence practically side by side of iron mines and extensive water powers, produce conditions very favorable to the electro-thermic process. The writer believes the Government would do well to foster the development of that branch of metallurgy as much as possible, to enable the country to realize on its natural and unique resources.

Many of the ores could doubtless be used direct, others would require concentration, and still others would have to be briquetted, but the economy of producing finished material wherever possible "on the spot" is obvious. Science and Art have now placed in the hands of those who will, means of utilizing these resources, and thus adding to the nation's wealth.

THE MICROSTRUCTURE OF NICKELIFEROUS PYRRHOTITES.

WITH SPECIAL REFERENCE TO THE DEPOSITS OF SUDBURY, ONT., ST. STEPHEN, N.B., AND SOHLAND, GERMANY.

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(Toronto Meeting, 1907.)

INTRODUCTION.

When we consider the work that has been done in the microscopical examination of ore-bodies in general and of the nickeliferous pyrrhotites in particular, we see that whereas the relations of the transparent constituents have been clearly worked by petrographic means, our knowledge of the relations of the opaque constituents is very often fragmentary and uncertain.

When we apply the methods of examination employed in metallography, most of our difficulties disappear, because the examination of a highly polished surface by reflected light both vertical and oblique, with or without the aid of etching, reveals the relations of the various constitutents in a striking manner.

The following paper gives the results of such an examination of various nickeliferous pyrrhotites and had for its object the determination of the genetic relations of the various opaque constituents, together with the mode of occurrence of the nickel. Typical specimens were obtained from the Sudbury deposits, from St. Stephens, N.B., from Sohland, Germany, from Norway, etc., and pieces of suitable size were polished (1). Their various constituents can be recognized under the microscope by the following characteristics.

Pyrrhotite—Light bronze colour, similar to pentlandite. Is rather more brittle however, and shows a more pitted surface.

(1) W. Campbell. The Microscopic Examination of Opaque Minerals School of Mines Quarterly XXVII, 414, also XXV, 390. Economic Geology I, 751.

Its hardness is 4. It is attacked by hot HO (1:1) while pentlandite remains unchanged. Therefore appears dark in the illustrations.

Pentlandite—Light bronze colour. Polishes rather better than pyrrhotite. Is distinguished from the latter on etching. H=4. Sometimes shows cleavage.

Chalcopyrite—Yellow colour. Polishes comparatively easily. H=4.

Magnetite—Steel-gray colour. Etches differentially giving "gridiron" structure H=5.5—6.5.

Pyrite—Pale brass colour. Polishes with difficulty, usually shows scratches. H=6—6.5. Polishes in relief. Hence we can easily distinguish between chalcopyrite, pyrite, pyrrhotite and magnetite by colour and habit, whilst pyrrhotite is distinguished from pentlandite by etching.

THE DEPOSITS OF SUDBURY, ONT.

Whether these deposits owe their origin to differentiation from eruptive magmas or have been deposited from solution is still a matter of great discussion. Dickson in his paper on "the ore-deposits of Sudbury, Ontario" (2) gives a clear summary of the deposits and from his observations comes to the conclusion that the ores are of secondary aqueous origin. Barlow (3) in a paper "on the origin and relations of the nickel and copper deposits of Sudbury" also summarizes the work done, but from his observations it would seem that the magmatic origin must be applied to these ores. The nickel occurs as pentlandite, but the exact relations of the pyrrhotite, pentlandite and chalcopyrite had not been worked out. Specimens were obtained from the Creighton, Gertrude, Copper Cliff No. 2, North Nickel Range, etc. and the relations of the sulphides worked out as follows.

The Creighton—In the hand specimen, veins and masses of chalcopyrite are seen embedded in pyrrhotite. Areas of felspar, hornblende, etc., which we shall hereafter call "Silicate," occur. On etching, the veins of pentlandite show up well. Under the microscope, both pentlandite and chalcopyrite are seen to occur as fine lenses within the pyrrhotite grains and also as irregular

(2) Trans., A.I.M.E., 1904, p. 3, et seq.
(3) Economic Geology I, 454.

veins and masses between them. The chalcopyrite in several places cuts the veins and masses of pentlandite and is therefore later. In fig. 1 the main mass is rough dark etching pyrrhotite whilst the lighter veins are pentlandite. The large ounrded dark mass in the right hand corner is an eroded crystal of silicate. Magnetite occurs as slightly rounded crystals in pyrrhotite and in the silicate. Thus the order of the minerals is seen to be (1) magnetite, (2) silicates, (3) pyrrhotite, (4) pentlandite, (5) chalcopyrite.

The Gertrude—The specimen showed veins of pentlandite and chalcopyrite in a ground mass of pyrrhotite. The silicate shows a rounding-off of angles and corroded sides and is strained. It contains crystals of magnetite with more or less sharp angles. The order is therefore magnetite, silicate, pyrrhotite, pentlandite and chalcopyrite.

The Copper Cliff No. 2—As before the pentlandite occurs as a more or less irregular network round the grains of pyrrhotite and also as finely oriented inclusions within the grain itself. Fig. 2 shows a vein of light pentlandite between two grains of dark-etching pyrrhotite. A little chalcopyrite occurs along with the pentlandite and in a few places cuts it as veins. When magnetite occurs in a matrix of pyrrhotite it is as more or less rounded grains. The silicate shows a rounding off and smoothing of angles, and is often strained forming a nucleus for the chalcopyrite which is intimately associated. Thus, again, we have the same order as before, viz., (1) magnetite and silicate, (2) pyrrhotite, (3) pentlandite, (4) chalcopyrite.

The relation of the sulphides to the silicates has been very clearly shown by Dickson, his illustrations (4) showing the replacement of the silicate by sulphide. In examination by reflected light the silicates appear dark and the sulphides light as in fig. 3, where bright grains and masses of pyrrhotite and pentlandite are seen set in a dark mass of the silicates. In other cases long veins of chalcopyrite are seen cutting the silicate crystals, very often along cleavage planes.

North Nickel Range—The specimens from this locality contained a good deal of pyrite, which, after polishing, shows up with

(4) Trans., A. I. M. E., 1904, pp. 32, 34, 35 and 38.

its characteristic rough appearance. Fig. 4 shows three crystals of pyrite which are scratched and on account of their hardness stand out in relief. They are set in a ground mass which consists of a mixture of silicate, chalcopyrite, etc., and shows the same order of origin as the other ores from the district. Magnetite is the oldest constituent, and apparently pyrite comes next, then the silicate, pyrrhotite, pentlandite and chalcopyrite. From the fact that the pyrite crystals are mostly rounded off and erodes, and in many cases have been broken and then cemented by the later sulphides, we must conclude that the pyrite is very much older than the pyrrhotite, etc.

Conclusions on the Sudbury Ores—From the above described results we must conclude that, for the specimens examined, there is a definite order of origin. Magnetite is the earliest constituent, then comes the silicates. Later on pyrrhotite comes in, which, in turn, is followed by pentlandite and then chalcopyrite. In many cases the silicates are strained and cut by both pyrrhotite, pentlandite and chalcopyrite being clearly replaced by the latter along cleavage planes, etc. Again we find the pyrrhotite shows evidence of strain and fracture previous to deposition to the pentlandite. Hence we must conclude that the three sulphides come in after the rock had formed and were deposited from solution. One thing is certain, which is, that the structures met with do not bear the faintest resemblance to those of mattes, as has been suggested.

The occurrence of the pentlandite as very fine lenticles within the grain of the pyrrhotite explains why magnetic separation was never a complete success.

THE DEPOSITS OF THE ST. STEPHEN, N.B.

In a paper read before this Society last March, Dr. Dickson describes these deposits and from a careful microscopic study comes to the conclusion that the ores are largely of a secondary nature deposited from circulating solutions by a metasomatic replacement of the rock minerals: that pyrrhotite at first, probably formed the larger proportion of the ore and chalcopyrite has been introduced still later.

Under the microscope our specimens showed the pyrrhotite to be either broken up or very fine grained. In it are seen quite a number of magnetite crystals and some small crystals of the silicates which are bent and often fibrous. The pentlandite and chalcopyrite were found to occur as small grains only and it was noticed that the chalcopyrite was often found deposited on the broken silicate crystals. The order of occurrence is magnetite, silicates, pyrrhotite, pentlandite and chalcopyrite. The relative ages of the pentlandite and chalcopyrite could not be ascertained, due to their mode of occurrence.

THE DEPOSITS OF SOHLAND, GERMANY.

In the second part of the paper (5) mentioned above, Dickson describes these deposits and gives Prof. Beck's conclusions, drawn from a microscopic study of the ore, which his own work confirmed. The conclusions are that sulphides came in after the complete cooling and differentiation of the rock magma and were deposited from solutions from considerable depth. Dickson was unable to isolate pentlandite from the ore.

Our specimens showed a banded structure due to chalcopyrite having a zonal arrangement within the pyrrhotite. After etching, pentlandite is found as small grains intimately associated with chalcopyrite. Fig. 5 shows the light mixture of chalcopyrite and pentlandite set in the dark-etching groundmass of pyrrhotite, which also contains minute flakes of pentlandite within the grain itself as has been described in the Sudbury ore. Very thin envelopes of pentlandite occur round the smaller grains of pyrrhotite. Fig. 6 shows such veins of light pentlandite occurring between the grains of dark-etching pyrrhotite. The structures met with show that the order of deposition is (1) pyrrhotite, (2) pentlandite, (3) chalcopyrite. The intimate association of the pentlandite and pyrrhotite as seen in fig. 6 explain why a magnetic or other physical means of separation was not successful.

NORWEGIAN NICKEL DEPOSITS.

The nickel deposits of Norway have been fully worked out by Professor Vogt who regards them as of igneous origin. They

(5) "Genetic Relations of Nickel-Copper Ores." Journal, Vol. IX p.

resemble in all essential particulars the nickel deposits of Sudbury (6). Specimens from the two principal localities, the Flaad Mine and the Erteli, were examined and the relations of the minerals were found to be the same as that at Sudbury. As before, the pentlandite varies from thin veins to thick masses and also occurs within the grain of the pyrrhotite as definitely oriented inclusions. Again the chalcopyrite is found to favor the shattered silicate crystals.

SUMMARY AND CONCLUSIONS.

In all of the above examples of nickeliferous pyrrhotites, taken from widely separated localities, we find certain points of similarity and a regular order of succession which are very striking.

The magnetite is an original constituent being older than the silicates which are usually more or less broken and contain veins and masses of the sulphides.

The sulphides occur in a definite order, viz:—

(a) Pyrrhotite.

(b) Pentlandite.

(c) Chalcopyrite.

The pyrrhotite generally shows evidences of strain and fracture before the advent of the pentlandite which was closely followed by the chalcopyrite, the two having a habit in common.

When we come to consider the evidence afforded by this metallographic examination of our specimens, we must come to the conclusion that the mode of origin of all was the same. Long after solidification the basic rocks were more or less cracked and broken, and then solutions deposited pyrrhotite by replacement, etc. Later on the pyrrhotite in turn became strained and broken and then pentlandite was deposited. The pentlandite was closely followed by chalcopyrite.

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(6) A. E. Barlow, Nickel and Copper deposits of Sudbury, Geol. Surv., Canada, Part H. an. Rep. XIV., p. 166.

We wish to emphasize the fact that these conclusions are based entirely on our specimens, because others who are familiar with the geological features at large and know the localities thoroughly may see a widely different interpretation on our work.

In conclusion we wish to thank C. W. Dickson, Ph.D., School of Mining, Kingston and Professor Kemp, Columbia University, for their kindness in supplying us with the material on which the work was done.

Fig. 1—Creighton Mine. x 88V.

Fig. 2—Copper Cliff. x 50V.

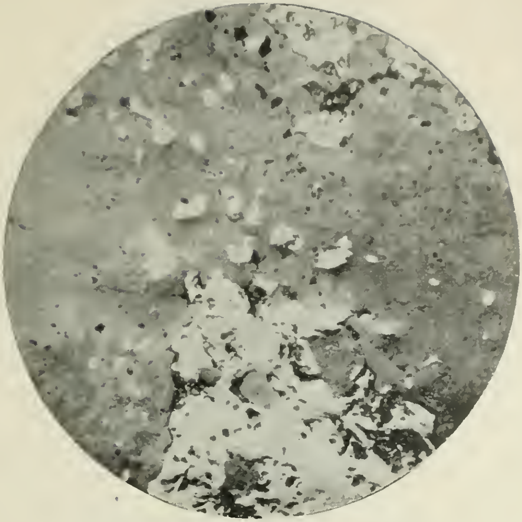


Fig. 3—Creighton Mine. x 88V.

Fig. 4—North Nickel Range. x 30V.

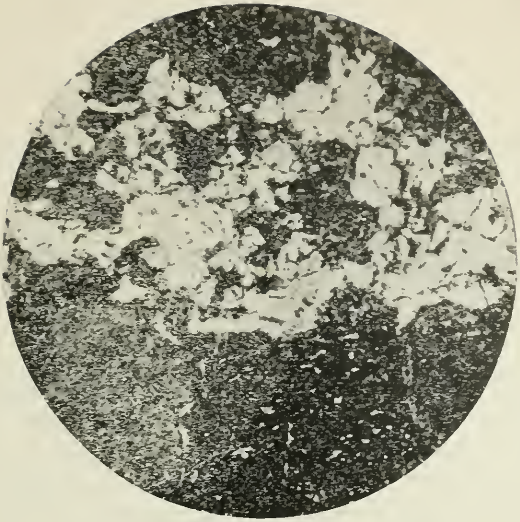


Fig. 5—Sohland, Germany. x 50V.

Fig. 6—Sohland, Germany. x 50V.

THE USE OF GRAPHIC FORMULÆ IN METALLURGICAL CALCULATIONS.

By D. H. Browne, Metallurgist of The Canadian Copper Co., Copper Cliff, Ont.

(Paper to be read at Toronto Meeting, March, 1907.)

The daily records of furnace practice, the charge sheets, analyses, blast records, &c., are of value only in so far as they leave a permanent record in the minds of the furnace superintendent and his foremen, which record is termed "experience." As all these data, daily accumulating, become in time too numerous for the mind to carry, it is necessary to reduce them to terms of some common denominator and to group them in ways that will make them understood. In furnace practice also certain calculations are daily necessary, and these may be reduced to simple tables or charts. The purpose of the present paper is to outline methods whereby the records of one particular ore may be tabulated and reduced to graphic formulæ. If a standard method, applicable to all ores, could be devised, then the science of metallurgy would approach the status of an exact science.

Suppose for illustration we have a large ore body consisting of chalcopyrite, pyrrhotite and diorite, and suppose that we have found by experience that the ore is regular in composition; varying only in the relative proportions of minerals and rock. A fair average analysis is, we will assume, as follows:—

Cu	4.50
Fe	40.06
S	25.66
SiO_2	18.20
Al_2O_3	6.30
CaO	3.00
MgO	1.20
	98.92

We have first to reduce this to its mechanical composition considering it as a mixture of chalcopyrite, pyrrhotite and rock. Starting with chalcopyrite we have the analysis and ratio of this mineral to guide us.

CHALCOPYRITE.

Cu	34.5%	=	1000 parts
S	35. %	=	1014 "
Fe	30.5%	=	883

The ore has 4.5% copper, therefore to form chalcopyrite this copper must be combined with iron and sulphur in the following amounts.

$$S = 4.5 \times \frac{1014}{1000} = 4.56 \text{ parts S}$$

$$Fe = 4.5 \times \frac{883}{1000} = 3.97 \text{ parts Fe}$$

We have in the ore as chalcopyrite:—

Cu......................	4.5%
S......................	4.56
Fe......................	3.97
	13.03% Chalcopyrite.

Deducting this sulphur and iron from the amounts in the original analysis we have:—

S =	25.66—4.56	=	21.1	Sulphur left.
Fe	40.06—3.97	=	36.09	Iron left.

Taking this 21.1 parts of sulphur left, we combine it with enough iron to form pyrrhotite of which the analysis and ratio is :—

PYRRHOTITE.

Fe	61%	=	1564 parts
S	39%	=	1000 parts

The iron combined with the remaining sulphur is

$$Fe = 21.1 \times \frac{1564}{1000} = 33.0\% \text{ Fe as pyrrhotite.}$$

We substract this from the iron we had left after the chalcopyrite was salisfied

$$36.09 - 33.00 = 3.09 \text{ Iron left.}$$

This must be combined with oxygen, and as such will form almost 4% Iron oxide.

We can now reconstruct the mineral portion of the ore as follows:—

	Cu	Fe	S
Chalcopyrite...........	4.5	3.97	4.56
Pyrrhotite.............		33.0	21.1
	4.5	36.97	25.66
		67.12	

Raising this to 100% we have

Cu..............................	6.7
Fe..............................	55.0
S...............................	38.2
	99.9

The rock materials which are left are

FeO................	4.00	=	12.2%
SiO_2	18.20	=	55.65
Al_2O_3	6.30	=	19.26
CaO................	3.00	=	9.1
MgO................	1.20	=	3.6
	32.70		99.8

For metallurgical purposes we can group these constituents as

Silica............................	55.65%
Bases............................	44.2

We have now the mechanical composition of the ore as

Minerals 67.12 parts containing	Cu.	6.7
	Fe.	55.0
	S.	38.2
		99.9
and Rock 32.70 parts containing	SiO_2	55.65
	Bases.	44.2
		99.85

We can now assume that any ore from this mine will, in large quantities, correspond to some definite mixture of this mineral and this rock, and we can plot a chart showing what the composition of any such mixture will be.

Lay off on quadrille paper a base line containing 100 horizontal divisions. At the left hand end erect a perpendicular, which we will call "Rock." Lay off on this rock line the distances from the base line corresponding to the percentage of silica and bases in "Rock," and connect these points with the zero at the right hand end of the base line. From this zero at the right hand end of the base line drop a vertical, which we will call "Mineral," and on this lay off with the same scale distances corresponding to the Cu, Fe, and S in the mineral. Connect these points with zero at the left hand end of the base line. We have now Figure I, a vertical cross-section of which at any point will give the percentage composition at this point. For the sake of clearness we can lay out the copper contents on a scale 10 times that of the other constituents.

Let us take silica as a standard, and lay off on Figure I vertical lines corresponding to 5, 10, 15, 20, 25, and 30% silica. We can now read off the ore composition for variations of 5% silica. For example:—

SiO_2	20 %
Bases	15.5
Sulphur	24.5
Iron	35.5
Copper	4.30

We can now draw up a slag chart covering the grades of ore we most commonly use. We take the pure mineral and calculate the proper slag for it; then we calculate the slag for an ore containing 20% Silica. By plotting these and continuing the lines we obtain a slag chart for ore of any composition between pure mineral and pure rock.

The pure mineral contains:—

Cu	6.7%
Fe	55.0
S	38.2

This sulphur will be roasted to 12 or 13% before coming to the smelter bins. This does not alter the slag calculation. We decide to make a matte carrying 40% Copper and a slag carrying 33% Silica. It is well known that copper mattes with 79% Copper contain no iron and that 64% iron mattes carry no copper. So by plotting Copper on a vertical scale and Iron on a horizontal, and connecting 79% Cu with 64% Fe, we get a diagonal line showing the amount of iron in mattes of any copper content. From this we find that a 40% copper matte carries 32% iron.

We make, for the present, no deductions for slag loss, but calculate as follows :—

6.7 parts copper forming a matte containing 40% Cu and 32% Fe will take 5.36 parts Fe into the matte. The mineral has 55 parts iron, and after deducting the iron which goes into the matte we have 49.64 parts iron to go into slag. One part iron makes 1.28 parts iron oxide, so 49.64 parts iron make 63.59 parts iron oxide. We have, therefore, 63.59 pounds iron oxide from 100 lbs. mineral, and we have to add silica so that the silica is 33% in the slag.

Let x = Silica to be added.

$$x = \frac{33}{100}(63.59 + x)$$

$$100x = 2098 + 33x.$$

$$67x = 2098 \qquad x = 31.3 \text{ lbs. silica.}$$

Therefore 100 lbs. pure mineral requires 31.3 lbs. Silica.

Take now the ore mixture with 20% Silica, which we found to contain:—

SiO_2	20 %
S	24.5
Fe	35.5
Other bases	15.5
Copper	4.3

This 4.3 parts Cu passing into matte requires $4.3 \times \frac{32}{40}$ Fe = 3.4 lbs. Fe. Deducting this from 35.5 Fe we have left 32.1 lbs. Fe to be slagged. Calculating this to iron oxide, $32.1 \times 1.28 = 41.0$ lbs. iron oxide to be slagged. The total ingredients passing into the slag are:—

Iron oxide	41.0%
Other bases	15.5
Silica	20.0
	76.5%

We have to add to this 20 lbs. silica a certain amount x of outside silica, so that 20 + x will be 33% of 76.5 + x.

$$20 + x = \frac{33}{100}\ (76.5 + x)$$

$$2000 + 100\,x = 2525 + 33\,x$$

$$67\,x = 525. \qquad x = 8 \text{ lbs. Silica.}$$

We have thus found that a pure mineral requires 31.3 lbs. silica, and an ore with 20% silica requires 8 lbs. silica. We can plot these on a chart and read the amount of silica required for ore of any silica content. Such a chart is drawn in Fig. II.

As we never have pure silica available for flux, we must lay off on the chart other lines corresponding to the amounts of quartz needed with varying silica content. Each 1% of bases in the quartz abstracts 0.33% of silica—so that a rock with 33% silica would have no silica available. We can lay out a table showing the flux value of various grades of quartz.

Per cent. SiO_2 in Quartz.	Per cent. SiO_2 Available.	Lbs. Quartz to equal 100 lbs. pure SiO_2.
100%	100%	100
95	93.35	107
90	86.7	115
85	80.05	125
80	72.80	137
75	66.75	150
70	59.20	169
65	53.45	187
60	46.80	213

We can now plot on Fig. II, the lines corresponding to the various percentage of silica in the quartz used for flux. The pure mineral takes 31.3 lbs. of pure silica. If a quartz with 90% silica is used, we have to take $31.3 \times \frac{115}{100} = 36$ lbs. of this quartz. Making out a table of this we have :

100 lbs. Mineral requires	31.3 lbs. Silica.
	36.0 lbs. 90% Quartz.
	39.1 lbs. 85 "
	42.8 lbs. 80 "
	46.9 lbs. 75 "
	52.8 lbs. 70 "

A similar calculation can be made for ore containing 20% silica:

100 lbs. Ore at 20% Silica requires	8 lbs. Silica.
	9.2 lbs. 90% Quartz.
	10.0 lbs. 85 "
	10.9 lbs. 80 "
	12.0 lbs. 75 "
	13.5 lbs. 70 "

Dotting in these points in their proper position and drawing the lines we complete Fig. II.

We can now read off the amount of flux needed for any per cent. silica in the ore mixture. For example: The ore is 13% silica; the quartz the same day has 80% silica. Finding 13% silica on the base line we follow it up and find it intersects the 80% silica line at 24 lbs. Therefore 100 lbs. of this ore will require 24 lbs. of this quartz to make 40% matte and 33% slag.

These lines, it will be noted, all intersect at 27%, showing that an ore with 27% silica and with the other constituents as shown by Fig. I, is self fluxing for a 33% silica slag. We may prolong this chart and see that ores with more than 27% silica require the addition of a base, such as lime, or an iron ore, or a basic copper ore. We will take limestone as an example, and assume we are using the same ore, making the same matte and slag, and using lime as the added base. Starting the calculations with the pure rock which accompanies the mineral in our ore. This rock by the calculation (page 15) contains:—

Silica	55.65
Bases	44.20

We desire to make this into a slag with 33% silica and 67% bases. Evidently the amount x of added lime must be such that 44.2 + x=67% of 100+x.

$$44.2 + x = \frac{67}{100}(100 + x)$$

$$33\,x = 2290.x = 66 \text{ lbs. CaO.}$$

We can now make Fig. III, laying off on the right hand side a vertical on which we mark 66 lbs. lime above the point showing 55.65% pure silica. As 27% silica ore is self-fluxing, we can draw a diagonal from this point to 66 lbs. lime and we have here a reading of the amount of lime needed for all ore between 27% silica and pure rock.

But as on the silica side we have no pure silica available, so on the lime side we have to work with crude limestone, and we have to make a table showing the flux value of these limestones. A pure silicate of lime with 33% silica carries 67% lime, or simplified, one pound silica equals two pounds of lime. So in a limestone with 5% silica, this 5% silica neutralizes 10% lime and cuts down the fluxing power of the limestone. We make a table of this :—

% Silica in Limestone	% CaO in Limestone	% Available CaO	Lbs. Limestone to equal 100 CaO
0	56	56	178
5	53.2	43.2	231
10	50.4	30.4	328
15	47.6	17.6	568

Suppose in the present instance our limestone has 5% silica and as we have shown 100lbs. pure rock needs 66 lbs. pure lime; we multiply 66 by 2.31 and find that 152.4 lbs. of this limestone are required.

We can now complete Fig. III, laying out the lines for pure lime and for any grade of limestone we have available.

Suppose we have an ore with 38% silica, Figure III shows that 100 lbs. such ore requires 60 lbs. of our limestone. We can check this very readily. From Table I we find that this ore carries:—

SiO_2	38%
Iron.	18
Other bases.	30
Sulphur.	12
Copper.	2.0

This copper requires $2.0\times\frac{32}{40}=$ 1.35 lbs iron in the matte, which leaves 18—1.35=16.65 lbs. iron to go into slag. Multiplying 16.65 by 1.28 gives 21.3 lbs. iron oxide to be slagged. The slag constituents are:

Silica.	38%
Iron oxide.	21.3
Other bases.	30.0
	89.3%

Or adding together all the bases we have:—

Total bases	51.3%
Silica	38.0
	89.3%

We desire to make slag with 33% silica and 67 % bases. Therefore

$$51.3 + x\ CaO = \frac{67}{100}(89.3 + x)$$

$$33\ x = \quad 853 \text{ lbs. } CaO$$
$$x = 25.8$$

Looking up Table III, we find this checks out almost exactly. But our limestone has 5% silica. Now 5% silica leaves 95% $CaCO_3$ or $95 \times \frac{56}{100} = 53.20$ CaO in this limestone. As 1 lb. silica in the slag neutralizes 2 lbs. bases, so 5 lbs. silica in the limestone neutralizes 10 lbs. CaO—so we have 53.20—10 = 43.20 available CaO. We have to use 25.8 lbs. CaO, therefore we use $25.8 \times \frac{100}{43.2} = 59.7$ lbs. of our limestone. Referring to Fig III we find 60 lbs. indicated which proves the accuracy of our chart. We could however have made this calculation in a much simpler way. From Fig. II we saw that the pure silica line ran from 31.3 lbs. required for pure mineral down to none for ore with 27% silica. If we prolong this silica line diagonally to the right below our base, Fig. IV, we get a chart showing excess silica or negative silica, which if taken from the ore would make it self-fluxing. We have seen that in our slag, 1 part silica equals 2 parts lime, so if we read off our negative silica and multiply it by two,we get the amount of lime it requires. For example on this chart an ore with 32% silica has 6 points excess, or minus silica as shown by the lower silica line. Multiply by two gives 12 parts CaO to be added which coincides with the amount of lime to be added as shown by Figure III. Again, ore with 40 silica has 15 points minus silica which means 30 parts lime, which also checks out by Fig. III.

We can in the same way plot mixtures of two or more ores in any fixed proportion. If the regular furnace charge be a mixture of two ores, the resultant mixture may be charted and a third ore figured as a flux. For example, if we have a mine A. yielding silicious ore No. 1, and a mine B. yielding an irony ore No. 2, we may decide on a standard mixture of say 1000 lbs. No. 1 to 2000 lbs. No. 2. This mixture can be charted and taken as a standard on which we may calculate the required amount of a limey ore No. 3.

Another interesting use of the graphic method is shown in Fig. V. Suppose the standard furnace charge is 12,000 lbs. of roast ore; and that this roast ore varies between 10 and 15% sulphur; and suppose further that it is desirable to keep the sulphur contents constant at 13%, and that we have a green ore containing 30% sulphur with which to raise the amount of sulphur in the charge. We can lay out a chart showing just how much green ore must be added to roast ore of any sulphur content in order to raise the sulphur to any given percentage.

We start the calculation with some standard weights, for example: 12000 lbs. roast ore and 4000 lbs. green ore, as folows:—

12000 lbs. roast ore at 10% S =	1200 lbs. S
4000 lbs. green ore at 30% S =	1200 lbs. S
16000	2400 = 15% S
12000 lbs. roast ore at 11% S =	1320 lbs. S
4000 lbs. green ore at 30% S =	1200 lbs. S
16000	2520 = 15.7% S
12000 lbs. roast ore at 12% S =	1440 lbs. S
4000 lbs. green ore at 30% S =	1200 lbs. S
16000	2640 = 16.5% S
12000 lbs. roast ore at 13% S =	1560 lbs. S
4000 lbs. green ore at 30% S =	1200 lbs. S
16000	2760 =17.27% S

12000 lbs. roast ore at 14% S =	1680 lbs. S
4000 lbs. green ore at 30% S =	1200
———	———
16000	2880 =17.9% S

Lay out on a vertical line at the left the different percentages of sulphur and along a horizontal line lay out the pounds of green ore—from 0 to 4000 lbs. Take the 10% sulphur which we find was raised to 15% by the addition of 4000 lbs. of green ore, mark the point corresponding to 15% S. above 4000 lbs. of green ore; connect this with the point corresponding to 10% sulphur with no green ore. This gives a diagonal line along which we can read the sulphur obtained by mixing 12000 lbs. roast ore at 10% sulphur with any amount of green ore at 30% sulphur. Connecting the other calculated points we have Figure V completed and can read from it any desired mixture of green and roast ore.

The method of charting the work of a furnace from day to day, so as to obtain a graphic record of its consumption and output and also to obtain a prophetic estimate of its probable tonnage for the current month, is well known, but may bear repetition in this connection. Suppose a furnace smelting about 350 tons ore and making about 12.3 tons copper a day. If this furnace continues in blast every hour during the month,we would expect 370 tons copper for this month. We lay off a horizontal line of 30 days—and on the 30th day erect a perpendicular upon which we mark a point corresponding to 370 tons which we connect by a diagonal dotted line with the point on the base representing the beginning of the month. We graduate the right hand vertical in a scale of tons from 0 to 370—and we graduate on the left a vertical column on a scale ten times as great for the daily output in tons. At the top of the left hand column we lay off a scale of hours from 0 to 24 showing the number of hours the furnace was in blast each day. As we mark in each day's tonnage, we also mark in the total tonnage of copper produced up to date. This total tonnage to date, as long as the furnace produces 12.3 tons a day, will coincide with the dotted line of expected production but will deviate from this and fall either above or below it according as the furnace produces more or less than the average amount of copper. Any delay or stoppage of the furnace is shown by the line representing hours in blast, and the cause of any delay may be marked by a circle enclosing a letter or figure referring to the usual causes of delay and explained in the legend. Such a chart from the first to the 15th of one month is shown in Fig. VI.

In the same way the output of the mines, the performance of day and night shift, the furnace records, tonnage of ores, flux, coke, analyses of the ore, amount or pressure of air may be tabulated from month to month. By plotting these on translucent paper, they can be laid one over the other for comparison and in this way interesting relations and points of economy may be discovered. For example the monthly averages showing copper in the matte and copper in the slag should be parallel; if they are not, a comparison of the silica chart of the slag with the copper in the slag may show the cause of difference. Again the matte grade and the life of the converter lining should be parallel; but if a better grade of matte in a certain month is not accompanied by an increased duration of lining, the explanation may be found in the analysis chart of the quartz used which may show bad quartz for the month in question.

Often, also, the continuous relation of two lines may open a field for study. For example the silica in the ore and the percentage of sulphur in the ore after roasting may be inverse one to the other; which on investigation proves that a certain amount of rock helps the roasting by cracking and swelling and so opening up the ore in the roast beds. This shows also the desirability of keeping a certain amount of rock in the ore. But the output of the furnace per month may also prove to be exactly inverse to the silica in the ore; and this raises the question of volume of slag loss and the metallurgical balance sheet. Frequently by such comparison we see that what is apparently the cheapest method is in reality the most expensive. It might be thought cheaper to leave silicious rock in the ore, than to pick the rock out and afterwards add barren quartz for flux; but a comparison of the slag volumes will show that in many cases this apparent waste is an actual saving of expense.

There is no factor of furnace practice, except perhaps the personal equation, which cannot be studied by the graphic method. Even the personal equation may be referable to some disturbing condition. The number of furnace accidents may be shown to be greater under one foreman than another, or may reach a maximum at certain hours of the day, showing either individual carelessness or improper conditions under which the men are labouring. All knowledge comes by the intelligent comparison of data and the graphic method is the readiest means of making our data intelligible.

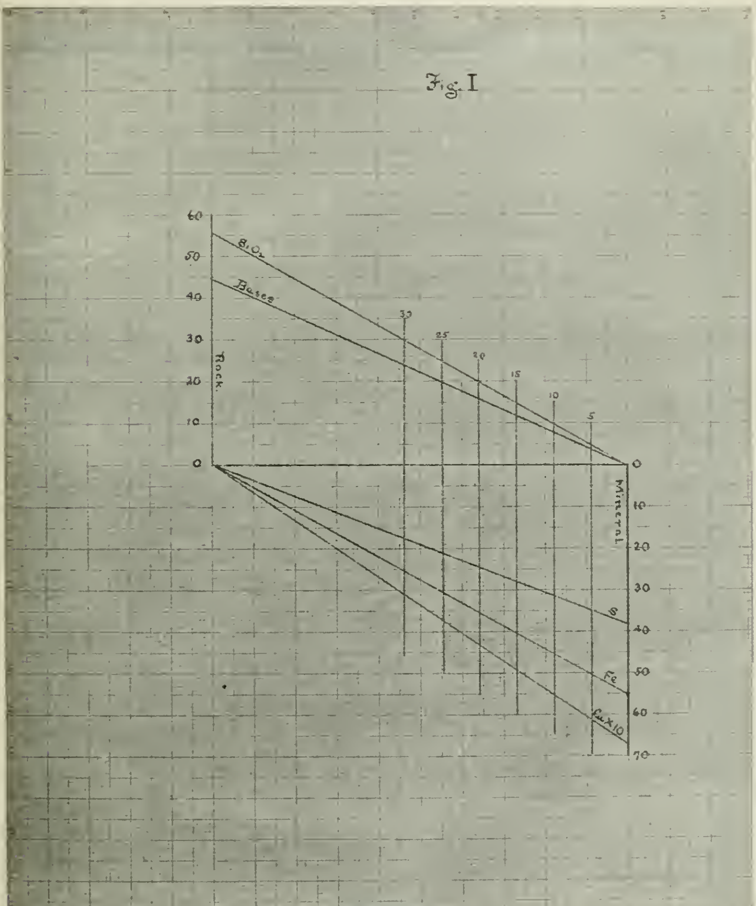


Fig. I
60
50
40
30
20
10
0
SiO_2
Bases
Rock.
30
25
20
15
10
5
0
Mineral
10
20
30
40
50
60
70
S
Fe
Cu x 10

Fig. I.

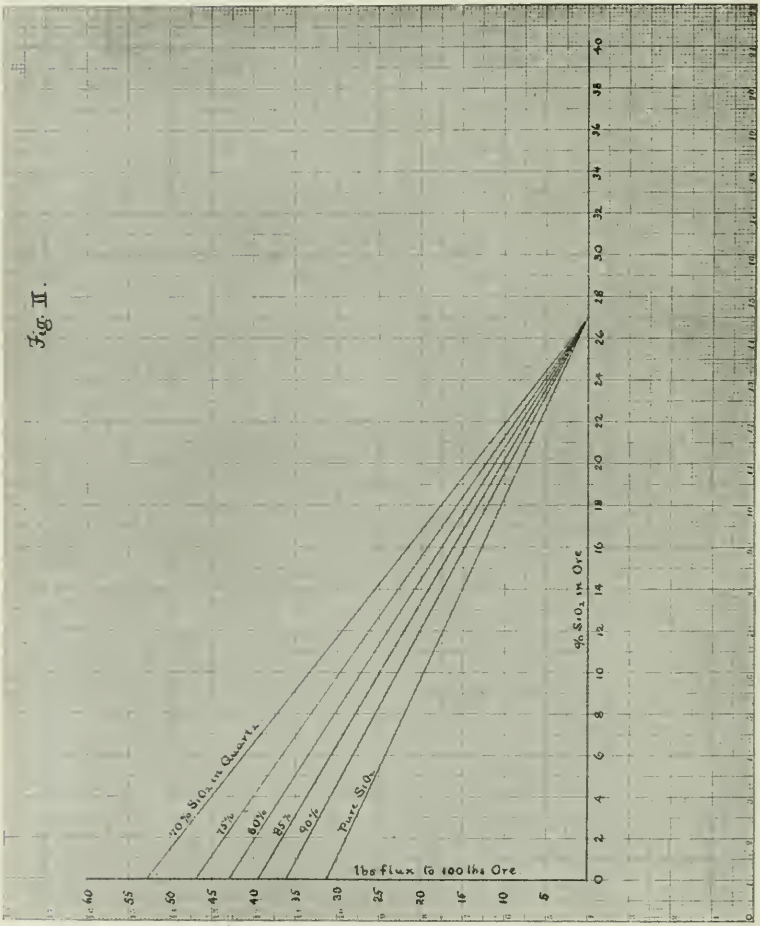


Fig. II.
70% SiO2 in Quartz
75%
80%
85%
90%
Pure SiO2
lbs flux to 100 lbs Ore
% SiO2 in Ore

Fig. II.

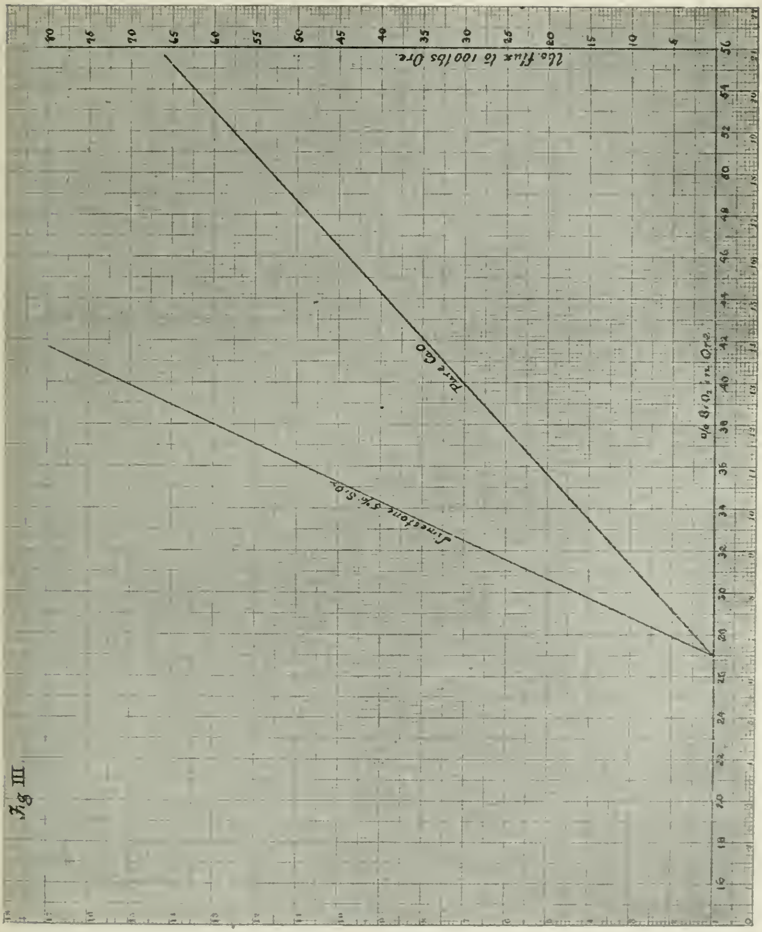


Fig III
Lbs. flux to 100 lbs Ore.
Pure CaO
Limestone 5% S.O.
% SiO2 in Ore

Fig. III.

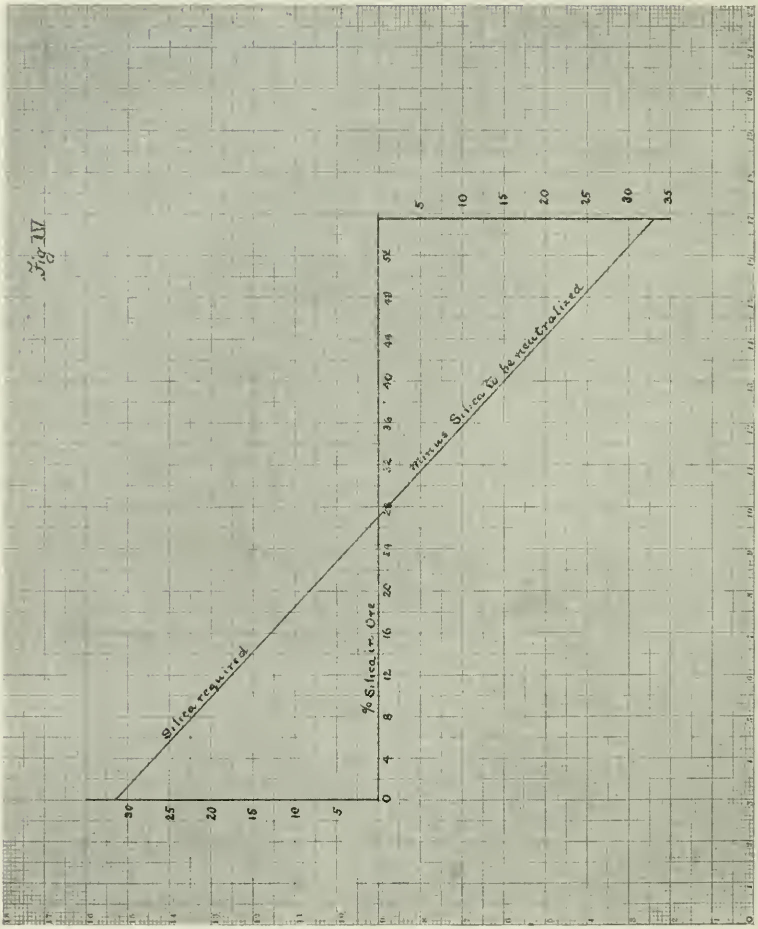


Fig IV
Silica required
% Silica in Ore
Minus Silica to be neutralized
0 4 8 12 16 20 24 28 32 36 40 44 48 52
5 10 15 20 25 30
5 10 15 20 25 30 35

Fig. IV.

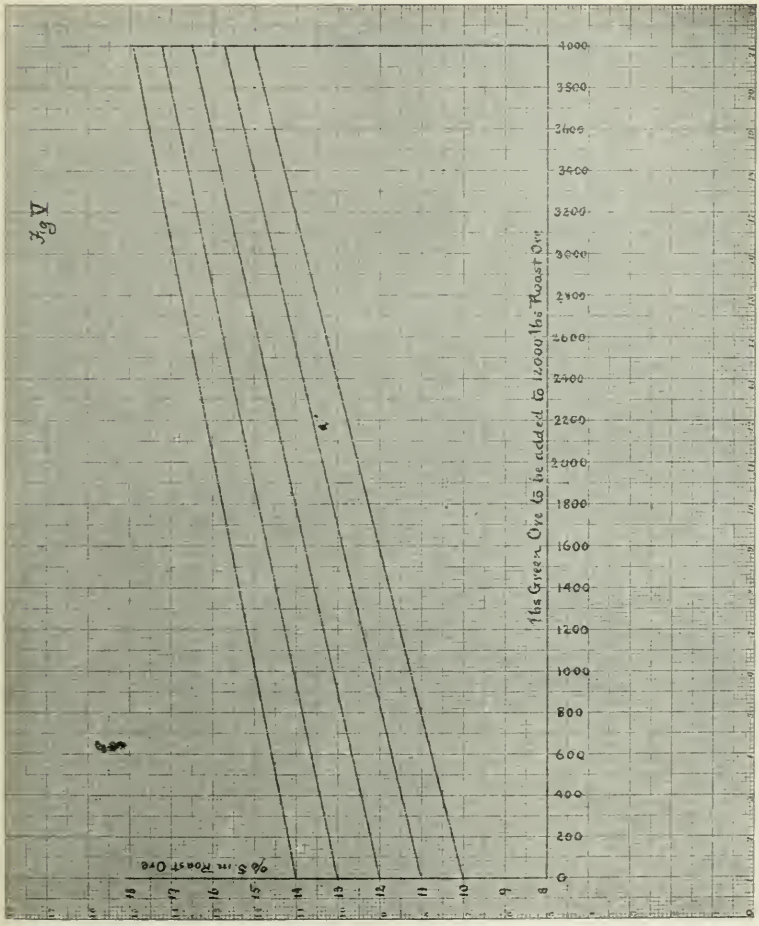


Fig. V.

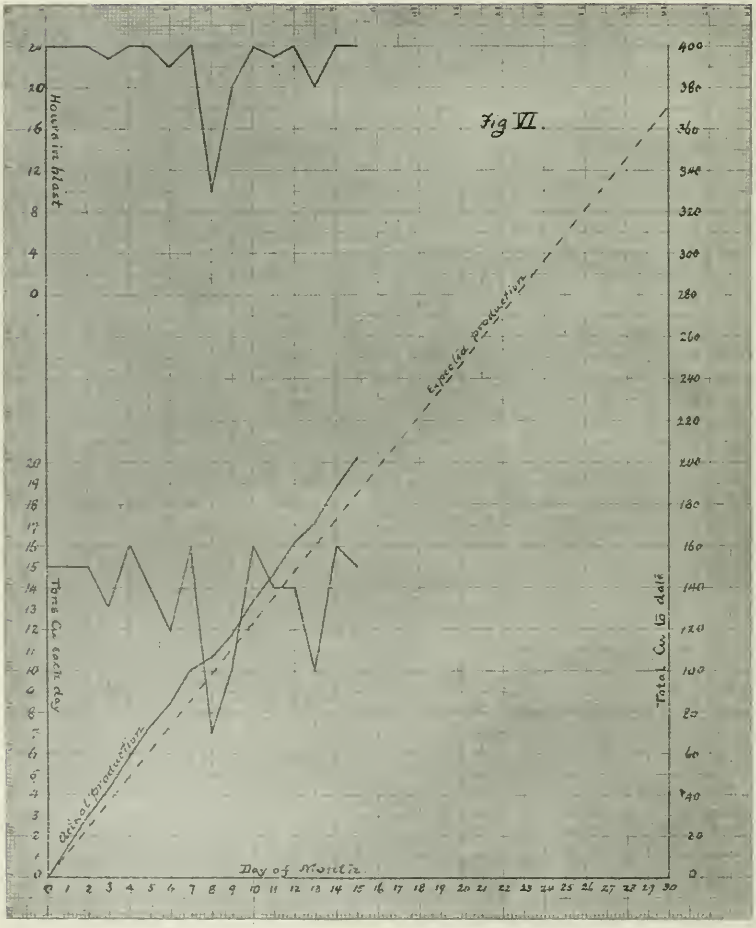


Fig VI.
Hours in blast
Tons Cu each day
Total Cu to date
Expected production
Actual production
Day of Month

Fig. VI.

MAGMATIC WATERS.

By Hiram W. Hixon, Victoria Mines, Ont.

Toronto Meeting, March, 1907.

The origin of the hot waters discharged by hot springs, geysers, and volcanoes has long been a matter of speculation, and continues to furnish matter for discussion. Without any desire to exaggerate the importance of its place in natural phenomena, the writer would say that it stands a close second to the force of gravitation in the importance of effects produced on the geological and geographical structure of the earth.

The nebular origin of the solar system is too well established to be a matter of doubt, and the earth as a part of that system has condensed from a ring of nebulous material surrounding the sun in the same manner as the rings of Saturn will in time condense to satellites of that planet. The force of gravitation which collects the nebulous material into a planet is the primary cause of all order and system in the universe. The crashing together of the falling materials as well as their mutual chemical affinities generated the heat, which has since that period been radiated to all parts of the universe where there was matter at lower temperature to receive it.

It is a mistake to assume that the sun radiates heat equally in all directions, for heat cannot exist apart from matter, and where there is no matter to receive it there can be no heat received. In case the rays encounter stars at as high or higher temperature, the exchange is effected without loss, and a possible gain may be made. Thus the great interchange of energy is taking place, the tendency being towards uniformity of distribution throughout the mass of the universe.

Geologists have estimated the age of the earth at five hundred million years, since water began the deposition of the sedimentary rocks. Astronomers have contended that the heat energy of the sun was insufficient to admit of such a length of time.

The life of the sun, estimated on the basis of the heat received by the earth (and assuming that heat energy is radiated equally in all directions), has been stated by astronomers at from twenty to fifty million years. The error appears to be on the part of the astronomers in assuming the loss of heat to untenanted space. While the heat of the sun is not radiated without the help of the ether as a medium of communication, the vibrations imparted to the ether must encounter matter before heat can be transmitted. The ether having no mass cannot absorb energy.

If heat could be expended on nothing, then $O \times \text{Energy} = O$: according to which equation energy is destroyed, which is contrary to the law of the conservation of energy.

Heat, being a form of energy, can only be expended on matter, and where there is no matter with mass there can be no heat energy given or received. Reducing the estimated rate of waste results in increasing the time that the heat of the sun will last; and, as a consequence, the geologists have proven to be nearer the truth, and the writer will endeavor to show, are probably too low in their estimates.

The presence of steam in fused lava is well known, and has been observed and mentioned by all geologists who have had opportunity to make observations on active volcanoes. Clouds of steam issuing from the molten rock and condensing as vapor above cracks in the fused mass first drew attention to the presence of magmatic waters. The downpour of rain accompanying volcanic explosions is another familiar example of the enormous amount of water blown out and condensed in the atmosphere.

Cold lava shows vesicles which have been occupied by expanded steam, and such lavas, when subjected to distillation, give off several times their own volume of steam at atmospheric pressure. Pumice is but a silicious lava highly charged with steam which has expanded before cooling, and has leavened the fused mass as yeast does bread. Obsidian can be changed to pumice by heating to a white heat in a blacksmith's forge. If the lump is taken out, cooled, and broken, the change from obsidian to pumice can be observed. A core of unaltered obsidian will remain in the centre, and the outer portions, which have been hottest, will be leavened with vesicles, like coke or bread. The proportion of water in obsidian is variable, but in some specimens examined by the writer it was close to 5%.

Tests have been made on other igneous rocks, with the result that it has been shown that they contain water in varying proportions. The presence of water or steam as a part of igneous rocks is so well established that a satisfactory explanation of its presence is sought as a consequence.

It is evident that pressure and capillarity are totally inadequate to explain the presence of water in molten lava. It is therefore evident that the presence of water is due to its having been incorporated with the rocks in the process of condensation from a nebula, and that it has been slowly coming to the surface ever since.

The temperature of the sun is such that all known substances are rendered gaseous, and under such conditions it is evident that steam would mingle with and combine with the other gases, either as steam, or as the gases hydrogen and oxygen. When the earth was at the same stage of its development that the sun is now, the same relative conditions existed, and it is therefore probable that the greater portion of the water which is now on the surface was at that time combined with the central magma as occluded steam. It has heretofore been held that all of the water now in the oceans was at one time in the atmosphere as incandescent steam, and no allowance has been made for the mingling and incorporation of steam with the other gases which condensed to form the central mass. The increase of temperature with depth shows that a depth of less than one hundred miles below the surface all known substances would be volatilized at atmospheric pressure.

The critical temperature of a substance is defined as being the temperature at which that substance will remain a gas, no matter what the pressure may be.

According to Boyle's law, the volume of a gas is inversely as the pressure with which it bears. Therefore, after passing the critical temperature, a gas may be compressed to a greater density than if it were a solid.

This is the basis of the theory advanced by Prof. Arrhenius that the central core of the earth, after passing below the point of critical temperature, is composed of gases enormously compressed by the superincumbent crust. This would explain the difference between the average specific gravity of materials of the crust and the density of the planet as a whole. The average specific gravity of materials at the surface is stated at 2.7, water being 1.0. According to astronomical observations and pendulum experiments. The average density of the earth as a whole is given as 5.5. This difference has been supposed to be due to the existence of a great mass of heavy metals near the centre of the earth which separated out by gravitation. This does not now seem probable, nor, in view of the recent developments in speculative science is it necessary to make such an assumption. The theory of the gaseous interior strengthens the evidence of the presence of water in the interior magma.

The radius of the earth is approximately four thousand miles, and if the magma contains only 0.1 of 1% of water, this amount would be equal to an average of two miles of water over the surface, without taking into account the relative density of water and the earth as a whole. As many of the lavas freshly erupted from volcanoes contain an excess of this amount of water, it seems probable that there is still incorporated in the interior magma more water than is on the surface or absorbed into the earth's crust.

Regarding the discharge of hot springs, geysers, and volcanoes, as additions to surface waters, we are brought to face the condition that the ocean areas are on the increase, and that there is at present more water on the face of the earth than at any period of its history. This being so, points to a time when the relation between land and water areas was different from what it is at present. Apparently the present ratio of three of water to one of land has obtained for a long time. There are certain geological conditions that point to the drying up of large sea areas in which were left great beds of rock salt, indicating that during the time of their formation the climate was exceedingly dry. This would indicate that there was a greater area of land than of water, and that as a consequence there were large desert areas in which salt lakes formed and completely evaporated, leaving the beds of rock salt, which in some cases are known to have a thickness of two thousand feet. During the early period of the earth's development, when there was much less water on the surface, the process of geological changes was much slower than at present; and, as a consequence, the time generally estimated for the deposit of earlier sedimentary rocks is too short.

In the dry climate of Egypt the wear on monuments and tombs has been less in 2000 years than in thirty years of New York climate. This has been proven by the effect on the obelisk which was set up in Central Park.

There are said to be over four thousand hot springs and geysers in Yellowstone Park, which collectively discharge a large amount of hot water. A portion of this is surface waters which penetrate the hot rocks and are thrown out with the magmatic waters. Just how much water is meteoric cannot be determined, but the amount is small compared to that of magmatic origin.

If all of the magmatic waters discharged annually could be determined, and divided into the waters contained in all the oceans, lakes, and rivers, we should arrive at the approximate age of the earth since water began to condense on its surface.

To enumerate the effects produced by the discharge of magmatic waters, we have to consider that anything which passes from the interior of the earth to the exterior reduces the diameter of the support of the solid crust, and this reduction will cause the crust to be broken and folded on itself. This is the condition found in all mountain ranges, and is the cause of continental elevations and depressions. Loss of heat by cooling contributes to the same results, but the main cause is the escape of magmatic waters to the surface. These waters collect in depressions, and carry in with them sediments, until the accumulated load results in depressing the depression and increasing the elevations. The escape of magmatic waters goes on until the erosion cuts down the elevation to the level of the ocean areas. By this time a large amount of steam has collected beneath that portion of the crust covered by new sedimentary rocks, resulting in an elevation of the sea bottom and flooding of the land areas. The new sedimentary series is brought to the surface, folded and fractured, allowing the escape of the magmatic steam. This promotes further folding, and where once was ocean there rises a mountain range.

The value of magmatic waters to man may be estimated if it be considered that all the metal veins, with the exception of the oxidised ores of iron, are collected directly and solely by the deposition of sulphides from ascending hot solutions. The igneous rocks contain a large amount of soda and potash; and these, when dissolved in hot solutions, exert a powerful dissolving action on metallic sulphides, as well as on silica. The mineral-laden solutions, traversing minute openings under enormous pressure, bring the sulphides from great depth towards the surface. Deposition is effected by replacement of soluble rocks, or by filling fractures caused by faulting.

The chemistry of this subject is so complicated that it is difficult to understand, but it seems probable that the metals may be sublimed as chlorides and tellurides and precipitate near the surface as sulphides.

All the gold, silver, copper, lead, zinc, mercury, and other metals of commerce, are won from ores deposited in this way.

Another remarkable effect produced by magmatic waters has puzzled astronomers ever since the first sun spot was observed. So far as the writer is aware, it has not been stated that sun spots are caused by magmatic waters. It probably has been suggested that sun spots are the effect of eruptions on the sun. The idea of tracing an effect to its first cause brings out the fact that as volcanoes exist on the earth and are caused by the discharge of magmatic waters, therefore if there are volcanoes on the sun they must have the same cause. The dark spot is the effect produced on the sun's atmosphere by the expansion of the rapidly rising column of gases discharged from the solar crater. It is well known that compression of a gas raises its temperature and when expanded it is cooled.

Situated as we are, we observe the discharge from solar craters from the top; and, as we never see the sun on account of its enormously expanded incandescent atmosphere, we can only see the effect produced on the atmosphere by the rapidly expanding gases. As the surrounding solar atmosphere is dazzling in brightness, the expanding gases produce an appearance as of a dark spot, because we look down through a great depth of that medium rising directly towards us.

The periodicity of sun spots has been noted and commented on: likewise the periodicity of volcanoes and geysers.

Sun spots show us that the solar volcanoes are active; and while we may be quite certain that we shall never be able to see the craters, we are able to record their eruptions.

Many explanations of the cause of volcanic action have been suggested to satisfy the imagination of generations of observers. These have varied all the way between the struggles of Vulcan to free himself and the effect of radio-activity.

There are fads and fancies expressed in the literature of science as well as in clothing, and any new discovery is eagerly seized upon to explain all difficult problems.

The real cause of volcanic explosions is the escape of steam and other occluded gases from the igneous core of the earth. The reason why this was not sooner recognized is that no satisfactory explanation was suggested to account for the steam and gases being incorporated with molten rock. The millions of years that have elapsed since the crust solidified would seem to have been more than sufficient for a proper adjustment of the materials with relation to each other. The effect of volatilization and intimate mingling of all the elements when in a gaseous condition has resulted in making the separation a much slower matter than the mind of man has been able to conceive. The inter-atomic diffusion of such large volumes of gases, held together by chemical affinities, would require aeons of time for separation. The fact that the crust of the earth is cold and impervious to the passage of gases retards their liberation, and retains the accumulation until it breaks through with explosive violence at the weakest point, as a volcanic explosion. This may be illustrated by the effect produced when a bottle of warm gasified mineral water or champagne is uncorked. The relief of pressure causes the sudden liberation of gas which blows out a portion of the liquid, and the gas will continue to escape with diminishing force until exhausted or restrained by re-corking the bottle. After a volcanic explosion the crater closes by lateral pressure or solidification of the lava plug, and the gases are bottled up until they accumulate sufficient force to break out again.

The lava may be brought from considerable depth, or it may be fused from the rocks near the surface by the heat of the escaping steam and gases, which act as a carrier for the heat from regions where the temperature is much higher than the rocks which are fused by it. In case the lava comes from great depth it will be more basic, and consequently more fluid, than if composed of fused surface material. This is evident for the reason that the rocks near the surface have been deprived of their basic salts, such as iron, lime, soda, potash, etc., by leaching of surface waters.

In case the crater traverses a fracture in quartzite, slate or schists, the lava may be highly silicious, due to the fusing of these rocks by the passage of the incandescent gases through them.

The presence of water in fused material has been shown to reduce the melting point to less than half that of dry fusion.

It is not to be supposed that the steam and other gases form into large bodies until near the surface. The accumulation is due to the gathering together of myriads of small bubbles, slowly ascending from the central gaseous complex magma. This magma is, according to Arrhenius, a gaseous complex above the critical temperature of the gases composing it, and so highly compressed that it has the rigidity and density of steel.

It is a great shock to the average mind to try to conceive of the rocks of the so-called everlasting hills as having been volatilized like steam, and it is to be expected that any theory involving that condition of matter should meet with opposition. Nevertheless we have only to look at the sun to see the conditions that at one time prevailed on the earth.

The earthquakes which accompany volcanic explosions are due in part to the sudden condensation of large bodies of steam when encountering rocks colder than necessary to produce condensation at the prevailing pressure. After the path of the steam has become hot enough, the eruption may continue without these earthquakes. The shock is due to the rushing together of bodies of water under enormous pressure and temperature when condensation takes place, producing a shock similar to the "water hammer" often heard in steam-pipes.

The other type of earthquake, not accompanied by volcanic explosions, may be partly due to this same cause; but it is generally believed that they are due to the readjustment of strains on the earth's crust, due to contraction. The contraction of the central magma causes the folding and faulting of the crust. The contraction of the magma is principally due to the escape of magmatic waters to the surface; and therefore, directly or indirectly, the escape of magmatic waters is the cause of earthquakes of both types.

DISCUSSION.

DR. COLEMAN—I have always been very much interested in these subjects, and from some points of view Mr. Hixon and myself agree very well; from others we do not. I do not suppose it is advisable to take up a purely geological discussion before a mining society such as this, but I should like to refer to two or three points that have a bearing on the subject. Mr. Hixon assumes, as do also some geologists and men interested in metallurgy, that the earth was once molten, in fact, that it was gaseous, and that it has been cooling down. But there is good reason to think that this theory has been altogether carried to an extreme. We can account for the world as having been cold in the beginning, not as having been a heated gas. I think the modern view entertained by most geologists is that the earth may have started as a cold body and may be warming up, instead of starting as an intensely hot body that has ever since been cooling down. I do not think that the question has been entirely settled, however. There is a point on which I heartily agree with Mr. Hixon; that is, that a large part of the water of the globe has come from the interior of the earth—a factor that has much to do with the shrinkage of the earth and with mountain folding. I am very sorry that two of the most distinguished American geologists, Professors Van Hise and Chamberlin, who might have taken up the discussion as to the cooling of the earth, although they are in this building at the present time, are not with us at this meeting. We have, however, another gentleman with us who has dealt with problems of this sort, and is equally distinguished—Prof. Kemp—who may give us his views on the subject. Meanwhile, when Mr. Hixon suggests that all ores—with the exception of certain iron ores—are to be accounted for by hydrothermal waters, I must entirely disagree with him. My own work in the Sudbury region has made it absolutely clear to my mind that the Sudbury ores—with which Mr. Hixon is very familiar from his own study as one of our very best metallurgists—have a quite different origin from the one he suggests. I think it has been proved without any chance of doubt that the ores of the Sudbury region came up with a great sheet of nickel-bearing rock; and I am quite willing that any geologist shall take the map which was prepared after three summers hard work in that region a few years ago, and go around the edge of that sheet to find out whether the ores are connected with the eruptive or not. Of course, secondary changes have taken place since in many of the ore bodies, and it is easy for one to mistake those secondary changes for primary causes of the ore deposits. However, in regard to the great marginal ore deposits, I think there is no doubt they are segregations from the eruptive mass itself. It would take too long to go into the matter, but I thought it was only fair to show that there is another side as well as the one Mr. Hixon has presented. (Applause.)

PROF. MILLER (Acting Chairman)—We are honored to-day in having with us one of the most distinguished authorities on ore deposits in America, and also a gentleman who is usually, I believe, classed as an "igneous man." I would like to ask Prof. Kemp to say a few words.

PROF. KEMP—It really is a very great pleasure to add a word to the discussion upon the topic which Mr. Hixon has set before us. I cannot help running back in my mind about 25 years to the time when I myself was a student in the Columbia School of Mines and listened to the lectures of my honored predecessor, Prof. Newberry. If anything aroused him to indignation it was the suggestion that igneous rock had anything to do with ore deposits, and he used to walk up and down behind his desk and was eloquent over the occasional statements which geologists were at that time rash enough to make, as to the importance of this connection. But as we have come to know the country better, and have been without any disposition to be dogmatic or reach wrong conclusions, or push our views to extremes, we have not been able to get away from the extraordinary connection that our veins in mining districts, and especially in the Rocky Mountain region, have with eruptive phenomena. The following point may not have occurred to all the members of the Society. If you wil run over in your minds the number of ore bodies that have been produced in the West since the Rocky Mountain upheaval at the close of the Cretaceous, and compare them with the very few—leaving out iron and manganese, which we all realise can be produced from the ordinary surface circulation, which are older than Cretaceous time—you will find that the former group vastly outnumbers the latter. If veins are generally produced from the ordinary surface waters it seems extraordinary that so few were developed in the early Mesozoic, Paleozoic and Pre-Cambrian times. We, therefore, really are forced to appreciate that there must be a very strong factor in ore deposition in the emanations from igneous rocks. When we add to this consideration the very significant features of contact metamorphism, and of ores which are now seen in increasing numbers in its zones, we have another very important argument. If we realise, too, that mining experience limits the depth of the ordinary ground water to a comparatively shallow amount near the surface, we cannot help being again somewhat strengthened in our disposition to put our faith in the magmatic waters as very strong and efficient agents in ore production. For these reasons and others that perhaps on reflection we might adduce in respect of the general thesis, we cannot help feeling that they are in themselves very well adapted to bring about the results, and that very likely they were extremely important factors in vein production in a great many regions. Nevertheless, we must also not overlook the fact that there are some mining regions in which we cannot discover igneous phenomena in any visible manifestations to-day. There are the lead, the zinc deposits in Wisconsin, Iowa and Illinois. There are the lead deposits of southeast Missouri and the zinc and lead of southwest Missouri. No igneous phenomena are known in their vicinity, and they seem to be limited to comparatively restricted strata of limestone in each case. We are not yet assured that they go to very great depths. While I must say that it rather staggers me, having seen the great stopes of lead ore that are to be found in southeast Missouri, to understand how downward passing surface waters could have brought in such insoluble minerals and have enriched the limestone to the extent that they must have, yet I see no tangible evidence for assuming eruptive rocks nor reason to connect the ores with magmatic waters. We may only vaguely suggest that we do sometimes find dykes of eruptive rocks in places where we would least anticipate their presence. One such striking occurrence I mentioned at the Ottawa meeting of the Geological Society last year. There is a dyke in south-west Pennsylvania in the almost undisturbed coal regions, and certainly 200 miles from any other known manifestation of eruptive rock. This and similar occurrences make us a little cautious about positively stating that there may not be such phenomena under surfaces where we cannot see them, but it does seem to me that in the lead and zinc districts of the Mississippi valley we have no observations justifying the belief that they are present. (Applause.)

MR. HIXON—I would like to ask Prof. Coleman or Prof. Kemp a question that I have asked several times without receiving a satisfactory answer, or even an attempt at an answer yet, in relation to magmatic segregation, and it is this: If we assume a fluid magma with fluid sulphides in this magma, then we have to all intents and purposes two fluids associated together, and after the separation of those fluids, by segregation or any other plan, what will happen? The heavier one will inevitably go to the bottom, and the line of demarkation of separation between the two fluids will be a flat surface. Now, if they assume that this Sudbury nickel ore deposit is such a separation like matte from slag, they should have a sharp line of separation between the two, and the line of separation should be a flat surface. I wish to say that no such ore body has ever been discovered, and it is the best evidence to my mind that they were not formed in any such manner.

PROF. COLEMAN—Mr. Hixon is too good a furnace man not to know that you may have your slags in various degrees of fluidity. There is a possibility of having a slag so pasty that shots of silver will be left in it. He explained that to us this morning quite correctly. You may have a slag, or magmatic fluid so pasty in its character that there will be only a very partial separation of the heavier sulphides from the lighter rock materials. Now, in the case of a great many eruptive rocks, we know that the method of fusion is not purely igneous. As Mr. Hixon has just explained, there is a large amount of water present in the rocks. That is undoubted. Now, an igneo-acqueous fusion will take place at a very much lower temperature than a purely igneous fusion in which there is no water present, giving a pasty mass. In many of the eruptive rocks the mass has been only pasty, not fluid, and it seems to me that was the case in the Sudbury region. The sulphide material went to the bottom as far as it could, but the separation could not be complete because the cooling had gone on so far that a large part was still retained.

MR. HIXON—You will excuse me if I state that the ore bodies are not on the bottom of the magma. They are on the side. They are standing against the greenstone and between the greenstone and the quartzite, in spite of what the Geological Survey has said. Our mine is situated between the quartzite and the greenstone. Quartzite is the hanging wall, and the green stone the foot wall. Now, in that position it is not on the bottom of the greenstone, it is on the side of the greenstone, and standing almost vertical. It is an impossible position for any such separation by gravity. Two ore bodies standing there practically parallel, about two hundred feet apart, each one of them from 35 to 100 feet in diameter not of any particular section, on any level, and they are in an impossible position for any such separation, and they have not a flat side to them.

DR. BELL—I would remind you that the depositions of nickel in the Sudbury region are not to-day as they were originally deposited. They flood out in the horizontal surface or with irregularities, and the heavy metal, more of the sulphides, sink to the bottom, and since then the whole deposit has been turned up on edge, and some of it over-turned. You can have a sulphate on one side, and a green stone on the other side. I am very glad to hear Prof. Coleman say that after three years' investigation lately he has proved that these depositions are formed as he has explained, because 20 years ago, when I first went to that district and looked at them, I pronounced as my opinion the very same view, and two or three years before that I set it forth at sonsiderable length in detail in a paper I read before the Geological Society of America, and I am very glad to find that after all that controversy, and the criticism to which my view has been subjected, that I proved to be quite right.

PROF. COLEMAN—There are ways of accounting for all the points that have been referred to, and if any one will take the trouble of reading the report on the nickel region prepared two years ago he will find that nearly all those points have been anticipated and touched. The shape of the mass of rock, and of the ore, is entirely different now from what it was in the beginning. Of course, points like that must come in, and it is really a very complex problem. But why all the ore bodies should be on the lower side of that one sheet of eruptive rock is absolutely incomprehensible unless they were produced by the aid of the eruptive rock, and came up with the eruptive rock.

MR. HIXON—Allow me to state what I have actually found to be the case up there. Between the station at Victoria mine and the mine, a distance of about 2 miles, according to the geological map, there is one continuous sheet of greenstone. That is all very pretty, but as an actual fact there are a series of bands there, 16 in number, between the station and Victoria mine, and in between those bands there are sheets of sedimentary rock. Now, everything points to this conclusion—that the surface has been folded into a series of folds following each other like waves in a piece of corrugated iron: that the tops of those anticlinals were glaciated off and the greenstone has been exposed as the core bands of those anticlinal folds Those bands of greenstone run across the country roughly in the east and west direction like the stripes of a United States flag, and in no other way can you account for their existence. They are parallel to each other, with sedimentary rocks in between.

PROF. COLEMAN—I know there is no chance of my convincing Mr. Hixon or of Mr. Hixon convincing me—(Laughter)—but I think it only fair to say that the map that Mr. Hixon depends on was made by Dr. Barlow at a time when this relationship of the great sheet of eruptive to the ores was not known. Mr. Hixon is quite correct in stating there has been sharp folding and anticlinal ridges and so on, but they have nothing to do with the nickel eruptive They were formed first and the nickel eruptive came up afterwards resting upon them and now and then making its way down through fissures in the underlying rock. His own particular mine and other mines are projections from the edge of the great nickel-bearing rock.

MR HAULTAIN—I am a stranger here, but I have read this paper with considerable interest and would advise others to read it. The author has told the Dominion Geological Survey and the Ontario Mining Department that they are all very small fry. Mr. Hixon has not only told all the astronomers that they are wrong, but he has told all our eminent physicists that they are wrong. No doubt the paper will be published, and a further opportunity will be afforded to discuss it. To those who are antagonized by Mr. Hixon, I can only say he has come out in the open, his guard is down, and they can go after him. (Laughter.)

PROF. KEMP—Might I add a word about one or two things that possibly some of us have seen in eruptive rock, that have not been folded, so as to bring the bottom up to the side. Very often we may observe trap dykes that have cut through sediments and that show no evidence of having been disturbed, and yet on the edges we do find that the rock is very dark and basic. The edges may run 5% or more in iron and magnesia and other bases than the middle. We find our felspar in the middle and our basic minerals at the sides. The heavy ones we would think ought to have sunk because of their high specific gravity, and yet through some effect of the chill at the outer edge there has been a concentration of the heavy minerals or of their uncuptallized components at the border of the eruptive rock. I do not know that I have any physical law to suggest in explanation further than the one that the dissolved minerals which first cuptallize do tend to migrate in relative richness towards the cooled portion. Mr. David Browne, chemist of The Canadian Company, twelve years ago prepared a very interesting paper on the variations of the nickel and copper mattes at Sudbury. The copper goes to the outer parts of a pot in cooling while the nickel become enriched at the centre. Yet the time for the separation in so viscous a mass is very short. We know, too, that if we take a pig of base bullion and sample it for silver we can get different analyses according to the place we bore. While these would not be the same compounds as the natural metallic sulphides, and the silicates, yet the processes do correspond to one another in appreciable degree, and they do suggest to us perhaps some of those solution and crystallization effects that we try to follow out in the eruptive magmas. I think we should not consider them as quite such entirely separated solutions as Mr. Hixon has implied, but that they are dissolved one with another and mixed together in such a complex way that they can only be affected by some such physical influence as chilling, connection currents or something of that sort.

MR. HIXON—That would apply to fused metals where they are through nearly all the same specific gravity. But where one fluid is almost twice as heavy as the other, the only possible separation is by the lighter one being at the top, and the heavier one at the bottom. That would have been inevitably the arrangement if no such an over-flow containing in sulphides had occurred, and they had separated in that way. Then, after that, in order to get the ore bodies in their present position, the whole series would have to be folded double and cut off so as to expose them on their edge. Well, they still should have had that flat side. (Laughter.) You can fold a coal vein vertically, and it has still got a flat top and bottom. I have seen coal veins at the base of a mountain range standing on edge, and there was not any change except here and there they were faulted.

MR. H. E. T. HAULTAIN (*communication to the Secretary*)—Mr. Hixon in his many disputations in the technical press has aroused the ire of several of our most eminent scientific men. He has upheld his own theories and flayed those of his opponents almost recklessly. But he is a free lance; in his own position he is well entrenched as a miner and a metallurgist; as a geologist he is a marauder. Those whom he has attacked are men holding public positions, holding them by virtue of their eminence as geologists and I should judge that the necessary dignity of their public office had prevented their entering the arena with Mr. Hixon in the style of combat that his attacks demand. These men, however, are neither chiefs nor vassals of mine that I should bear arms on their account, but in this paper Mr. Hixon has left the haze of conjectural geology for a moment and has ventured into the clearer atmosphere of physics where anybody can see him and answer his attack. If his theories in the former are no stronger than in the latter, those geologists whom he has attacked have full justification for their restraint in dealing with him.

In the first part of his paper he settles in a few lines and in the simplest possible manner the long standing and mighty controversy between the geologists and the physicists; and he as recklessly slays the world's astronomers as he would our own geologists. He says:—"The error appears to be on the part of the astronomer in assuming the loss of heat to untenanted space," and by a delightfully simple, and equally absurd, equation he would prove to us that the sun radiates energy only in those directions where ponderable matter lies ready to receive it, and from this deduces the startling conclusions that the rate of dissipation of energy by the sun is only one-tenth of what we hitherto believed, and that the astronomers may now safely tell us that the sun has lasted ten times as long as they previously calculated. To follow Mr. Hixon's hypothesis we must assume either that the sun's rays will return with their full quota of energy when they have found that they have missed their mark, or else they must refrain from starting in a direction which will lead them into unending clear space. In the latter case they would have to take into their calculations, before they started, all the phenomena of reflection and refraction, in addition to the movements of the objects aimed at. But the small boy playing with a mirror would completely upset this explanation of the equation and leave us to accept the theory that the sun's disappointed rays returned of their own accord and with their full energy.

I am neither a physicist nor a geologist, and I cannot at the present moment set down clear reasons why these rays should not return, but the suggestion seems to me hopelessly absurd. It is possibly without proof one way or the other, for in this we get into regions of infinity where arguments and theories fail; if we like we may believe that the ends of a straight line produced indefinitely will meet in infinity. I would, however, draw Mr. Hixon's attention to the fact that some of the celestial bodies are quite some considerable distance from the sun; the limits of inter-stellar space have not yet been defined, and the sun might well grow cold before the would-be-returning rays had discovered their mistake and found that they had really passed the last lone star. Light travels slowly when we compare infinite distances with our own ideas of time.

When he returns to the centre of the earth as the field of his imagination the results may be as wide of the mark as when he travelled in outer space, but they have a surrounding haze, a haze which protects a marauder, but baffles the regular forces. Much of that which he tells us in regard to Magmatic Waters, I am most willing to accept. Nobody will gainsay that Magmatic Waters have played a very large part in ore deposition. But there are many conditions that he describes or interprets, which, despite the haze, seem clear enough to warrant attack. For example, he would have us believe that this old world is keeping fully up to date and is pneumatic-tired, if not entirely, at least in part, for the seas are resting on gigantic bubbles of steam, bubbles sufficiently large to "result in an elevation of the sea bottom and flooding of the land areas." Further on in his paper he tells us that these bodies of steam and other gases are due to "The gathering together of myriads of small bubbles slowly ascending from the central gaseous complex magma." In the very next sentence he tells us that this magma "has a rigidity and density of steel." It may be the haze that prevents it, but I certainly fail to imagine small bubbles slowly ascending in solid steel. But enough! I only wish to emphasize the fact that Mr. Hixon, the Metallurgist, and Mr. Hixon, the Marauding Geologist, must be totally different men.

MR. H. W. HIXON—In answering Mr. Haultain's criticism of my papers read before this Institute, I shall disregard his generalities and his allusions to "chiefs and vassals," etc., and merely consider such argument as he presents. He finds fault with the contention which we designated as absurd that O x energy=Zero. I would say to Mr. Haultain that the primary arithmetics all agree that O x anything=O and unless he can prove to the contrary I shall continue to believe energy is only expressible in terms of mass, times, velocity or temperature.

The idea which I wished to convey was that the sun radiates energy potentially in all directions and that it is absorbed or dissipated *only* when it encounters matter. According to the mechanical theory of heat it is the result of the vibration of the molecules of matter. Therefore if there are no molecules to vibrate there can be no heat and as a consequence the temperature of untenanted space must be constantly absolute O.

To make the matter appear in another way, I will use as an illustration an alternating light circuit actuated by an alternating generator belted to an automatic steam engine. Transformers are located along the line and when the lights are turned off, the generator simply maintains the voltage on the line. The engine is only developing such power as necessary to overcome friction. Under such conditions it is impossible for any size of engine to develop more power. Now turn on all the lights or throw on the load to the motors and observe the effect.

The transformers take current from the mains, and these in turn call on the generator, and it on the belt, and it finally gets back through the engine to the boiler and the fire-box to the fuel which is the ultimate source of earthly energy. Fuel means wood or coal and this means vegetation and that means sun energy.

The point to be made is that the energy delivered by the generator to the lights cannot be expended or dissipated or made apparent until the lights are turned on. In other words energy cannot be expended on nothing; if it could, then I repeat O x energy=O and this would mean that energy may be destroyed, which is contrary to the law of conservation of energy.

This law may, according to Mr. Haultain, be another delightful absurdity, but I will rest my argument on it in the hope that he and his "vassals and chiefs" may admit its truth without contesting the point further. Mr. Haultain seems to think that the sun's rays are made of some substance like a fifty pound shot or a bar of soap. If such were the case, straw hats and sun shades should be made of bomb-proof, and a sun bath would be as fatal as any form of sudden death.

The heat produced in the atmosphere depends upon the density of the atmosphere as can easily be demonstrated by taking the temperature at sea level and on the top of high mountains or by means of balloons or kites. This shows that if it were possible to take the temperature of space we would find it to be absolute zero. There being no molecules to vibrate how can heat be developed or absorbed from the sun?

Mr. Haultain makes use of the word marauder as freely as if he knew what it meant. I have not stolen anything or killed anybody unless putting a few ideas into their heads has been fatal to his "chiefs and vassals." If he had said I was an iconoclast he would have probably expressed his meaning and in the sense in which he would apply the term it would not be uncomplimentary to myself.

Regarding the elevation of the sea bottom as a result of the rising of magmatic steam, I can refer Mr. Haultain to several cases in the Mediterranean and among the Aluetion islands where islands have appeared above the sea for a time, and after discharging enormous amounts of steam and volcanic mud, have again sunk below the sea.

What I have said on the elevation of continental areas and their subsequent depression is merely the application on a large scale of knowledge from ascertainable data. Regarding the gathering together of myriads of bubbles in a medium as dense as steel, I wish to call Mr. Haultain's attention to the fact that I have Van Hise, Chamberlain, Arrhenius, and other authority for the statement, that after passing the critical temperature, steam itself is capable of being compressed to a density greater than steel. Under these conditions it could probably overcome any objections that Mr. Haultain could offer.

THE STATUS OF THE MINING PROFESSION.

By J. C. Gwillim, Kingston, Ont.

(Toronto Meeting, 1907).

At a recent meeting of the American Mining Congress, October 16th to 19th, 1906, Governor Pardee, of California, introduced the draft of a bill intended to make the dishonest promoter fear the law. The bill is as follows:

"An Act to prohibit the making or publishing of false or exaggerated statements or publications of or concerning the affairs, pecuniary condition, or property of any corporation, joint stock association, co-partnership, or individual, which said statements or publications are intended to give, or shall have a tendency to give, a less or greater apparent value to the shares, bonds, or property, or any part thereof, of said corporation, joint stock association, co-partnership, or individual, than the said shares, bonds, or property shall really and in fact possess, and providing a penalty therefor.

"Section I. (Enacting Clause).—Any person who knowingly makes or publishes in any way whatever, or permits to be so made or published, any book, prospectus, notice, report, statement, exhibit, or other publication of or concerning the affairs, financial condition, or property of any corporation, joint stock association, co-partnership, or individual which said book, prospectus, notice, report, statement, exhibit, or other publication shall contain any statement which is false or wilfully exaggerated, or which is intended to give, a less or greater apparent value to the shares, bonds, or property of said corporation, joint stock association, co-partnership, or individual, or any part of said shares, bonds, or property, than said shares, bonds, or property, or any part thereof, shall really and in fact possess, shall be deemed guilty of a felony, and upon conviction thereof shall be imprisoned for not more than 10 years, or fined not more than $10,000, or shall suffer both said fine and imprisonment."

The Congress unanimously adopted the bill, and the following resolution:

"That the officers of the American Mining Congress respectfully suggest to Governors of States and Territories that when in any State which has adopted the law, known as the Pardee resolution, charges of its violation are made, the Governor of the State in which alleged mining properties are claimed to exist, at his discretion may, upon request, authorize the Commissioner of Mines, or other appropriate officials, to examine such alleged mining properties sufficiently to determine and report on their approximate reality, and the State may charge a reasonable fee, to cover the cost of such examination and report, this fee to be paid by the parties requesting such examination."

The following resolution was also adopted:

"That a committee of five members be appointed by the President of this Congress, for the purpose of devising and demonstrating methods for preventing fraudulent mining schemes, and report the same to the Secretary of this Congress eight weeks before the meeting of its next session, who shall mail such report to each member of this Congress at least three weeks before its next session."

There has been some comment upon Mr. Pardee's resolution: some affirming that so long as a constituency of dupes and gamblers is to be found, so will the "get rich quick" scheme prosper. Others again point out that mining engineers would have little time to devote to other work, were they required to investigate all the numerous cases of misrepresentation and fraud in connection with mining promotions.

It is argued, moreover, that we now have a law covering the obtaining of money under false pretences, by which men may be found guilty of misdemeanor or felony, according to the magnitude of the offence.

The fact, however, stands, that misleading literature and often absolutely untruthful statements are circulated to a lamentable degree by company promoters, without challenge. Yet the effects thereof are ruinous to legitimate mining.

To the Journal of the Federated Canadian Mining Institute for the year 1897, the late Mr. J. Bawden, Barrister of Kingston, contributed a paper on the subject of "The Economics of Joint Stock Companies," written at the time of the late British Columbia mining speculation.

At the present time, in Ontario, and in many other mining districts of this continent, conditions are not dissimilar to those obtaining in 1897. It may not, therefore, be out of place to call attention to some passages in Mr. Bawden's paper, relating to the promotion of the gambling element in mining. He says, "Let the buyer beware." "The Law interferes only to protect men's stomachs from adulterated food, not by any preventive process to protect from pickpockets in the guise of vendors of valueless shares. The question, whether in the interests of the public, it is advisable to interfere with the right to sell valueless shares lest individual liberty and the inalienable rights of British subjects be imprudently invaded, is a question of expediency which those who have at heart the development of mining enterprise, may discuss without a tilt with brokers or jurists. The sale of worthless shares injuriously affects the sale of valuable shares. It goes without saying that capital seeking investment in mining shares is a limited quantity; that it is coaxed out of hoards, at the cost of much wind in the form of reports, advertisements, puffs, editorials; and that the characters of many people are staked upon representations, sometimes made in good faith but too often discredited by adverse results. The argument therefore against the legality of worthless shares is founded on the economic ground, that the business should be prohibited by legislation because it will work irreparable injury to honest enterprise."

It is often affirmed that mining is, in any case, a gamble; this is not true. There are many mining enterprises carried on in such a way that the gambling element is almost eliminated; but these bona-fide enterprises cannot operate in a field where properties have been given a fictitious value, due to stock promotion and manipulation. It is said *Chance* is so large a factor in mining that, from the point of view of the investor, this industry suffers in comparison with other industrial enterprise. But, the writer ventures to assert, if roguery, misrepresentation, and lack of skill were eliminated from mining, to the same degree as they are in the operation of railroads, manufactures, and other industrial undertakings, we might deal successfully with the element of chance, and reduce speculation to investment. Mr. Bawden further remarks: "Industrial stocks cannot be put on the English market without estimates carefully prepared by chartered accountants. The plan of organization of such companies leaves nothing to be desired in the way of reasonable safeguards for the protection of shareholders." And again, "The mining share certificate neither binds nor obliges any. In fact there is not a more innocent, vague, unrepresentative, and yet plausible piece of paper in the world than a mining share certificate. It may stand for a share in a mine which has no existence; for a part of the capital of a scheme which never had, and never will have a dollar in its treasury; or it may represent the title to a share in a 'bonanza,' honestly administered, paying the largest profits ever realized, and be good documentary evidence of the ownership of value many multiples of the money share stated on its face."

Such a condition is accepted by many of us as inevitable. If then, mining is so much at the mercy of chance and unscrupulous people, what is the object of educating men to become technical engineers, unless it be to infuse into the industry a higher level of honesty and attainment, which shall do as much for the mining profession as Scientific Medicine has done for sickness, to eliminate "The Act of God" and "Ignorance"? Surely the jeopardy of life is as great as that of mines. Yet Medical Science has gathered honor and a considerable control of its specialty. Mr. W. R. White, in the discussion following Mr. Bawden's paper, said: "I do not agree with Mr. Bawden's position, when he speaks in regard to the institutions that are turning out young men; I do not think these young men when turned out are competent to do much more than push a barrow in a mine. They may get technical knowledge, but they require the practical experience before they become mining experts or engineers; they are no better than beginners in any other profession in this respect."

A period of probation is certainly necessary to acquire experience and knowledge in all professions. It would be a benefit to mining engineering, if all who are training could work for a time as "understudies." A great majority now do this, but there seems to be no good reason why a mining graduate should pass through the mucking, wheelbarrow stage while graduates in civil engineering, law, or medicine pass directly into professional work. Surely these are equally wanting in practical experience. Moreover, the graduate of our mining schools is nowadays as well equipped as men graduating into other professions to do efficient service. Give him his place and honor, and he will work as honestly and as well, as any other young professional man. The every day accusation against mining is its *Chance* and *Misrepresentation.* Surely the technical graduate has not spent four years in learning how to increase these factors. Mismanagement is not often in his power, and if it is, he has as much at stake as the practical man. Concerning this, Mr. Bawden says, "As a general rule the so-called mining expert, is, in cases of misrepresentation, the chief wrong doer. The evil will, it is hoped, diminish w th the increase in numbers and respectability of mining engineers. The director is often the dupe of the expert and prospector as the means of luring ignorant shareholders. The engineering profession owe it to themselves and to the best interests of the country that they shall have a registered membership.

"We shall have ere long a registered body of mining engineers zealous for the reputation and honor of a learned and noble profession, from whose lists will be struck off any guilty of unprofessional conduct." The codes of professional ethics in Civil Engineering, Law and Medicine demand the protection of the public in their own interests. In mining, the investor cannot invest because of the speculative and fictitious values of mining property. While on the other hand, the graduate, or otherwise trained and honest engineer is forced to compete professionally with a host of so-called and self-styled "mining men" who are ready enough to become the tools of the promotor. But the question remains, how to remedy this state of affairs. The channel chiefly used by the promoter to reach the public is the newspaper advertisement. It is well known that it is no difficult matter to secure all the capital necessary to exploit a really meritorious mining property without resource to advertising; and consequently, the majority of schemes to which the public are invited, by the advertising method, to subscribe, may be regarded with suspicion. The press, meanwhile, disclaims responsibility; the statements, as published, are frequently not even vouched for by a reputable person, much less by a technically qualified man; yet the public speculates, and the mining profession loses both credit and occupation.

Among the purposes for which the Canadian Mining Institute was founded are these: "to take concerted action upon such matters as affect the mining and metallurgical industries of the Dominion of Canada;" and "to encourage and promote these industries by all lawful and honourable means."

Dr. J. Bonsall Porter, discussing Mr. Bawden's paper as above mentioned, remarked: "We engineers cannot of course undertake the herculean task of putting down or even denouncing all of these frauds, but I do think that many of us, and perhaps the Society as a unit, falls short of its real duty."

The writer would suggest that the Canadian Mining Institute, which is in part supported by annual grant from the Federal Government, undertake to deal with at least this abuse; namely, the publication of prospectuses of an irresponsible character, the statements in which are not vouched for by some person of recognized standing.

If such advertisements disappear entirely under these restrictions, the loss will fall only on newspaper publishers and on those who prey upon or mine the public. Meanwhile other professions are protected by legislation whereby they are raised above the level of the unscrupulous and incompetent. The Manitoba and Quebec Acts of the Canadian Society of Civil Engineers are for the purpose of the protection of both public and profession. So are the B. C. Assayers Act and the Acts which protect the legal and medical fraternities. If any unqualified or irresponsible person were permitted to practice their profession without question, what complications and dangers would ensue. The state interests itself in mining to the extent of taxing, limiting and protecting the prospector and inspecting his claims, but there is yet no effective law to protect the public from the fraudulent promoter, or to provide for the inspection of so-called mines offered to the public. The Press, as an interested party, aids and abets the promoter, whose prospectus is circulated among thousands of readers, who know nothing of mining, mining engineers or conservative mining journals.

To remedy this evil, such advertisements should be published subject to restrictions and in fear of penalties, as suggested by the Mining Congress. There might also be stricter regulation governing the issuance of Letters Patent incorporating companies. Promoters should, furthermore, be made personally responsible and answerable for their published statements. Again an incorporated company before going to the public, should be required to have a paid up capital to a reasonable amount. This would ensure the company having some guarantee of bona-fide intention. This paid-up capital might be either held as a guarantee fund, or used in the companies operations. The company might be made responsible for the statements contained in the prospectus issued, and this fund held available for any loss sustained.

A method which would apparently prove most effective, would be to insist that reports for prospectus purposes be prepared and signed by professional men, who would be brought to book professionally for mistatements or misrepresentation.

Mr. George E. Collins, writing in the *Denver Mining Recorder*, anent the "Pardee Resolution," says:—

"The only people competent to say whether a man is qualified to practise as an engineer are his own fellows. I think the time has come for the American Institute of Mining Engineers to follow the example of its English junior (The Institution of Mining and Metallurgy) and confine its membership to such as have attained a definite standard of qualification and experience. This qualification, in any case, could not mean much, but would be better than nothing.........Later, state legislature could enact that no person should be placed in responsible charge of property employing more than a certain number of men, or should presume to make a written report for money on a mining property unless he were a member of this body."

An editorial leading article in the same journal, October 18th, 1906, contains the following paragraph:—

"Has not the mining industry reached that degree of importance and magnitude, when some States, at least, should take steps to discriminate in regard to who shall practise the science and art of mining." It is sometimes said: surely the qualified man can compete successfully, therefore why should he require the law's protection? But the laws protecting and regulating the professional practice of Civil Engineering, Law and Medecine are not framed with the object of protecting a class, but of guarding the public against incompetence, fraud and misrepresentation.

DISCUSSION.

DR. A. R. LEDOUX—It seems to me that undue stress is often laid on the duty of the mining engineer, and not quite enough upon the duty of his employer—the promoter—or business man at the head of the projected mining enterprise. We all know how frequently it occurs that men come to us with absolutely absurd statements in regard to mines, which statements they have invented or inferred from reports which they did not understand; that they often attribute statements to the engineer which he has never made, and which cannot fairly be deduced from his reports.

We know that some of the very best and most upright business men, conservative in other lines of business, get excited over a piece of ore exhibited, and what absurd statements they will often make through misunderstanding technical reports. And how infrequently they consult a mining engineer! And how often they try to excuse their statements by disclaiming all responsibility and laying it all upon their engineer, if they have one.

Some years ago a prominent banker from another city entered my office in New York and said that his bank had been obliged to take over a mine; that they did not wish to go into the mining business and had determined to sell the property, and had been referred to me. I asked him what he had to offer. His reply was something like this:

"We have a copper mine with 90,000 tons of ore on the dump that will assay 12% copper. The ore is exposed for such a width in such and such shafts and carries enough precious metals to pay all the expenses of mining and extraction, leaving the copper clear profit."

I made notes of his remarks and read them to him, and asked what he wanted for his mine. He said a million dollars would buy it. I replied "I will take it." He seemed greatly surprised and wanted to know if I really meant it; that he had not expected to sell the property as readily as that. Did I not wish to look at the mine and verify his statements? I told him that I knew with whom I was dealing; that his reputation was very high in the East and I added, "Now, let me see what I have bought."

Then I read to him his statement about the tonnage and grade of the ore, and added that I had a bargain; that although I was not in the business of buying mines, I would have no difficulty in doubling my money on this. He seemed to be getting more and more uneasy, and finally said: "Of course you understand that I do not know anything about mines myself; that I have never seen the property." I said, "That makes no difference. Your guaranty is good enough for me." He became still more uneasy and promised to send me the report of his engineer. I took pity upon him and told him that he must surely have overstated the conditions unintentionally; that the statement of ore on the dump did not tally with the statement of the excavation, and that I had never heard of a mine—certainly not in the State he mentioned—that ran 12% copper on the average, with so much gold and silver that the copper was a net profit. I added, "Mr. . . . ., you do not realize your position. Supposing you had gone to J. P. Morgan as you came to me and said 'Mr. Morgan, I am so and so, President of such a bank. We own a railway in North Carolina, which we will sell to you for such a price. Its earnings are so much, there are so many miles of track, so many passenger cars, so many locomotives, etc. My price is so much.' If Mr. Morgan said he would take it, would you not feel that your reputation and responsibility were behind your statement? Would you not expect to deliver exactly what your statement contained? You would not think of saying, 'You know, Mr. Morgan, I do not know personally anything about the railroad, but rely on statements furnished by others.'"

My visitor thanked me for the lesson and promised to send me such a statement as he was prepared to stand by—I have never heard from him since.

That illustrates one fact which I think should be publicly emphasized. The public, and especially the *honest* promoter and the investor are very careless in engaging alleged experts. I remember the head of a large New York drygoods firm who brought me some papers, and in a shame-faced way asked me to look them over. He had known me from my boyhood. I met him frequently, but he never had mentioned that he was interested in mines. *The papers on the face of them showed that the property in question was no good.* There was no fraud, but admitting the facts, the mine could not pay, where located. I asked him why he had not consulted me before he made the investment and what induced him to make it. He said, "Oh well, a friend of mine came in my office with a fine looking miner. He had a rock in his pocket and *I could see the gold in it myself.*" I said, "Mr........., I once heard you say that you never trusted your own judgment in laces, though you handled quantities of them; that you called in your lace experts. Why did you not show me this statement or ask some other expert's advice?" There was no answer to this question, of course.

Is it not upon that phase of the problem that emphasis should be laid, rather than upon the comparatively rare cases of really dishonest mining engineers, willing to lend themselves to fraud?

MR. GWILLIM—My reference is not so much to dishonest mining engineers as to those disreputable people who call themselves, without right to the title, mining engineers.

MR. COSTE—I was glad to see a suggestion in Mr. Gwillim's paper recommending the advisability of stricter regulations governing the issuance of Letters Patent to companies. This is a matter of very vital moment at the present time. Every week now one may find in the Ontario *Gazette* the advertisement of new mining companies representing in the aggregate many millions of dollars of capital on paper. It is said that already the capitalization represents in the neighborhood of from three hundred to four hundred million dollars. Unquestionably this capitalization is not based on any sort of real value. Under present conditions it is an easy matter for three or four quite irresponsible persons to join together for the incorporation of a company, and by filing the necessary papers and paying to the Government a small fee, they practically receive the Government's sanction to sell stock to the public on the strength of some worthless prospect capitalized at millions of dollars.

I submit that the Government is responsible for this state of affairs and I think that now a new Company's Act is being introduced to the Ontario Legislature by the Hon. Mr. Hanna, that the time is opportune for the Institute to make some recommendations in regard to this matter. What form this recommendation would take I am not just at the moment prepared to say; but I think such a clause as this might possibly serve the purpose, viz.:—That before a charter is granted, the applicants therefor should show to the satisfaction of the authorities that at least ten per cent. of the capital stated had been subscribed for and set aside for the purposes of the company, thus: If ten per cent. of the three or four hundred million dollars representing the capitalization of the companies operating in Cobalt had been subscribed before these companies were granted charters, there would of least have been a guarantee of a large available sum for development purposes, while at the same time this requirement would have gone a long way towards stopping or restricting the wild gambling in stocks of which we have recently had experience.

The Ontario Government shortly after coming into power took much credit for putting a stop to the gambling in the pool rooms at Fort Erie and at Toronto Junction. But this speculation in mining stocks is a still more invidious form of gambling, and is indulged in by a wider circle; moreover, it is a detriment to legitimate mining, and it is therefore just as important that the Government should endeavour to check it.

Dr. Porter—Mr. Gwillim in his paper refers to the publication in the newspapers of misleading advertisements inviting the public to subscribe for stock in mining companies. We all know that there are pages of mining share advertisements appearing in the press daily, and these advertisements are as misleading as the ingenuity of the advertisement writer can make them. I am afraid, however, that misleading advertisements are published in respect to businesses and matters other than mining, although of late there may have been more relating to the latter. Even in the carefully guarded profession of medicine, if we stop to look at the newspapers I think we shall find advertisements which are quite as untrustworthy, and even more pernicious. The story is the same in all directions and there is little prospect of one being able to exercise any control over the advertisingmatter of such an irresponsible sheet as the ordinary daily paper. It seems to me the point Mr. Coste made this afternoon is more likely to lead to something definite. Undoubtedly one way of controlling the valuation and capitalization of mines is to follow the Dominion Act and insist that ten per cent. of the capital be actually paid in before incorporation is possible. That would not, in my opinion, interfere with legitimate mining, because if a mine is worth anything at all it is easy to get subscriptions amounting to ten per cent. of its necessary capitalization; and if the promoter cannot raise such a sum they should have no right to come before the public and offer shares for sale. Similarly, if the Government is in need of revenue and tax a mine at its true worth the mine is merely treated as any other property. Our mine owners all say that they have no objection to legitimate taxation. Now the true capital of the mine, that is the real cost capital which is subscribed to buy the property and equip it, can properly enough pay a reasonable tax and such a tax upon the basis referred to would not be an excessive burden upon the property. It seems to me it would be a very good thing if the Institute could express its sense of the importance of trying by every legitimate means to limit the issue of shares having a face value in excess of the reasonable value of the property. The Government could quite properly demand not only the ten per cent. deposit but also, if possible, a certain percentage of taxation based on capitalization with a view to keeping promoters within bounds. A reference was made to gambling dens, pool rooms, etc. Nine people out of ten who gamble in "dens" go there with their eyes open and because they want to gamble. If they lose they merely get what they deserve and no great damage is done to anybody but themselves; but in mining it is different. A considerable proportion of people who buy mining shares do not think they are gambling. They are more or less innocently led into making so-called investments, which are in reality mere plays in a game in which the dice are loaded.

MR. DILLON MILLS—It is of course well known that companies are not promoted for the benefit of the public. It would seem to me that legislation should be introduced, which would make it a misdemeanor if stock were sold for any other purpose than to provide funds for the actual development of the mine.

MAJOR CURRIE—I think there are several aspects to this question. In the first place, with reference to incorporations, it does not matter if the Government refuses a charter for mining companies altogether; company promoters can get charters in other countries easily and cheaply. The principal and largest gamble in Ontario mining stocks is a Cobalt concern. The charter of that company is not an Ontario charter because the Ontario law contains a clause that the profits on promotion must be disclosed. To avoid this the promoters of this concern obtained a charter in the State of Maine. So you see there are various ways of avoiding legal restrictions. To my mind the less Government interferes in matters of this kind the better. The mere fact that the Government examines properties before title is given has led to a great many innocent people being wronged. If you read some of the American papers you will see large advertisements to this effect: "No more risk in mining investments in Canada; the Government guarantees this property a mine; it has been inspected by the Government Engineer, and proved to be a mine before they give it a title, consequently there is no risk." Now the more the Government does and we ask the Government to do, the worse for the public. Over much paternalism is not a desirable thing. The Government should avoid responsibility in any manner, shape or form. Its duty is simply this: If an association of men get together and say they are going to form a company, adopt the English plan, let them form a company, and register as such. That is all the guarantee the Government should afford, namely, that such or such a company is allowed to do business, and the public is given to understand that they as investors take their own chances. I think that is the only way. If the Government puts the stamp of its approval on charters or companies, by any limitations, the investor will have really less protection, for he will be less cautious, thinking the Government guarantee a protection.

In reference to another question raised in Mr. Gwillim's paper on the subject of the qualification of mining engineers, I have visited possibly the chief mines of the West, the great iron mines of Minnesota and the copper mines of Northern Michigan, and I made a very thorough examination of them and a long visit lasting over three months to the iron mines of Michigan and Minnesota, during which I was accompanied by one of the pioneer engineers of that region; but I failed to find one of those mines in charge of what could be called a qualified mining engineer. Mr. Pengilley in charge of the great Chandler Mine and others told me —others who were chief engineers in the management of 600 or

700 men, and hoisting thousands of tons of iron daily—that if they could get the young men who go to the schools to go through a short course in the mines, as mine foremen, or shift bosses, and become practical they would not ask for anything better. But what they said was this; that as soon as a young man passed through the mining schools, the first thing he did was to set up a little, small "dinky" laboratory and become a worthless expert or chemist. He would not rough it and take his chances in the mines, and become a practical man as well as a theoretical man. The same thing is true of college men in all lines of industry. If you go into the iron industry in Pittsburg, you will find lots of young college men wheeling wheel-barrows. Mr. Scott of the Isabella Furnace told me last summer he had a number of graduates of various Universities working at the furnaces and there was only one or two of the whole lot, if he came to one of them in the morning and asked him what the air pressure was on the furnace who could answer him. They did not take sufficient interest in the practical work to suit him, but if it were a poor fellow that has to depend for his livelihood on what he had to learn he would very soon know. For that reason I say this, that the mining engineer's duty to his profession as a mining engineer is to know his work so that he will be able to operate a mine, with economy. What is the definition of an engineer? He is a man who by his education and experience can do for one dollar what would cost any ordinary person two dollars. This matter of experting, of inspecting the surface with glasses, and pretending to judge that there are millions underneath does not constitute a profession. The ordinary layman can usually judge from the surface about as much as the best engineer. To prove that to you, I know of a mine to-day in this province that was offered to me for $500.00. I examined it myself, a qualified engineer examined it for me and we both turned it down. To-day it is worth possibly $2,000,000. I think you want to take the practical view of mining. Don't let us involve the Government in wild cat promotions by asking that investors be guaranteed either by the form of the charter of the company or by the examination of the properties by Government mining experts. And in the education of our engineers, let us impress upon the students and schools that education in mining only begins in the college, and that all the college can do is to equip

students so that they can more quickly become efficient mining captains than if they had to fight their battles in the hard school of experience. Experting, so called, is not the proper profession of a mining graduate, but practical mining. (Applause.)

MR. E. JACOBS.—The Act in force in California discountenancing wild-cat promotions is being very effectively put into force and at the present time Mr. Louis Aubrey, the State Mineralogist is prosecuting one man who is charged with having obtained some $200 or $500 for selling worthless mining shares. When the Chambers of Commerce congress delegates went west from Montreal in 1903, I had the pleasure of meeting a well known Montreal gentleman who had been active in municipal matters, is now active in political matters, and prior to that had been very active in commercial matters. As the Secretary of one of the local Boards of Trade he thus appealed to me: "Can't your Board of Trade give us in the East some guarantee that the properties offered to us are of value?" I said, "Mr. So-and-So, you want to go into the Fishing Industry ; do you ask the Board of Trade for a guarantee? You want to go into the Lumber Industry, you don't ask them, you get specialists to advise you. If you go into mining and expect Boards of Trade to give you expert advice, you are leaning on broken reeds; you must do as you do in every business, get the advice of expert men." I don't think it is so much the mining engineers's side of the case that we should now consider. I take it for granted that mining engineers are all honorable and honest men. I have had to read the notes of a number, and it has only fallen to my lot to think differently of one. Just now I am dealing with a promotion at Cleveland, Ohio, of a supposed big copper property in British Columbia. The reports on that property in the hands of the promoters were from qualified men; the heads of the firms who supplied these reports, the senior members are both members of the American Institute of Mining Engineers; I believe one of them is a member of this Institute. But these reports are not quoted from. One engineer says that if you put in certain tunnels and make certain connections, and the ore continues, you will have a block of so many thousand tons of ore, and if the assays, so far as we have gone, are so much, and values maintain, you will have ten million dollars worth of ore.

These people issued a prospectus or rather they published it in the newspapers in New York and Winnipeg, and maybe elsewhere —I have had several of them sent to me—and they show not that this is what may happen, but they show that the ore is blocked out, or that is the inference. It would appear that they consequently possess ten million dollars worth of copper, in "the richest copper district in the world." and they furthermore point out, as was stated just now, that the Canadian Government protects the investor. The Lieutenant-Governor received a letter from somebody in the United States asking if this were the case. The letter was passed on to the Mines Department and the Provincial Mineralogist kindly showed it to me. In reply it was pointed out that this proposed company was not registered, had no standing, and even if it were registered the Government offered no special protection to the investor, except under the ordinary laws dealing with obtaining money by false pretences. What seems to me necessary is to punish the fraudulent promoter—the men who make misleading statements, and I would also like in some way to punish the newspapers who publish these statements; but I am afraid the field would be too big; but in view of the fact that several of the States across the line have tackled the problem—it is not confined to California—it is very desirable that Canada should not be backward in the matter of penalizing fraud of this nature. One more point and that is the application of the money subscribed. The provision that ten per cent. or whatever percentage may be stipulated, of the capital, shall be merely subscribed, does not cover the point. It should be stipulated that a certain per cent. of capital subscribed shall be spent in legitimate development. Dr. Porter's suggestion—apart from the question of fraud —about the sliding scale in taxation, has been in force in one of the Australian Colonies for years. The higher the capital the larger the taxation. If the capital is £100,000 a certain tax is paid thereon ; if it is £500 000 the tax is perhaps smaller proportionately, but still a larger sum has to be paid. The system is perfectly workable and legitimate, and is a check on the extravagant amounts that are named as capital, and are only capital on paper.

THE PRESIDENT—I am sure we are all very much indebted to Mr. Gwillim for his paper, and we are also indebted to the gentlemen who have discussed it. If the suggestion made by one or two of the members as regards a recommendation from the Institute to the Government along the line suggested, is thought advisable, a notice of motion to that effect can be given in the regular way Speaking as a member of the Institute, however, I feel in making such a recommendation we should be treading on dangerous ground. Mining is a bit of a gamble at the best, and always will be. Whether this Institution is prepared to put itself on record as being able to say that we ought to be able to dictate absolutely as to what advice a man shall take or not is questionable ground to my mind.

DR. PORTER—I had hoped that some other person in the room would mention one matter which was raised by a gentleman a moment ago in regard to the inefficiency of the graduate of mining schools. Possibly, if applied to conditions twenty years ago, the remarks of the speaker are true, but the statement that mines —Michigan was specially instanced—are now'all in charge of men who have not had the advantage of college training is by no means correct. The majority of the mines both in the copper and the iron districts in Michigan are in charge of college graduates, and I shall be supported in saying that the majority of mines—I do not refer to mere prospects—in this country and in the United States are managed by men of this class. Moreover, there is no longer any difficulty in inducing students from at least the better class mining schools and universities to undertake plain practical work in the early years after graduation, and thus qualify themselves. It is quite true they are not competent to take responsible positions until they have had practical experience, but taking the men turned out from McGill University, seventy-five per cent. of them naturally go into common mining work, and qualify themselves without any of the indifference or high-mightiness which was suggested as being characteristic of them.

DR. GOODWIN—I am happy to support what Dr. Porter says. The facts are so well known, I did not think it was necessary at all to make any remarks in that direction. Just one fact will emphasize this truth, and that is that the graduating class at the School of Mining in Kingston were every one of them employed, that is had places marked out for them—good employment in mines—before they graduated. They had formed connections during the previous summer and we have had applications for three times the number of men we have graduated during the past year for responsible positions in mines and metallurgical works. I think facts like that speak for themselves; they hardly need comment or remarks.

MR. LORING—I would like to ask whether these gentlemen who have spoken would take the opinion of a young man just graduated as to the value of a mine in Mexico or Nevada or British Columbia, in preference to the opinion of an illiterate man who has had 20 years experience in mining. I submit that when a young man graduates from college he has secured merely some of the tools that prepare him to become a mining engineer, and I think there is no profession in the world that needs more practical experience than mining engineering, and if the protection of the public depends on the opinion of the young graduate the public is depending on a very weak reed. The assayer or the surveyor, the young fellow who has studied some metallurgy or mine work, is absolutely unfitted until he has had several years of practical experience to either manage a mine or express an opinion on it. I think a man who has taken no matter how complicated a course in geology knows no more about mining than the layman. There is no profession that needs a more general experience. Every mine and every district has its own special conditions and a man can learn to judge as to the economics of mining or the conditions of a mine only after long experience. More so than in civil engineering because that is a more exact science in many ways. There is nothing more dangerous than the empirical knowledge of the young mining engineer, except perhaps that of the young physician who has to kill a lot of people to gain experience. After a man has graduated from college he is equipped to commence to learn. But it seems to me that this argument that the young mining engineer is better capable of protecting the investor, than the so-called mining man, is not very sound. The ideal, of course, is a combination of theory and practice.

DR. PORTER—I imagine that these remarks are aimed at what I just said, and if so, I might emphasize what the last speaker has very clearly brought out regarding the absurdity of employing a young graduate to examine and report on a mine; but might I ask whether employing the plain practical miner for the same purpose would not be something like getting some old woman to act in place of the trained doctor? (Laughter). Why should not you choose not the practical miner nor the young graduate, but show a reasonable degree of intelligence and employ a man who is no longer a young graduate, but who combines practice and theory.

MAJOR CURRY—As some of the foregoing remarks have been directed partly at me I wish it to be distinctly understood that I have no wish to attempt to discredit the mining engineering profession or the young man who learns that profession, but what I do wish to emphasize is this, that as Mr. Loring has said, that those gentlemen who are entrusted with the training of the young engineer should impress on him that after getting his degree he is only just beginning at the beginning.

DR. GOODWIN—It seems we are all agreed after all. (Laughter). Those who have taken part in this discussion have been looking at the two different sides of the shield; when we each turn the shield round we arrive at a full understanding of the whole subject. We are all agreed that the best possible man we can have for the mining profession is the man who has been thoroughly educated in the principles of the subject and who has got experience. I hope the gentlemen who spoke immediately after me does not have any sort of suspicion that Dr. Porter or I, or anybody else engaged in the education of young men for the mining profession would send them out to manage a mine immediately after graduating. That is not the case; we would send them out, to get the best position they could to gain experience by which they would learn how to manage a mine.

ROYALTIES ON MINERALS IN ONTARIO.

By J. M. Clark, K.C., Toronto, Ont.

(Toronto Meeting, 1907).

It might safely have been predicted months ago that the increased interest in the mining industry of Ontario would result in an agitation for royalties or taxation. All that was required was to apply the maxim that history repeats itself. The elder generation will recollect that many years ago there was a considerable interest in the Hastings District. This resulted in a Statute, 27 and 28, Victoria Cap. 9m, Section 34, which provided for the payment to the Crown of certain royalty on gold as there specified. The inevitable result was a very decided check to the growth of the industry. So much so, that in the first Parliament after Confederation the matter was taken up in the Ontario Legislature and all the royalties, taxes and duties before referred to were repealed and abandoned and a Statutory Declaration introduced that "such lands, ores and minerals shall "henceforth be free and exempt from every such royalty, tax "or duty." After a number of years with this Legislation on the Statute Book, some interest was gradually awakened in the mineral resources of the Province, with the result that another agitation for the imposition of royalties arose and certain royalties were imposed by the Statute of 1891, but confined to the lands located, sold and granted or leased by the Crown on or after the 14th day of May, 1891. The result of this legislation, though its application was limited, was to make it practically impossible to interest foreign capital in exploration and these royalties were in consequence subsequently repealed. The declaration above referred to, namely, that such lands, ores and minerals shall be free and exempt from every such royalty, tax or duty, was substantially continued in our Statutes, and appear in the Revised Statutes of Ontario, 1897m, Cap. 36. The question of taxation is of course a vexed one, but it can be laid down as a general principle that the utmost good faith should be shown towards investors. The fact that the characteristic ores of the Province are of low grade and requiring as a general rule large amounts of capital for their development and working, would call for grave consideration of the whole problem. The great need of Northern Ontario is capital which cannot be secured unless faith is kept with investors. The immense injury which will result to the business, manufacturing and agricultural interests if the tremendous inflow of capital into this country is seriously checked, is so obvious as to require no argument to emphasize it. Many explorers and prospectors have spent all their resources and a large part of their lives in searching for mineral deposits in Northern Ontario. If a blow at the mining industry is now struck by the Legislature the fruits of their labors will be unjustly snatched from them. It is needless to add that if prospecting and exploration are discouraged there is not much hope of developing a great mining industry, which would be a great factor in the prosperity of the province. In short, it is a foolish thing to kill the goose which lays the golden egg.

SIR WILLIAM E. LOGAN AND THE GEOLOGICAL SURVEY OF CANADA.

By Dr. Robert Bell, F.R.S., Ottawa, Ont.

The life of the late Sir William Logan and the history of the Geological Survey of Canada are so intimately connected with one another that a complete account of the one would necessarily comprise that of the other. It is not the intention however, in the present paper to attempt even a brief history of the life of Logan, but rather to give a selection of incidents and anecdotes illustrative of the man from all points of view. These are personal reminiscences, as the writer had the honour of being intimately associated with Sir William from the beginning of 1857, now 50 years ago, till he left this country, or during a period of 17 or 18 years, and of seeing him under a great diversity of circumstances. A correct narrative of a sufficient variety of incidents bearing on all points in a man's life gives one a truer idea of the man himself than the general assertions of a biographer, who pictures his subject only as he himself wishes, or as he thinks he should be described.

In referring here to the history of the Geological Survey it it is sufficient to say that its origin was due principally to the action of the Natural History Society of Montreal in presenting a petition to the first Parliament of the united provinces of Upper and Lower Canada. This petition, which, by the way, it is understood originated in a suggestion from the late Rev. Dr. Mathieson of Montreal, was seconded by a similar one from the Literary and Historical Society of Quebec. The first grant for the survey was only £1,500 sterling, but after that the amount for some ten years was £2,000 sterling annually. It was not, however, until toward the close of Logan's administration that the amount exceeded $20,000 a year, and the average annual grant during his time may be said to have been only about $15,000. This should be remembered in estimating what he accomplished. Mr. Logan was appointed Provincial Geologist in 1842 and began the Survey in the spring of 1843.

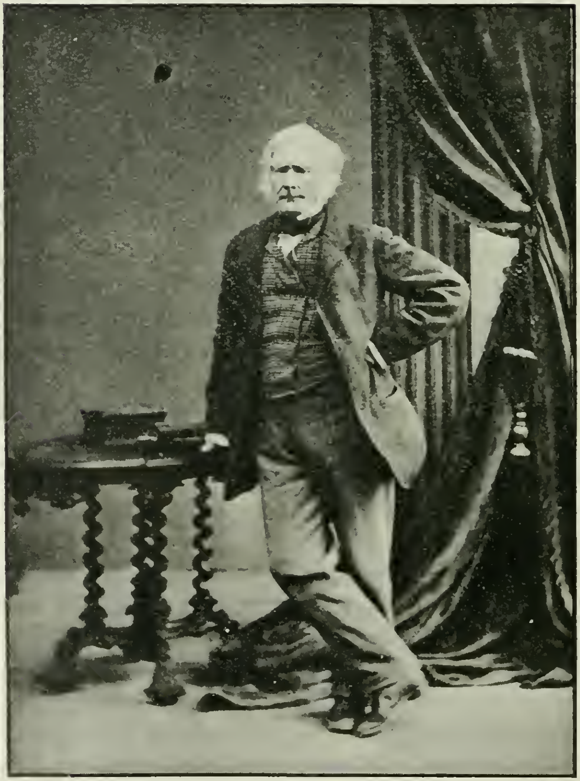
At the time work was commenced on the Canadian Survey, field geologists were often subjected to a kind of annoyance from which they are now almost free, thanks to the greater enlightenment of the present time which has given most people some notion of what they are doing. I refer to the fact that a geologist when seen at work was generally mistaken for a lunatic. In case this may be doubted by young geologists who have never been so misunderstood, I will give in the course of my narrative two or three out of a large number of cases of Logan's difficulties which occurred mostly between fifty and sixty-five years ago. Even strangers who were otherwise well enough educated, on noticing Logan pounding rocks, have been known to enquire, "is he all right in the head." Logan's indifference to appearances in the matter of dress often added to his troubles in regard to his supposed insanity, as we shall see.

Logan was born in Montreal of Scotch parents. As a young man he had been engaged in the copper-smelting business at Swansea in South Wales. In connection with the coal supply required at this centre of metallurgical industry he was led to make a geological survey of one of the Welsh coal fields, which was found to be so complete and accurate that it was soon after adopted *in toto* by the official Geological Survey of Great Britain.

Logan's selection as Provincial Geologist of Canada was due partly to the fact just stated and partly to his being a native Canadian. Mr. Alexander Murray from Scotland, a naval officer who had a liking for geology, was chosen by Logan as his chief assistant.

When the Survey was commenced in 1843 that of the State of New York had already made some progress and as the same rock formations extend from that State into Canada, Logan wisely adopted the formational names of the New York geologists in order to secure as much uniformity as possible.

One of his greatest services to geology was his early investigation of the ancient crystalline rocks, his separation of the Huronian from the Laurentian, to which he gave those names, and his working out of some areas of the Laurentian in the Ottawa Valley as well as his coöperating with Murray in defining the Huronian in the Lakes Superior and Huron regions.



SIR WILLIAM LOGAN

While Murray worked principally in Upper Canada, Logan's time was mostly devoted to the rocks of the Lower province south of the St. Lawrence. In connection with this work, the subject of metamorphism played an important part, but in these field investigations Logan had not the advantages he might have derived from the microscopic study of rocks if he had lived a generation later. But even without this most important help he did a marvellous amount of good work in classifying the rocks and in accurately mapping in great detail their structure and distribution over the large area which comprises the Eastern Townships.

Among his discoveries in the course of this work was that of the great fault or dislocation which runs up the valley of the Hudson river, passing through the Eastern Townships and down the course of the lower St. Lawrence river.

At the time the Geological Survey was begun, only a few economic minerals were known to exist in Canada, but Logan rapidly extended the number and since that time the Survey has sent fine collections to every International Exhibition which has been held from that of 1851 to those of the present time. One of the red-letter incidents of Logan's life was the great banquet given him by the citizens of Montreal on his return from the Paris exhibition of 1855, just after he had been knighted by Queen Victoria. On this occasion he was presented with a beautiful silver fountain with several basins, one above another, on which were engraved unusually fine pictures of Carboniferous flora, symbolical of his work in Wales which had contributed largely to his Canadian appointment.

The office and museum were first located in Great St. James Street, Montreal, at the corner of what is called Dollard Street, on the site of Savage and Lymans, afterwards Woods' jewellery store. After three or four years the headquarters were removed to the Natural History Society's rooms, near the east end of Little St. James Street. About 1852, when the Crown Lands Department had finally vacated its building, No. 76 St. Gabriel Street, it was handed over to Logan to be used for the Geological Survey. At the time the writer began work on the Survey, early in 1857, the interior of this building was being fitted up as a museum, out of a government grant obtained by the late Hon. John Young, who was a great friend of Logan. Sir William had often told him how much he would like to secure two or three hundred pounds for this purpose. In 1855–56, Mr. Young was Commissioner of Public Works and without any special application from Sir William he got £1,000 currency, ($4,000) passed in the estimates to cover the expense of this work. Sir William was almost overpowered by the liberality of the grant, which was so much larger than he had hoped for.

Sir William's ardent devotion to his duties, both in the office and the field were well calculated to inspire enthusiasm in others. In the office, besides laboring from early in the morning till 6 or 7 in the evening, he always came back to work at night, except on those occasions when he went out to dinner. He paid daily and sometimes more frequent visits to every man in the office and interested himself with everyone's ideas of his work, correcting any erroneous notions and imparting in the most pleasant manner an immense amount of instruction in all branches of known geological science, and also in regard to drawing geological sections and topographical and geological maps, in which arts he was himself very proficient.

His own industry was almost phenomenal. He slept in the museum among his idols as a child likes to sleep with her toys around her. No one seemed to know when he arose and went out in the morning. He appeared to be generally attending to the outside business of the Survey up to half-past seven or eight o'clock, when he breakfasted at Madame Duperry's boarding house, round the corner from the office, in Little St. James Street. When the reports were in press he visited Mr. Lovell's establishment in St. Nicholas Street at 7 o'clock or earlier. Mr. Lovell, who was an intimate and life-long friend of Logan's, informed the writer that on some occasions he came to work as early as 5 o'clock. He never took any luncheon, but indulged in a hearty dinner at 7, after 12 hours of continuous work. This could not fail to be injurious to his health and his medical adviser, the late Dr. Fraser, strongly urged him to eat something in the middle of the day. Sir William tried to do so, but was so absorbed in his work that he almost always forgot about it till too late in the afternoon. If any of us reminded him that it was luncheon time, he would say, "O, bother the lunch" and proceed to swallow a few mouthfuls as if he grudged the requisite time.

To give an idea of the amount of work he accomplished, it may be mentioned that in addition to his daily round of visits of instruction or consultation with every member of the staff, he kept all the accounts with his own hand, carried on an extensive correspondence, without the aid of the type-writer, then unknown, plotted all his own surveys and constructed his own original maps, wrote his reports, edited the reports of his assistants, examined all the fossils, minerals and rock-specimens collected during the year, studied the reports of the geological surveys of the different American States and of any other geological surveys which might be going on, in order to correlate the Canadian work with that of other countries so as to keep up with the times. The interruptions caused by visitors, to whom he was always accessible, occupied a considerable portion of each day.

For a number of years, four MS copies of all reports including the annual Reports of Progress were required—one for the Governor-General, one for the House of Assembly, one for theLegislative Council and one for the printer, and Logan wrote out all of these with his own hand. Even the device of copying by damp paper in a press had not been thought of at that time. Imagine writing a book of geological details four times over! No one but a man of the utmost industry and patience could have endured it.

Another irksome task which he plodded through year after year, almost to the last, was auditing all the detailed accounts of petty expenses and copying every item, including the vouchers, into his books, which he kept with his own hand, by double entry in the most beautiful style. In talking of this matter with him one day, the writer ventured to remark that he might spare himself a great deal of drudgery by employing a book-keeper. He replied that he would rather leave a record in his own handwriting of how he had expended every penny with which the Government had entrusted him. Said he, "After I am dead no one will ever be able to find fault with my books of accounts."

Sir William's room in St. Gabriel Street, was of a good size on the second floor and had but one large window, which looked into the yard. This room served for office and mapping room, reception-room, bed-room, wardrobe, etc. It contained only the most essential articles of furniture and these were but three or four in number. There was no curtain or even screen in the window, which faced the south and the unbroken rays of the sun shone unheeded on Sir William's head. There was, of course, no carpet—not even a small rug on the floor. A plain table and the cheapest kind of chair stood in the centre of the room, and a common washstand, with pitcher and basin in one corner. He slept in this room, but no bedstead was visible. The way he managed was this: He had an ingenuous sort of combination iron bedstead and chair. During the day this occupied a corner and looked like a large easy chair, but Sir William was never known to sit down in it. At night the caretaker of the building folded this out straight and revealed inside of it the same blankets which served him in camp. What forced itself most on the attention of a stranger entering the room for the first time, was the great number of worn boots and shoes which it contained. They stood in a row against the wall around a considerable part of the circumference of the room. A few surveying instruments and a large collecting basket stood about or hung by straps at the back of the door. The clothes he wore in the woods (and which will be presently described) also hung on pegs or nails on the wall.

Such was the room in which Logan worked, but about 1860 a new feature was introduced in the shape of an immense slab of sandstone which entirely covered the wall on one side. This slab was from Perth in Upper Canada, and was traversed by crustacean tracks called *Climacticnites Wilsoni*. Every morning Sir William gazed on this slab with fond admiration, first with one eye and then with the other, as he held his towel and dried his face with alternate hands.

Sir William had a singular disregard for appearances. If he happened to come into town from his field-work, he would not always put on his city clothes, only doing so when he returned for the winter. About 1862 he purchased a new coat for city wear. It was a sac or pea-jacket of most durable brownish-gray Irish frieze, and, if I am not mistaken, he wore it every winter till he finally left the country in 1874. During the same period, and probably for some time before, he wore a waistcoat with large squares formed by narrow white lines at right angles. We got so accustomed to these garments that they seemed to form part of the man himself.

The trouble of getting anything new to wear, or the change it made in his appearance, seemed distasteful to him. He walked so much that he wore out more boots than clothes. When he happened to notice that his last pair would hold out no longer, he would suddenly ring his bell and on the care-taker presenting himself, would say, "Michael, go and get me 3 or 4 pairs of new boots. You know the kind I want." This would fit him out for a year or two.

In the city, he wore a beaver hat of the original old pattern and material—a regular shaggy old fellow, of genuine beaver fur—none of the modern kind covered with thin shiny silk. This hat became as familiar as the genial face beneath it. But one day, while some of us were looking out of a window in the wing, (among the number being Dr. Hunt), Sir William passed through the yard on his way out to the street. "I declare," exclaimed the Doctor, "Sir William has got a new hat at last"—and, sure enough, there was Logan with the most gorgeous silk hat, which money could buy. Towards evening, when the Doctor wished to go home for dinner, he came back to enquire if anyone had seen Sir William return; for, said he, "the fine hat he was unconsciously wearing this afternoon is my own and I have no other in the place. I'm a prisoner for want of a hat!" We suggested that as Sir William was wearing his hat, he might fairly take Sir William's. He replied that he "might do so when it got dark enough."

The modesty of Sir William's attire enabled him to preserve a pretty general incognito, even in Montreal. Here is an example. One day the writer was talking with a prominent citizen of the time, in one of the rooms of the Museum, when a well-dressed member of the staff walked through. As soon as he had passed out of the door, my friend, looking after him, said, "What a fine-looking man Sir William is!" "That's not Sir William," I said, "that's Mr. O'Farrell the care-taker." "Well now," said he, "for years I have taken that man for Sir William Logan and I am sure many others in Montreal are doing the same thing at this moment."

It will thus be seen that Sir William's dress in the city was unpretentious, but in the country and in camp, in the bush in particular, it may almost be said to have been a little careless. To avoid a semblance of exaggeration the following description of himself is copied from one of his note-books : On the occasion referred to, Sir William and his party had entered the house of a settler named Barton and their appearance very much frightened his wife. He wrote in his notes of the day: "We are all pretty-"looking figures. I fancy I cut the nearest resemblance to a "scare-crow. What with hair matted with spruce gum, a beard "three months old, red, with two patches of white on one side, a "pair of cracked spectacles, a red flannel shirt, a waistcoat with "patches on the left pocket, where some sulphuric acid, which I "carry in a small vial to try for the presence of lime in the rocks, "had leaked through—a jacket of moleskin, shining with grease "and trousers patched on one leg in four places and with a burnt "hole in the other leg; with beef boots—Canada boots as they are "called—torn and roughened all over with scraping on the stumps "and branches of trees, and patched on the legs with sundry "pieces of leather of divers colors, a broad brimmed and round-"topped hat, once white but now no color and battered into all "shapes. With all these adornments, I am not surprised that "Mrs. Barton, speaking of her children and saying that here was " 'a little fellow, frightened of nothing on earth,' should qualify "the expression by adding, 'but I think he's scared at *you*, Sir.'"

Even when working in settled parts of the country and staying at taverns and farm houses, his attire was not much better. He was so entirely absorbed in his work that he never gave the matter of his personal appearance the least consideration and still less did he seem to care what other people thought of his clothes, although desirous of their good opinion in all other respects.

One day a gentleman and his wife were driving along a main road in the Eastern Townships, when they saw Sir William walking towards them. He appeared to be muttering to himself, for he was counting his steps, as he usually did, in order to note the distances of the various rock exposures. The gentleman knew the great geologist, but the lady would scarcely believe it could be he. However, as she had requested it, he stopped the carriage and when Sir William came up he introduced him to her. The geologist had just come through a fresh brulé and his light colored slouched hat, fustian jacket and gray trousers of "étoffe du pays" were all streaked and blackened by the charred sticks and logs he had been scrambling amongst. Notwithstanding the appearance of his dress, the lady was so charmed by his conversation and manner that she immediately forgot all about the clothes, and after an interesting conversation, she gave him her sweetest smile as the carriage drove off and Sir William resumed the counting of his paces.

A good story is related by the late Mr. Andrew Russell, the veteran Surveyor and Deputy Commissioner of Crown Lands of Upper Canada. Mr. Russell was spending a night with a man named Michael Murphy in the Township of Stoneham, on the Jacques Cartier river behind the city of Quebec. In the course of the evening Mrs. Murphy said to her husband: "Till Mr. Russell "about the quare little mon that stopped wid us last wake." "Faith an' I will" said he. "It was beginning to git dark whin I "sees him cumin out av the wuds at the corner av the clearance "beyant, right furnint the house. When he came to the dour, "siz he 'wull yez allow me to stop over night wid yez, sayin' as "there's no public house onywhers near?' Yer kindly welcome, "Sir, siz I, and wid that he steps in. His clothes were purty well "tore, an that, but still an all he was a civil spoken little man. "Thur was a wet rain that afternoon an the poor mon was drinched "to the skin. So the owld wuman there tuk pity on hum an siz "she 'take hum up to the loft Mikie and give him a change av " 'clothes. I tuck notice he had good clane flannels under his "owld coat, an thurs nothing like flannels; thur so warum an "dh y aven whin they do be wet an cowld."

Here Mrs. Murphy interjected. 'Well sur ye ought to 'a "sane the little mon whun he came down the lather wid Murphy's 'clothes on, fur ye say what a size Murphy is. He was the quarest "luckin' soight ye evur did say when he thried to walk round "wid the baggy clothes Ah but he wus the fine company "though, sorr, and he made the avnin' pass most beautiful, he "wus so fair spoken. In the mornin' he offered to give us some-"thin for kapin' hum, but av coarse we wudn't take a pinny from "a poor stranger the likes av hum. But fur all that he gave two "and six pence to ache av the childer, as he wus lav n the house. "His name was Logan—did ye uvir hear tell av hum, Mr. Russell? "Oh, yes," said Mr. Russell, "I know him very well. He lives in "Montreal and owns a great deal of property." "Do ye till me "he's a mon av substance?" 'Oh, yes—he's considered rich, "perhaps the richest man in Canada, and besides he has a good "income from the Government." "Will! Will! thin he *is* a "mon av substance. The quarest thing ivir I heered till av. "Logan wid the ragged clothes is railly a mon av substance. Will, Will! It bates all!"

The following incident illustrates the inconvenience which may arise from a shabby outfit: In 1856, Sir William was working in the Township of Chatham, on the north side of the Ottawa, and wishing to go to Montreal, he walked down to Carillon one afternoon and went on board the steamer "Lady Simpson." He had forgotten to put off his camp suit—if, indeed, he had a change of clothing with him. Sitting down in the upper saloon he waited for the steamer to start. Presently he was discovered by an officious cabin boy who marched up to him with a consequential air and said: "Look 'ere, old fellow, I guess you've made a mis-"take." "Not that I am aware of," said Sir William, "what do "you mean?" "Well, I mean you're in the wrong place. Git "down below just as quick as yer know how." As Sir William did not respond immediately, the boy went for the steward, who took the same view of the situation and was about to enforce compliance with his orders, when another passenger arrived who fortunately knew Sir William and saved him from being ignominiously ejected.

Here is another instance of the effect of neglect in the matter of dress: One Saturday evening in 1870 Sir William and Mr. T. C. Weston of the Survey staff, landed on the shore of the upper end of the Island of Orleans, opposite the city of Quebec. Mr. Weston is always "natty" about his dress, even under adverse circumstances, but on the day in question, Sir William's appearance was pretty shabby, as they had both been roughing it for some time in the back country. Sir William suggested that as Mr. Weston was the more respectably dressed, he should go up to the hotel and try to arrange for something to eat. The latter went accordingly and ordered dinner to be got ready as soon as possible. Returning to Sir William, Mr. Weston reported favourably and in the meantime they examined some fossiliferous rocks nearby. After a while the hotel-keeper came to Mr. Weston, and looking very doubtfully at Sir William's trousers which were tucked into a pair of rusty long boots, enquired if he would set separate tables, or if Mr. Weston "would allow his man to eat with himself."

Some years before this time, his supposed peculiarities had almost caused him more serious inconvenience. He was trying to get an idea of the thickness of an immense section of the rocks along the sea shore about Percé at the east end of the Gaspé Peninsula. The strata are there well shown when the tide is out. The beds run diagonally across the beach all along and at the same time dip at a considerable angle to the horizon. Sir William was measuring the section by counting his paces, while he walked at right angles to the strike from high tide mark to the water's edge. Then by following the bed he happened to be on, back to high-water mark, he would start out afresh and "pace in" another part of the section. This process he repeated over and over again for a considerable distance along the beach.

He had been in the neighborhood for some days. At that time, the arrival of a stranger was an event in the history of the place, which was a self-sufficient gossipping little village. The present stranger was the subject of much serious discussion and many were the knowing shakes of the head when his sanity was called in question. His conduct certainly appeared very strange in the narrow light of the wisdom of Percé. He had no ostensible business to bring him there. No one knew him and he did not care to take time to make friends or to talk to the inhabitants. Some of them had watched him and found that as he walked along he muttered to himself, counting big numbers, and now and then wrote something in a note-book. It was remarked "he "carries a hammer and pounds the rocks, like an idiot," and what proved that he was crazy was the fact that he would take pieces of the broken stone, exactly like all the rest of the rock around, and would actually wrap them up in paper and carry them about with him in a bag, and even store them carefully away in his room at night. When he was out at work, the wiseacres of the place would visit his room and paw over these pieces for the positive proof of his insanity, and with a sympathetic, "poor fellow," they would retire to consult as to what was to be done. They concluded that his lunacy was apparently of a harmless type, but that he might next wander off to some other place where the people would not take such a kindly interest in him and that he might, therefore, come to grief. It was consequently resolved by the petty local authorities that he should be gently secured and sent up to Quebec en route for the Beauport Lunatic Asylum by a schooner which was ready to sail. His long zig-zag walks on the beach convinced them that he was not only hopelessly demented, but was rapidly getting worse, so while he was in the act of making one of his slants across the measures, he was seized by two men. Great was Sir William's surprise, but when they explained their object, he burst into a hearty laugh and for the first time since his arrival at Percé, he condescended to explain all about his visit and the meaning of what they had considered such queer conduct. His captors were astonished at his reasonable and interesting conversation and his affable and gentlemanlike manner, as well as by his knowledge of the French language. From that time the authorities ceased looking after him.

This was not the only time he was mistaken for a lunatic. He used to tell the following story with much glee: One morning while staying at the St. Louis Hotel in Quebec, having finished his preparations for a day's geologizing, he told the clerk to order a calèche to drive him to Beauport, about ten miles off. When Sir William appeared at the door, dressed in his "regimentals," with uncommon and unrecognizable implements dangling from a wide belt, the driver took it for granted that he was one of the pay patients about to return to the lunatic asylum, after having been on a visit to the city, as was permitted to some of the better class patients at Beauport. The calèche man was disappointed with the appearance of his fare even for a lunatic, but as the hotel clerk had hired him, he considered that the house would be responsible for the payment if he should not be able to collect anything from the crazy patient himself when he delivered him at the Asylum. He, therefore, somewhat reluctantly started. After having gone some miles out of the city, Sir William ordered a halt and went off a few yards to break a rock in search of fossils. Having reduced a quantity of it to fragments with a large hammer, he put some of them into his collecting basket. The driver was impatient over this delay, as he concluded he would not be allowed anything for the lost time when he should return to the hotel. Besides his "fare" was proving more crazy than he thought he was at first and, in fact, he began to consider him dangerous. He mistook the leather cover of his large prismatic compass for the holster of a pistol and that of his clinometer for the sheath of a dirk, while the broken stones were probably intended to throw at the driver.

Having again started, he positively refused to stop to let Sir William off a second time, but made for the Asylum by the shortest road possible. It was in vain for Logan to remonstrate. The man told him he was a dangerous lunatic and that he had orders to drive him straight to the Asylum, "where you bailong, sair." When they arrived at the gate of the Asylum grounds, it was (unfortunately for the calècheman) closed and locked. By this time Sir William's temper was fairly aroused and he flourished his geological hammer around the driver's head, telling him in tones that were not to be mistaken to "drive on." The calècheman was now really frightened. He had got the most dreadful lunatic that had ever been allowed to go out, and there was no help for it but to humor him for the time being. Sir William then resolved that the only way to make the man useful for the rest of the day was to keep up the terror he had inspired, so he compelled him to drive a long distance beyond the Asylum and only got out of the calèche to examine the rocks at such places as he could keep the driver within what the latter considered pistolshot. While thus halted, whenever a habitant happened to pass, Sir William's Jehu would stop him and relate (in French) his grievance—that he had the worst fare he ever drove in his life, that he was being compelled by the lunatic to lose his time, as, of course, he would have no money himself and he was sure that the most Mr. Russell, the proprietor of the St. Louis, would allow him was the tariff rate as far as the Asylum and return. He explained to the passers-by how, in the course of the day, his lunatic had attempted to murder him with a long knife, a pistol and a big hammer. Sir William understood French thoroughly and could hardly conceal his laughter during these dreadful recitals.

In the afternoon, by means of one argument or another he persuaded the calècheman to drive him all the way back to Quebec. On arriving at the door of the St. Louis, where he would have the protection of the police, while Sir William was carefully removing his day's collections, the driver waxed very eloquent over his adventures and related to the other calèchemen around how bravely he had defended himself from this lunatic whom he had just brought back. He then asked to see Mr. Russell himself and demanded from him three dollars which was at that time a full day's hire, totally ignoring the presence of his "fare", whereupon Sir William handed him a five dollar bill. While the man gazed in astonishment at the money, all the calèchemen about the place offered to drive him the next day for the same amount and stand their chance of being murdered.

One more case showing how often geologists, before they were properly understood, were taken for lunatics: When Logan was working at the geology of the country behind the town of Lachute, while calling at the house of Mr. Peter McArthur in the village of Dalesville, he became engaged with that gentleman in an argument on the subject of the creation of the world. Bye and bye, Mrs. McArthur, becoming impatient, said to her husband in Gaelic, "Hoot, don't bother with him any longer, don't you see he is crazy." Sir William understood the Gaelic and told the story at Lachute the next day with great relish.

When making his reconnaissance of the geology in settled districts, Logan did most of his topographical work by counting his ordinary steps while walking along the roads, at the same time noting carefully the bearing of every stretch. While thus engaged, if he was about to meet anyone likely to interrupt him, he halted and marked in his field-book the number of paces from his last note and resumed his count as soon as the person had passed.

One day, while counting his steps as usual, a dog startled him by a sudden rush which made him doubtful of his number. He remembered the odd paces exactly, but was not *quite* sure of the last hundred although he could scarcely have been mistaken. He had run up a score of nearly a mile, but rather than leave the least doubt about it, he trudged all the way back to the point he had last registered and did the work over again. But, it may be asked, how did he know the right spot from which to start again. The way was this, and it is another evidence of his painstaking exactness. He registered not only every natural feature such as the crossings of brooks, the crests of ridges, etc., but when there was nothing of this sort he noted a boulder, the kind of rock it consisted of, a big stump of pine, spruce or whatever wood it might be, or anything else which would be a local mark to refer to. His field-books contain even sketches of the peculiarities of gates, stables, houses, etc., by the way side, which might be thus identified and used again by himself or any one else for further measurements on the same ground.

Logan's first summer in the thick woods was that of 1844, when he made a complete traverse of the Gaspé peninsula, by ascending the Rivière Ste. Anne des Monts from the St. Lawrence, abandoning his canoes at the head of navigation, crossing over the top of the high range of the Shick Shock Mountains, a distance of fifteen miles, building new canoes on the south side of the watershed and descending the Cascapedia River to the Bay of Chaleurs. At that time, Sir William was new to this kind of work and his outfit, picked up here and there, was scanty and ill adapted for the undrtaking, compared with the elaborate equipment which even our junior geologists now take to the field. John Basque, an extraordinarily skillful and intelligent Mic Mac Indian of Gaspé Bay, who was then young, accompanied Logan on this "voyage," as John called it. This Indian figured largely in Sir William's notes, and he subsequently considered himself a regular member of the Geological Survey, having been afterwards employed by Mr. Murray, Mr. Richardson, Mr. Weston and the writer for some years. Many an interesting "yarn" John has spun at our camp-fires about the wonderful doings and sayings of "Mr. Sir Logan", as he called him, and between whom there appears to have been a profound friendship.

On one occasion in coming to a river, when exploring in Gaspé accompanied by John Basque, he wished to have a more correct approximation of its width than a mere guess and he hit upon a rather ingenious method. "John," said he, "bring me "some pieces of stone to throw across the river." "Do you "want pieces of conglomerate or limestone or slate, Mr. Logan," said the Indian. "Any kind will do," and after throwing repeatedly till he had just gauged the force necessary to land a stone on the opposite edge of the water, he threw with the same force along the side he was on and measured the distance. John Basque was fond of using any new word he learned. Hearing the word "fossils" and noting to what it referred, he would bring Mr. Logan pieces of stone with little marks on them and say "almost "fossils here, Mr. Logan."

On the occasion of the long traverse referred to, the appliances, as above mentioned, seem to have been most unsuitable.

For example, the dishes were all of common heavy delf instead of tin. Yet they were carried for months in soft bags which were many times daily put down upon the stony margins of the rivers and the sharp rocks of the mountains, squeezed into the little canoes with the axes, hammers and geological specimens and portaged overland on men's backs; yet not one was broken or even cracked during the whole season. At its close Sir William presented the lot to John Basque as a reward for his share in preserving them intact.

The survey through the country referred to was made by measuring the distances along the rivers with the Rochon micrometer telescope and across the mountains by the chain. Notwithstanding the many turnings and the difficulties in the long distance through an unexplored wilderness, the total length was within a fraction of what it should be according to the Admiralty survey round the coast between the extremities. A few more instances of Sir William's accuracy as a topographer may be noted. It was he who made the first survey of 180 miles of the Ottawa River and this was adopted by the Government for laying out timber limits and for other purposes.

In order to work out a certain area of the Laurentian rocks which, as he used to say, would serve for ever after, as a type of their structure or as a key by which to understand the rest, he selected the Grenville region and began to work there in 1853. His MS geological map of that region, constructed by his own hand, was a perfect marvel of neatness and accuracy.

Logan held that accurate geological mapping was impossible without accurate topography. Otherwise what is really a straight line might appear curved or crooked and a crooked one straight. So accurately did he lay down his geological lines in the wilderness of the Grenville hills, that by their means he checked off the surveyors lines sub-dividing the land and showed that the whole township had been very badly laid out.

No two lots were of the same shape or size as they should be and the concessions all had different widths. In one instance two concessions started from one side of the township and ran together into one line before they reached the other side. Had it not been for Logan's great accuracy, it would have been a long time before these errors were discovered. As it was, the Government ordered a resurvey of the whole township. He made good topographical surveys of all the rivers, lakes, mountains, etc., within the area he had selected for this typical geological survey. So exceedingly careful was he to secure the greatest degree of accuracy that he was in the habit of sighting from a fine transit on a thin knife blade fixed in the top of a staff.

He spent years in working out in the most painstaking way the geology of the townships around Richmond and Melbourne in the province of Quebec, all the time accompanying his geological work with a precise actual topographical survey, plotting the work with his own hand. During these years he made his headquarters and boarded much of the time at Gee's little tavern at the upper village of Melbourne. This small hostelry was well enough for the purpose it was intended to serve, namely, as a little road-side stopping place for farmers, and it is no reflection on Mr. Gee to say that it was no fit home for such a length of time, for a man whose life was so valuable as Logan's. The comparative discomfort and poor coarse, monotonous, and (for Logan) ill-cooked food, no doubt had a very bad effect on his health. He certainly deserved a better fate and would have had it if he had thought his own comfort worthy of serious consideration.

In the single township of Shipton, Logan spent two whole summers in making the same kind of painstaking geological and topographical surveys. It is to be regretted that when Logan died, there was no one to take advantage of the great store of material he had accumulated in his later years even after he had given up the Geological Survey, so that the results of all this admirable work are still lying dormant.

In 1862, when Mr. Jules Marcou called in question the accuracy of the work of some of Sir William's assistants at Point Levis, and the conclusions we had arrived at as to the geological structure, Sir William, instead of bandying words with him, went back to the ground and surveyed it over again to make doubly sure (although he knew already that we were right). He laid down to a scale every band of rock in its exact position and with its true thickness and flexures on the surface. The resulting map, published with his reply to Marcou, is a beautiful production and would serve as a model from which Sir William's would-be critics might profitably learn. This map was the foundation of his rejoinder, which was short and dignified and to this effect: "Here is an absolutely correct representation of the area in question from actual survey and it cannot be gainsaid. If you assert that the structure is different, you necessarily say what is not true."

Sir William's reply is addressed to Mr. Joachim Barrande, and the opening words are as follows: "I have neither time nor inclination for controversial geology. I have never criticised any of Mr. Marcou's remarks on rocks in Canada or out of it, nor have I suggested any such criticisms to others; but a charge of carelessness on the part of public officers in the discharge of their duties appears to me, on the present occasion, to require a few words of reply, lest you and others might suppose the accusation to have some foundation." Here we have an illustration of one of the chief reasons why Sir William was able to establish such a noted *esprit de corps* on the Survey and why he had such an enthusiastic following.

Examples of Logan's accuracy as a surveyor and draftsman might be greatly multiplied, and he was equally careful in other matters. Thus if there was any doubt at all as to a number or a technical name, which was to appear in one of the reports, he would spend any amount of time and take no end of trouble to enquire or to hunt up all available authorities on the subject in order to have it right. He was a very close proof reader and yet he would never allow the forms to go to press until Mr. John Lovell, the printer, had also read and signed them. Hence very few mistakes are to be found in the reports he supervised.

At one of these final proof readings (Mr. Lovell informed the writer) a question arose as to whether there should be an *e* or an *a* in the spelling of the name of an obscure French Canadian who lived in Terrebonne, and which was casually mentioned in a report. Before Sir William would allow the form to go to press he wrote out to Terrebonne and awaited a reply.

To get through so much painstaking work, of course, required long hours. It has already been mentioned how he started work even in the city, as early as 5 o'clock in the morning and with an interval of about one hour for breakfast, kept it up till seven in the evening and again after dinner till all hours of the night. The rest of us often worked in the office till about midnight all winter, but at that hour Sir William appeared as little disposed to stop as earlier in the evening. No person seemed to know when he did retire. If one happened to pass the office at 1 or 2 o'clock in the morning he could always see the gas burning brightly through the curtainless windows and Sir William intently at work over a mapping table or standing at his high desk. He could certainly get along with very little sleep and being tough and strong he stood it well. But there is no doubt it told upon him in the end and must have been the means of shortening his life. He was very reluctant to give up the active administration of the Survey, to which his heart was so devoted, and it was only on the urgent advice of Dr. Craik (who was his physician after the death of Dr. Fraser) that he consented to resign.

In the field, Logan did a large share of hard labour. He would never accept any assistance, even from his hired men, for any work he thought he was strong enough to do himself. He appeared to take great pride in carrying home big loads of specimens, and a geologist's specimens are of a heavy kind. Sir William had a fishing basket of the largest size, which he would fill to the top daily. Each rock-specimen was nearly half as large as.a brick. If one of the men insisted on relieving him of his load, he would say, rather sharply, "Do you suppose I'm too weak to carry it myself.." He would say to members of the staff: "You must never grudge to carry home a good specimen, no matter how heavy, if you can manage it at all."

A friend of Logan's, the late Col. William Osborne Smith, once accompanied Sir William on a geological tramp to the "Back River", north of Montreal. During the day the latter loaded both himself and his friend with fossils. At first they managed to tote them around pretty well; but even before they started back for the city, their burdens felt very heavy and irksome. Sir William had filled his basket with all the smaller specimens so as to keep them together, while two great slabs with some fossil shells upon them had been awarded the Colonel to carry, one on each arm. The latter, who was a large man, not to be outdone by the little geologist, struggled along as best he could, but was thoroughly "used up" on reaching home and formed a very unfavourable opinion of the pleasures of field geology.

Although the branch of geology at which Logan more especially distinguished himself was the crystalline rocks, he was very fond of palaeontology and could make excellent drawings of fossils. He delighted to collect and study them. "Fossils," he used to say, "are the poetry of geology." A working man belonging to the United States side of Missisquoi Bay and who had been observing Sir William one day, and "taking stock of him," as he expressed it, remarked dryly, "he jest gloats over them putrifactions."

Logan was always so completely interested and absorbed in his field work of the day that he never thought of his camp or his boarding house until reminded by the darkness that he could work no longer. Even then, he was often so intent on doing a little more, that he would light matches or get his assistant (if he had one) to light them for him, so that he might read his compass and thus be able to take a few more bearings. He may have begun in the morning miles away from his quarters and perhaps worked gradually further off all day, so that after reluctantly buckling up his instruments, it would frequently take him till all hours of the night to trudge back to his supper and bed. The ordinary government employé might consider that, after he had worked from daylight to dark, with little or nothing to eat, climbing over rocks or scrambling through the woods, and then walking 5 or 10 miles home, he would be entitled to go to bed after eating his frugal supper of bread and pork. Not so, however, with Logan. All the way home he had been considering the results and general interpretation of the day's operations and as soon as he had had something to eat he would get out his field-book and first "ink" over the pencilled notes and figures made during the day, then write up his general impressions, and, if he could possibly steal a little more time from sleep, would get out his plotting sheets and lay down to a scale some or all of the measurements made in the course of the day.

In his camp, far away in the woods, when his stock of candles ran out he would get the cook or any of the party, less tired than the rest, to prepare a lot of birch bark rolls or torches, and when he had spread his mapping sheets on a box at his tent door, would get the man to hold a blazing torch a short distance above his head, so that he might plot his day's work before rolling himself up in his blanket. As one torch burnt low, the man would light another and another, and so enable the indefatigable geologist to work till far on in the night.

One of the great secrets of Logan's success and the high estimation in which he was universally held, was his fine sense of justice and his real desire to promote the welfare and interest of all with whom he had to do. He took great pleasure in giving the fullest credit to all of his assistants and in aiding them by his wisdom and judicious foresight, no less than by his knowledge of geology and other sciences. His great modesty prevented him from giving any indication of his knowledge until circumstances required him to use it. Many a time he had to listen respectfully to a man displaying his ignorance of a matter with which he himself was well acquainted, but one never heard of him offending the feelings of such a man by making him feel his ignorance. He never appeared impatient of hearing what a man might wish to say on a geological subject, nor was he above learning from the humblest.

In prosecuting the work of the Survey, he tried to surround himself with the best men he could find, and he succeeded wonderfully well, especially when we consider the limited amount of money at his disposal.

But his assistants were only human after all, and like other individuals of our species they might occasionally make a mistake or even get into a little scrape once in a while. On such occasions, Sir William would always interest himself in the case, as much indeed as if it were his own, and would not rest till the matter was rectified and everything going smoothly again.

Sir William, although an undemonstrative man, was very much attached to his assistants, and notwithstanding such failings or shortcomings as might be their misfortune, he took a pride in them simply (as it were) because they were his own men. This was another factor in keeping up the marked *esprit de corps* which existed. The staff of the Canadian Survey appreciated the great interest which Logan took in their welfare and they in return did all they could to carry out his wishes and this aided materially in building up the great reputation he enjoyed.

He availed himself eagerly of every opportunity to speak well—even flatteringly—of us to strangers. As a Canadian, I was much gratified at the meeting of the British Association at Bath in 1864, to notice the great respect and esteem in which *our* geologist was held by those of Great Britain and the Continent of Europe.

In regard to religion, Sir William was supposed to be a Presbyterian like his father before him, but he made no parade of his piety, nor did he claim to belong to any particular sect.

During his early life there was not the same liberality and toleration in religious matters as at the present day, and it is possible that circumstances may have occurred to disgust a man of his broad and generous views, with the narrow bigotry which denies salvation to every man who cannot fall in with the narrow views and the peculiar shade of doctrine which they have formulated for the information and guidance of the Creator. Be this as it may, religious discussion was a thing Logan always avoided. He was not, however, to be considered by any means an irreligious man. He always treated the clergy, and spoke of them, with the greatest respect and among their number he counted many of his best friends.

Sir William himself used to tell a story of the first time he went to a place of public worship. It appears he was taken by his pious parents when a very small boy to St. Gabriel's Presbyterian Church. After he had dangled his legs about as they hung from a high board seat, and yawned and fretted through a tedious service, the collection plate was passed round. Little Logan's interest was at once awakened at the sight of so many "bawbees." He marvelled at the kindness of the old gentleman when he presented, as he thought, the whole plateful to him. He joyfully seized all the coins he could grasp in one of his little hands and was about to grab with the other, when his father caught him by the wrist and whispered to him to drop the treasure. But the boy, believing he was fairly entitled to what the old elder had offered him, refused to surrender, and it was not till his parent had rapped him repeatedly over the knuckles with his other hand, that the little fellow was forced to drop the money.

Sir William did not believe in inconsiderate generosity or indiscriminate charity. He acted as if every one should feel that he had earned all he got. Still there were cases when he was very liberal. On one occasion he presented a man who had been for a time on the Survey, with a hundred pounds, when he thought he needed it, and other members of the staff have experienced his liberality not only in money but in other considerate acts.

When in the woods or the country he rather sympathized with the youthful frolics of his assistants and of the Indians. The latter got drunk whenever they could and many stories were related of their escapades while enjoying an occasional spree, which in those days society did not regard as so reprehensive an act as it would be considered at the present time.

He was not a time-server nor a respecter of persons, and of course no suspicion of toadyism could ever be laid to his charge. As he scorned to flatter anyone, so no one would be likely to gain anything by attempting to flatter him.

At the International Exhibition of 1855, when the Queen honored the Canadian geological section with a visit, Mr. Logan, as he then was, escorted Her Majesty through the collection and talked to her precisely as he would to any other lady, in his usual genial manner. Her Majesty was delighted, not only with his charming grace and manner, but with his innocent, sincere and independent nature. And it was with a real pleasure that she soon after conferred on him the honor of Knighthood for his great services both to science and his native Canada. On the occasion just referred to, she had personally invited him to pay a visit to Windsor Castle for this purpose.

Sir William, as is well known, was a confirmed bachelor and all his brothers were also unmarried. Being rich, clever, kind and generally eligible, he was often advised by the ladies to marry or asked why he had not taken a wife already. This was a matter he would rather avoid and so would change the subject as soon as possible. To one lady who had attractive daughters he said in reply to her question, "I am already wedded to the rocks." To another he answered: "It would take up too much of my time. I really have not the time to spare. Other rocks than 'rock the cradle' claim my whole attention."

Another story says that he took his stand as a bachelor from his sad experience of the obstinacy with which the fair sex insisted on tidying up his rooms according to their own preconceived notions, no matter what vexation and inconvenience it caused him. Without dreaming that any one could be so sacrilegious as to disturb the papers, maps and specimens in which his soul was centred, when staying at a country hotel, for example, he would leave his work spread out on the table and the specimens which he had collected and carried home with so much labor, lying round the room. On returning in the evening, his disgust was supreme on finding the table pushed into a corner, covered up with a cloth, his papers gathered into a neat pile and all his specimens gone. The saucy chambermaid said that she "had pitched out those dirty stones and had done up the room as it ought to be, and if the missus was goin' to allow any more of them unregularities about any of her rooms she would pack her trunk and leave the house."

It was said that on one occasion a house-maid, not only threw away a number of fossils which Logan valued very highly, but actually took the trouble to carry them off and hide them in the corner of a fence, so that "that queer little man," as she called him, "would not be likely to bring them back again to mess up the room." Sir William probably reflected that if housemaids and landladies can be such tyrants, what might a wife prove to be.

Logan used to plot his maps on unfolded sheets of foolscap. It is related that at one tavern, at which he stopped for some time, the housemaid took a fancy to him and said to her friends that althoug! his clothes were a little rough he was a "steady" man, hadn't taken a drop since he came to the house and there was something about him she liked; and in fact a girl might do worse than marry such a man. But as the little man did not appear to understand or notice her advances, she resolved to declare her love. So during the day when he was miles away, she quietly wrote a lot of love verses of her own composition, addressed to him, all over the face of his map-sheets, thinking when he read them on his return that such a rough-looking man, at his age, would feel flattered by the endearing sentiments of a young, fresh and good-looking girl. Good-natured as Sir William was, this was altogether too much for him; and great was the disappointment and even astonishment of the maid when he could not conceal his annoyance at the occurrence. It was not the girl's sentiments themselves that annoyed him so much as the spoiling of the beautiful original maps, on which he had spent many a night's labor. She had used pen and ink in her literary efforts and, of course, Logan did not care to fyle them among the records of the Department with such permanent ungeological notes scrawled all over them in a woman's hand-writing.

Although Sir William was such a devoté of science, he was by no means unsociable, but would occasionally take an evening to dine with friends in whose society he took pleasure. Among these were the families of the late Judge Gale and the Hon. John Young. On such occasions he was the centre of attention. The whole company listened to the charming stories he told or to the Scotch songs he sang in a voice of rare sweetness.

His stock of capital stories, jokes and *bon mots* seemed inexhaustible, so much so that a lady once said to him, "Sir William, I don't know where you find all those witty things and good stories, unless you geologists do nothing else all day but crack jokes and make up new stories, when you are supposed to be cracking stones and puzzling over theories about rocks." Although this impeachment was not literally true, still without apparently stopping to think of it, jokes and witty sayings, suitable to the occasion, would come to him as readily as to Sir John Macdonald, and his merry, hearty laugh used to echo through the building as sure as he got into conversation with any congenial spirit.

He would also enjoy a little fun in a more homely way, as the following will show. When he and Mr. Richardson were working on the Kemp road towards Lake Temiscouata they slept in the farm houses, but in their own blankets, generally on the floor, near the stove, the favorite resort also of the cats and dogs. The result was that after a time the blankets became alive with fleas. Sir William resolved to be rid of them. So one morning, in a house where there were a lot of smart little children, while breakfast was being prepared he spread his blanket on the floor and offered the children a penny a dozen for all the fleas they could catch and drown in cups of water. At first there was plenty of game for all the little hunters, but after a time, when the stock was reduced the search became keen, and Sir William enjoyed the sport immensely. Near the end of the hunt, when a fresh flea was discovered and two little hands would grab for it at the same moment, the unsuccessful hunter would call out, "Now, Johnny, that's my flea. I saw him first." and appeal to Sir William to settle the dispute.

When an intelligent man who might appreciate a lesson in geology, called on Logan in the Museum, he took great pains to explain everything. This he had the faculty of doing in such a way as to completely fascinate the listener, and these incidental lectures from such a master, imprinted on the listener an appreciation of the science of geology which he would never otherwise have had. When he was willing to bestow so much trouble upon strangers, it will be understood that he took pleasure in teaching his assistants. His revisions of the reports of the members of the staff were lessons not only in geology, but in English composition.

Sometimes his earnestness and his paternal desire (so to speak) to benefit his student would cause him to talk very plainly, but the mutual good feeling was so thorough that nothing was thought of it. In fact, this was so well understood by every member of the Survey that if he showed a studious politeness instead of the usual unceremonious style, one might be sure there was something wrong and that he was temporarily annoyed.

One day the late Mr. Richard Oatey, the practical miner of the Survey, discussed with Sir William a question connected with a theory of the filling of metalliferous veins, and in the course of discussion, Mr. Oatey remarked, "Sir William, iron is the mother of all the metals." "Oh, it is, eh?" said Sir William. "Then pray tell me which metal is the father."

One point led to another and finally Sir William gave him a short sketch of geological history in general, occupying more than an hour. Oatey listened patiently, but as soon as the lecture was over, he retired to a sort of smoking room in the basement of the building and filled his pipe. When he got it fairly a-light and drawing to his satisfaction, he remarked to two or three of us around: "Sir William was very good to take so much trouble to tell me all these things. He is a fine man, is Sir William, and talks beautifully. But after all's said and done, I believe the world is just as God made it, and what Sir William said won't make me think any different." "I am sure Mr. Oatey," said I, "that Sir William is also of the opinion that God made the world, and he is devoting his life to try to find out just how it was that He did make it."

Logan had a keen sense of humor and would aid in a little fun even at his own expense. In 1858, when he was working in the valley of the River Rouge, in Argenteuil county, he had as one of his assistants a most gentlemanlike and estimable young man, but unfortunately perfectly deaf. One day he got lost in the woods and did not return at the time appointed. The dog belonging to the camp had followed at his heels, but apparently with misgivings that his master did not know where he was going. Sir William, who was a good bush-ranger, went in search and after some time came up with him, although he could not use the ordinary method of shouting for a lost man. Sir William said that when he approached them, the dog started to come to him, but after a few steps, he stopped and turning his head round towards the young man gave him a look which said as plainly as words could utter it: "I'm hanged if I'll ever go with you again."

About 20 years ago, when he was working on the east side of Missisquoi Bay, about Phillipsburgh, Highgate Springs, etc., he was returning to his stopping place late in the evening, very tired and hungry. As he passed the railroad station on the way, he saw the "chore-boy" of a tavern with an express waggon rolling a barrel of whiskey, which had just been landed from a train. He asked if he might drive with him to the village. The boy said, "All right, as soon as I get up this whiskey barrel." When he had rolled the barrel up a plank and fastened the back board of the waggon, he said, "Now, old man, jump up and sit a straddle of the barrel to keep it from rollin' about, and I'll give you a ride up for nothin'." Sir William did as he was ordered and had a grand ride up town, no doubt chuckling to himself all the way; but he said he would as soon not have met any of his city friends, as he was thus trying to make himself useful in steadying the whiskey barrel.

During Sir William's lifetime, Marcou was his chief detractor but since his death his reputation has been assailed by others, but we may well afford to smile at these individuals. Logan's name and fame will flourish long after theirs are forgotten.

His goodness of heart took the form of kindness and consideration rather than of liberality in expenditure. He did not strive for fame or reputation from narrow, selfish and egotistical motives, or, as is often said of others, "to make a name for himself." Sir William's object was to do good work and to benefit his native Canada, without apparently a thought of fame. A scientific name and reputation above all other Canadians, he certainly got, but it came incidentally and unsought. Sir William Logan's death was keenly felt by thousands and his memory will be ever green in the hearts of those who knew him and loved him.

STUDENTS' PAPERS

BASIC OPEN-HEARTH STEEL MANUFACTURE, AS CARRIED OUT BY THE DOMINION IRON AND STEEL COMPANY, AT SYDNEY, C.B.*

By FRANK E. LATHE, McGill University, Montreal.

INTRODUCTORY.

The ore used in the blast furnaces at Sydney is the "Wabana" ore, obtained from the company's mines at Bell Island, Newfoundland. It is a silicious hematite of medium grade, as will be seen from the following typical ore analysis:—

H_2O	1.76 %	Al_2O_3	4.81%
Fe	50.07	CaO	2.05
SiO_2	13.79	MnO	trace
P	0.746	MgO	0.42
S	0.042	$C_4H_6O_6$	0.34

The phosphorus, as always happens in the blast furnace, passes into the pig, giving in this case an iron of about the following average composition:—

C	3.75 %	S	0.03%
Si	1.10	Mn	0.30
P	1.40		

To treat such a pig in any acid furnace is impossible, because for the retention of the phosphoric acid in the slag the latter must be strongly basic, a condition which can evidently not be reached in an acid-lined furnace. Neither is this pig suited to basic Bessemer practice, because, while phosphorus is the enemy of acid work, it should be present in quantities of from one and a half to two per cent. to furnish by its oxidation sufficient heat in the basic Bessemer converter. Hence, any pig containing less phosphorus than this, and more than could be allowed in the finished product, is best treated in the basic open-hearth furnace.

* Student's paper presented in competition for the prizes offered annually by the Institute. Awarded President's Gold Medal and Prize of $25.

HISTORICAL NOTE.

The open-hearth process was made possible by the work of the Siemens Brothers, who, by the manufacture of producer gas and the invention of the regenerative furnace, rendered comparatively easy the attainment of the necessary temperature. Their great difficulty was to find a furnace material sufficiently refractory, but persistent effort in this direction was also successful, and in 1868 steel was being made at Birmingham of scrap and ore. About this time P. and E. Martin, in France, melted together pig and large quantities of scrap, the latter serving to dilute the impurities of the former. In all modern work, however, it is customary to use ore, scrap and pig, thus uniting the two early processes.

MODERN PRACTICE—NATURE OF CHARGE.

Basic open-hearth furnace charges consist of pig-iron, scrap, ore, and lime or limestone. The pig iron may be either cold or fluid, though the tendency now is to use hot metal where obtainable. Its content of carbon, phosphorus and silicon may be almost anything, as they are easily removed, but for satisfactory work the percentage of sulphur should be low. As will be explained later, some sulphur may be removed by a rather lengthy process, but in general it seems easier to perform this operation in the blast furnace. The scrap, as phosphorus is not very objectionable, may be obtained more cheaply than that for acid open-hearth work. Ores charged are sometimes phosphoric, but they should be low in silica and sulphur. They are generally chosen with considerable care. The lime or limestone should, in general, be of high quality, but slight variations in this will be discussed later. The purpose of the lime addition is to render the slag very basic, and thus enable it to hold in combination considerable phosphoric acid. This addition of base effects a great saving of iron, which would otherwise be oxidized and enter the slag. After the charge is melted, and during the process of purification, it is generally found necessary to add ore to complete the oxidation, and sometimes lime or fluorspar to make the slag of right fluidity.

Attainment of Temperature.

To melt the scrap, which may be very low in carbon, to keep it fluid during the endothermic oxidation of the carbon by the ore, and to have it in condition for tapping out the charge even with a very low carbon content, an extremely high temperature is required. The puddling furnace gives us an example of about the highest temperature to be obtained by ordinary means, but this is insufficient to keep the low carbon iron in a fluid condition. The following account of open-hearth construction will show why it is a comparatively simple matter to reach the necessary temperature in one of these furnaces, which are always made regenerative.

A regenerative furnace, in the ordinary acceptance of the term, means a furnace using gaseous fuel, and from which the gases pass out to the stack through one of two sets of chambers filled with loose brickwork, a suitable reversing gear enabling the waste gases to pass into the other set, while either the incoming air for combustion, or both the air and gaseous fuel, pass through the already hot brickwork. Let us suppose for a moment that the furnace and all the chambers are cold, and that air and gas at zero centigrade are burned in the furnace. A temperature of T° is produced, and the gases passing out through one set of chambers heat them to nearly that temperature. If then the direction of the gases is reversed, the incoming gases will be highly heated before combining, and if an equal amount of heat be generated by their combination, this time the temperature will be nearly 2T°. It is easy to see that by continued reversal an enormously high temperature could be reached, which would find its limit in the temperature of dissociation of the products of combustion did not the melting-point of the best silica bricks fix a lower limit. Of course in actual practice there is a very considerable amount of radiation, and some heat must also be supplied for the chemical reaction and to heat up the charge, but with a generous supply of even ordinary producer gas, with its sixty per cent. of nitrogen, the real difficulty is not in reaching the desired temperature, but in doing so without melting down the furnace.

FURNACE ACCESSORIES.

In the older types of furnace the regenerators were usually placed directly underneath the hearth, thus greatly economizing space, but years of experience have proved that while such an arrangement may work well for a time, the alternate heating and cooling, together with the weight of the furnace, render the life of the regenerators a very brief one, and the support for the furnace decidedly unsafe. Hence, in all modern practice it has been the custom to place the regenerators away from the furnace, and to support the latter on steel girders, which thus allow a good air circulation. Between the furnace and the regenerators, at either end, are usually placed "slag pockets," or "dust-catchers." Many fine particles of solid matter are swept over into the gas and air passages by the strong current, and if they were allowed to pass into the regenerators would quickly clog them up and necessitate stoppage for repairs. But coming into the slag pockets, which are large open spaces, much of the dust settles, and the regenerators have a considerably longer life. Also in repairing the ports, or "block," many bricks fall down the passages, and can be removed from the slag pockets, while such an operation would be impossible if they entered the regenerators. Most modern furnaces have for the reversal of gas a water-sealed valve, and usually a "butterfly" valve for the air. Each furnace has a separate stack, with damper, while dampers also control the admission of gas and air.

TYPES OF MODERN FURNACES.

Open-hearth furnaces are of two general types, stationary and tilting. In the former there is solid brickwork connecting the ports with the main body of the furnace, this being quite immovable. In the latter the ports are separate from the furnace proper, and the furnace either rolls forward on a horizontal support, as in the Wellman type, or turns on rollers in a circular support, thereby making continuous work possible, as in the Campbell furnace. Certain advantages have been claimed for each, and they may be summed up as follows:—

(1) Stationary furnaces are cheaper to construct, and last longer, both in frames, roof, etc.

(2) (*a*) Wellman furnaces, though more costly than stationary, are less so than those of the Campbell type. The tap-hole may be made ready for opening up some time before the actual tap is made, and thus the furnace can be tapped at a moment's notice. This is very valuable for special steels. The back wall can be made higher up with the furnace tilted, thus saving the brickwork. Holes in the bottom may be easily drained by tilting the furnace, thus simplifying repairs.

(*b*) The Campbell furnace has all the working advantages of the Wellman, and these others:—In tapping the furnace the ports do not become separated from the furnace opening, thus letting in cold air. In a Wellman furnace the gas and air have to be shut off if the furnace is tilted far, while this need never be done with a Campbell furnace. While the back wall of a Wellman may be made higher than that of a stationary furnace the lining often does not set well owing to the cold air which necessarily enters, but as the axis of rotation of a Campbell furnace passes through the centre of the ports the gas can be kept on, thus insuring a good set.

THE DOMINION IRON AND STEEL COMPANY'S WORKS.

General Description.

The open-hearth plant consists of ten fifty-ton furnaces, eight of the Campbell type and two stationary, supplied by a two hundred and seventy-five ton Campbell mixer, which holds molten metal from the four blast furnaces. The open-hearth furnaces are built with the charging floor on the ground level, and slag-pits, fifteen feet deep, behind. As intimated above, all these are basic furnaces. Producer gas is supplied by forty-three water-bottom producers, twenty-seven of these being on one pipe line and supplying six of the furnaces, while two sets of eight producers supply two furnaces each. For use when the producer gas supply is short are pipes carrying coke-oven gas, this being admitted directly to the furnaces without regeneration, while the producer gas is always regenerated, as of course is also the air. A trestle running just behind the producers, as shown in the drawing, brings up coal, ore and limestone for use in the open-hearth furnaces. The furnaces are charged by two Wellman electric chargers, running on tracks of fourteen feet four inches gauge, and carrying boxes holding up to three tons of pig or scrap. Running directly over the furnaces and extending away from the charging tracks to the opposite side of the building are three seventy-five ton electric cranes, used for tapping, pouring into ingot moulds, removing slag, etc. Each crane has also a twenty-ton runner. In one corner of the building, steel castings are made, and running along here on standard gauge tracks is a steam crane for handling moulds, etc. Regenerators are situated directly under the charging tracks.

Furnaces.

The furnaces, as may be seen from the drawings and photographs, are rectangular in shape, the hearth being twenty-seven feet six inches long and twelve feet ten and one-half inches in width. They are made of the best silica brick enclosed almost entirely by riveted steel plates, and bound together by strong tie-rods. In the front are three doors, each about three feet square, for charging, and at the back are the tap-hole with runner, and the hole with basin used in charging molten pig iron. Facing the ports at each end is a water-jacket. The roof, of silica brick, is about seven feet above the door-plate, allowing the gases to run through the furnace very freely without excessive roof contact. The hearth of the furnace is made of basic material, up to within twenty-eight inches of the door-plate on the bottom, and sloping gradually up to the doors, extending even higher between them and at the back . The weight of the roof is carried largely on angle irons placed lengthwise along the furnace, just where the roof joins the sides. This prevents an excessive pressure of the silica brick upon the magnesite brick below. It is not found necessary to put any chrome brick between the two, although this used to be done as a safeguard. The magnesite brick runs about six inches above the door-plate level. The method of making the bottom and sides, and the materials used, will be described later.

The Ports.

As will be seen from the drawings, the gas and air are not allowed to come into contact with each other until they enter the furnace. The effect of this will be seen in the regulation of the temperature. The passages are inclined downward so that the gases may rather come into contact with the metal than the roof, and the gas port is underneath that for the air so that there may be no excessive oxidation of the metal, and to facilitate a mixture of the light producer gas and heavier air. Silica bricks are used in their internal construction.

Slag Pockets.

These are three feet wide, six feet in extreme height, and extend back about twelve feet till they open into the regenerative chambers, near the top. Clay bricks are used in their construction.

Regenerators.

The regenerators vary slightly in size for the different furnaces, but the following may be taken as an average:—length, twenty-nine feet two inches, both gas and air; width, gas, five feet nine inches; width, air, eight feet nine inches; height of checker-work in each, eight feet; greatest depth above drains, twelve feet; depth of drains, two feet six inches; number in air chamber, four; in gas chamber, three; width of spaces between bricks, four inches. Clay bricks are used in these, and are simply stacked without any mortar or cement.

Hydraulic Cylinders.

They are two in number for each furnace, and are placed under the charging floor and betweed the regenerators. They have fifteen-inch cylinders and a nine-foot stroke.

Reversing Valves.

These are on the ground level, in the sheds shown in the drawing. A Forter water-sealed valve is used for the reversal of gas, while a butterfly valve controls the air.

Starting a Furnace.

(*a*). *Drying*—Before making up the bottom the furnace must be thoroughly dried. A fire is first made at the back of the stack, and the hot gases are allowed to pass up the chimney to cause a draft. Wood fires are made in the furnace—or more often coke-oven gas jets are put in—and the gases pass out through the regenerators, this continuing for several days. Then some coke-oven gas is turned on through the ports and burnt for about twenty-four hours, reversals being quickened from about once in two hours to once in half an hour. At such time great care has to be exercised to keep the roof in shape, for it generally expands very unequally, and has to be kept down by wedges under the tie-rods where it tends to rise highest. There is also a danger of overheating the roof, for a new roof is much more easily burnt down than an old one, and in a comparatively cold furnace the light gases rise to the top very quickly. When the regenerators on the outgoing side have assumed a dull red heat, the producer gas is first put on. Great care has to be observed in this, for if an unburnt mixture of gas and air, present in the regenerators on account of the furnace being too cool to cause complete combustion, should be returned to the furnace, an explosion is likely to occur, destroying the checker-work, and perhaps also wrecking the furnace walls and roof. This danger is lessened by standing the reversing valves on the centre for about half a minute before throwing completely over, and thus allowing the passages to become thoroughly cleared of any unburnt gas. The time of reversal is soon reduced to twenty minutes, and the furnace should now be hot enough to allow work to commence on the bottom.

(*b*). *Making Bottom.*—All brickwork that will at any time be in contact with slag or metal should be covered with magnesite and this is mixed with about one-third its volume of slag before putting in, because of itself it is so refractory that it would not set. Only a little can be put in at a time, and it is allowed to thoroughly frit on, being spread in a fairly even layer. This is continued till the bottom is raised to a height twenty-eight inches below the door-plate. Slag is not mixed with the magnesite used on the front and back walls, but instead the magnesite is stirred up with tar, which in coking binds the refractory particles firmly together. For the final protection of the somewhat costly magnesite, burnt dolomite, mixed with tar is thrown in. This is considerably cheaper than the magnesite, and though eaten away more readily can be easily replaced. When the furnace is well lined it should be prepared for charging by filling the tap-hole, which is about five inches in diameter, with dry magnesite. On the outside is put a plug of mud, which dries and keeps the magnesite in position, while the spout or runner is also made up with mud. The magnesite on the inside of the hole comes in contact with the slag, and sets sufficiently to keep the metal from escaping.

Early Charges.

The first charge of an open-hearth furnace is made considerably under the maximum weight, and the charges are increased only gradually until the furnace has proved itself to be in good working condition, and the brickwork has become well seasoned. Great care is necessary at first, as a new roof is very easily melted and requires constant attention.

Working a Regular Charge.

There is first put in about seven thousand pounds of Routledge limestone, carrying a small per centage of silica; then about twelve thousand pounds of stone from the company's quarries at Marble Mountain, which is practically pure. This is followed by perhaps ten thousand pounds of iron ore and eleven thousand more of the Marble Mountain stone. Then comes the scrap, varying in amount from twenty to forty-five thousand pounds, but averaging rather under thirty thousand. These are all charged in quick succession. If fluid pig shall not be available during the progress of the heat, cold pig is added, either at once or after the lapse of a couple of hours. Pig, cold or fluid, is added to make the charge of pig and scrap about one hundred and fifteen thousand pounds.

After charging, the furnace does not need watching for some time, as with the cold stock in there is no danger of overheating. In the course of three or four hours the scrap will usually have melted down a little, and if then available, the fluid is added. A violent boiling commences at once, for not only is carbon monoxide being produced by the oxidation of the carbon in the pig by the ore, but also much carbon dioxide rises from the limestone, this being considerably reduced in passing through the pig iron, so that a great deal of the monoxide emerges from the bath. At such a time the gas needs to be shut down very materially, and even if cut off altogether a considerable flame will remain. In charging it has been observed that a silicious limestone is put in first, and the purer limestone on top. Were pure limestone put in the bottom in contact with the basic lining of the furnace, as is sometimes done, the chances are that it would remain there, and the metal would perhaps be quite phosphoric, even though sufficient limestone had been charged. But with a certain amount of silica in the limestone it loosens very much more readily from the bottom and thus quickens the operation. It often happens that a large amount of lime rises in a compact mass from the bottom, and floating on top of the metal would remain almost unchanged without special treatment. A few shovelfuls of fluorspar, however, cause it to melt rapidly, and it passes into the slag. Usually the slag at this stage is too thick, and some fluorspar is added to make it more fluid. Little fluorspar is required by a heat when it is boiling well under the action of the ore. When the lime has cleared up fairly well from the bottom, tests are taken out and poured into small wrought iron moulds, being removed as soon as solid, water-cooled and broken. From the fracture it is easy to judge whether the percentage of carbon is very high. Should it be unusually high, and the bottom almost clear of lime and ore, a box of three thousand pounds of magnetite is sometimes put in by the charging machine, but it is more usual to shovel in smaller amounts by hand. When the melter—the man in charge of the furnace—believes the carbon is down to about eight-tenths of one per cent., the steel being for rails, a test is usually taken, air-cooled and sent to the laboratory to be analysed for carbon, phosphorus and sulphur. If the last two are below the limit, four hundredths of one per cent. for each, approximately, no more analyses will be made for them, and further tests will be for carbon alone, at intervals of perhaps half an hour. When the carbon is found low enough, down to six-tenths, a wrought iron bar, one and three-quarters of an inch square, and having a carbon content of about fourteen hundredths, is put in to test the temperature of the steel. If hot enough for tapping and pouring, the bar will be quickly melted almost squarely off, though sometimes the bath is so cold that the bar will scarcely melt at all. If hot enough, the tap-hole is at once cleared of all loose magnesite, and the large ladle brought into position by the crane. Fifteen hundred pounds of eighty per cent. ferro-manganese, three hundred and fifty pounds of fifty per cent. and three hundred of ten per cent. ferro-silicon have already been brought and placed on iron plates, ready for throwing into the ladle, and enough coke dust is now brought to recarburize the steel to the proper composition, the percentage of carbon in the metal having been estimated by the foreman. The tapping bar consists of three wrought iron bars clamped together, and is brought up by the crane runner and forced through into the furnace by several men. Usually very little trouble is experienced in this, and the tap can be made in a few seconds after all is ready. The coke, ferro-silicon and ferro-manganese, are now thrown into the ladle as the steel pours out. The ladles are made to hold all the steel, but only a part of the slag, much of which overflows into the pit. The ladle is then taken away, and the ingots, weighing about sixty-one hundred pounds each, are cast. The ladles have each a two-inch hole in the bottom, into which a graphite stopper is put from the inside of the ladle. The ingot moulds stand on narrow gage cars, and the latter are taken away to the ingot stripper, where the moulds are removed, and the ingots, still almost white hot, carried to the blooming mill. The ladle is taken away from the furnace as soon as all the steel is out, and the last of the slag is simply poured into the pit. When the furnace is completely empty it is turned back from the tilted position necessary for tapping, and the melter looks carefully for any holes there may be in the sides or bottom. Usually the bottom will be found in good condition, though there may occasionally be a very considerable delay for repairs. Holes may be drained by tilting the furnace, or in stationary furnaces, by the slow and difficult process of cleaning out with long rabbles. It is seldom that any hole has gone deep enough to require the use of anything but dolomite. The sides are almost always eaten away along the slag line, because the pig iron contains up to one and a half per cent. of silicon, and makes an acid slag which attacks the lining. Burnt dolomite is thrown all along the back and sides, and is put in at the front by means of a long spoon. During this operation the gas is shut off to enable the workmen to see well, but it is then immediately again turned on, and in about ten minutes the dolomite will have set enough to admit of the furnace being recharged.

EXAMPLES.

To give a clearer idea of the practical work, two actual heats are shown here:—

HEAT A.

Previous heats on roof	78
" " ports	114
" " regenerators	114

Tapped previous heat, 6.55 a.m. Began charging, 7.25 a.m.
Finished charging cold stock, 8.15 a.m.
Finished charging fluid metal, 11.30 a.m.

Charge:—

Steel scrap pit	26,000 lbs.
Cold pig	33,250 "
Fluid pig from mixer, 10.45 a.m.	17,300 "
Fluid pig from mixer, 11.30 a.m.	40,900 "
Total charge	117,450 lbs.
Iron ore	11,000 "
Marble Mountain limestone	32,000 "

Quick Tests:—

When taken.	C.	P.	S.
7.35 p.m.	0.65 %	0.250 %	0.035 %
8.10 p.m.	0.58	0.090	
8.35 p.m.	0.51	0.045	

Estimated carbon at tap, 0.45%.
Carbon ordered between 0.50% and 0.60%.

Added during heat to furnace:—

Ore	1,000 lbs.
Fluorspar	1,400 "

Added in Ladle:—

Ferro-manganese	1,500 lbs.
Coke dust	120 "

Analysis of Ingots:—

C.	P.	S.	Mn.
0.60%	0.039%	0.030%	0.84%

Heat tapped, 9.25 p.m.—time 14 hrs.

HEAT B.

Previous heats on roof	100
" " ports	136
" " " regenerators	136

Tapped previous heat, 8.25 p.m., June 18.
Began charging, 8.55 p.m.

Charge:—

Open hearth castings	17,050 lbs.
Blooming mill crops	27,200 "
Fluid pig from mixer, 12.20 a.m.	43,900 "
Fluid pig from mixer, 12.25 a.m.	30,900 "
Total charge	119,050 lbs.
Ore	11,000 "
Marble Mountain limestone	25,300 "
Routledge limestone	5,600 "

Quick Tests:—

When taken.	C.	P.	S.
9.20 a.m.	0.45 %	0.400	0.050
9.50 "	0.29	0.075	0.049
10.25 "	0.29	0.060	0.040

Estimated carbon at end, 0.18%.
Carbon ordered between 0.55% and 0.65%.
Added during heat to furnace:—

Ore	500 lbs.
Fluor-spar	1,500 "

Added in Ladle:—

Ferro-manganese	1,550 lbs.
Ferro-silicon (50% Si))	350 "
Ferro-silicon (10% Si)	300 "
Coke dust	640 "

Steel quiet in moulds.
Product, 18 ingots, 1 butt, skull of 500 lbs.

Analysis of Ingots:—

C.	P.	S.	Mn.
0.57%	0.047%	0.040%	0.84%

Heat tapped 11.05 a.m., June 19—Time, 14 hrs. 10 min.

TIME REQUIRED FOR A HEAT.

This varies greatly, and depends upon different conditions of furnace, regenerators, gas producers, etc. Ordinarily if the gas supply is sufficient, and the furnace and regenerators are in good working order, a heat can be made with fluid pig and scrap in ten or eleven hours, or with cold pig in perhaps an hour longer. Most of those furnaces which are on the main line of producers, as shown in the drawing, are often short of gas, so that even when working well the heats take longer. One furnace, No. 5, has very little trouble, and when this one is off for repairs there is enough gas for the remainder. For instance, in the latter part of

May, No. 5 was off for some time, and No. 3 made heats readily in eleven or twelve hours; when No. 5 was on during June and July, the average time for No. 3 was about fourteen hours; and when No. 5 went off again the latter part of July, No. 3 made some heats under eleven hours. The scarcity of gas is due rather to a poor quality of coal than to a deficiency of producers. Of course coke-oven gas is largely used when producer gas is not available in sufficient quantity, but though possessed of greater calorific power it has not the advantage of regeneration, and, being very light, acts more on the roof than on the stock in the furnace. The following are approximately average analyses of producer and coke-oven gases, with calorific powers calculated:—

Constituent.	Producer Gas.	Coke-Oven Gas.
CO_2	6.68%	3.66%
H_2S	0.45	1.00
O_2	0.20	1.34
CmHn	0.73	3.20
CO	21.27	5.80
H_2	13.17	38.12
CH_4	2.80	23.82
N_2 (difference)	54.70	23.06

PRODUCER GAS.

Constituent.	Vol. Per Cent.	Cal. Power.	Calories.
H_2S	0.45	5,513	2,480
CmHn	0.73	15,000 (nearly)	10,950
CO	21.27	3,062	65,200
H_2	13.17	2,613	34,400
CH_2	2.80	8,598	24,070
Total heat evolved			137,100

COKE OVEN GAS.

Constituent.	Vol. Per Cent.	Cal. Power.	Calories.
H_2S	1.00	5,513	5,513
CmHn	3.20	15,000 (nearly)	48,000
CO	5.80	3,062	17,760
H_2	38.12	2,613	99,600
CH_4	23.82	8,598	204,600
Total heat evolved			375,473

These calorific powers are in large calories per cubic metre, and show the coke-oven gas to be almost three times as good for actual production of heat as is the producer gas, but so great are the difficulties with coke-oven gas that there are few cases in which a sufficiently high temperature can be reached for tapping by its use alone.

LOSS OR GAIN OF IRON.

It is difficult to make a satisfactory balance sheet for the furnace without knowing the actual composition of everything charged and tapped, so that the calculations here given must be considered as simply an attempt to show the nature of the work. On an average the iron charged in the pig and scrap is just about recovered in the ingots, the iron of the ore passing into the slag.

Let us now take particular instances and see what has happened. The composition of pig iron will be taken as that given in the introduction, and scrap as having 0.60% C, 0.04% P, .04% S, and 0.80% Mn.

HEAT C.

Time of heat, 10 hours, 55 min.

Charge.		Iron Content.
Pig	99,050 lbs.	92,600 lbs.
Scrap	23,200 "	22,900 "
Ferro-manganese	1,800 "	300 "
Total iron charged		115,800 lbs.

Ore used, 29,500 lbs.

PRODUCT.

116,650 lbs. steel (98.67% Fe) containing 115,000 lbs. Fe. Loss of Fe charged in pig and scrap, 800 lbs. This indicates a slight loss, or, in other words, shows that the ore was reduced to protoxide and passed entirely into the slag, with a very little protoxide produced by the oxidation of the metal charged.

An example will now be given of a much slower heat.

HEAT D.

Charge		Fe Content.
Pig	86,600 lbs.	81,000 lbs.
Scrap	30,750 "	30,300 "
Ferro-manganese	1,700 "	300 "
Total Fe charged		111,600 lbs.

Ore used, 29,250 lbs.

Product.

110,700 lbs. steel (98.75% Fe) containing 109,300 lbs. Fe.

Loss of iron charged in pig and scrap, 2,300 lbs. This again shows a little iron oxidized and going into the slag, as well as about the same amount of ore, a condition not very different from that of the previous example, yet indicating that with longer time there is more oxygen taken from the air or limestone.

Oxidation Problem.

This is perhaps the problem, which, more than any other, makes the open-hearth melter realize that he does not yet know all about the manufacture of steel. It will be noticed in the examples which follow, that the amounts of oxygen derived from the air (including probably some from the limestone as well) do not vary greatly even under very different conditions. In heat E, given as an example, though little more than half as much ore was used as in the other cases, the charge melted soft—very low in carbon—while the phosphorus was still high. Here some of the ore was added especially to remove the phosphorus, as will be explained later. It would be very interesting here to know the acidity of the slag, for this was apparently so great as to prevent the retention of the phosphorus. One thing noticeable in all cases is the comparatively small part that the ore plays in the oxidation, and this shows partly why a considerable variation in the amount of ore used does not very materially affect the reduction of carbon. In these calculations the ore has been taken as pure magnetite, and this is probably not far from right, for though there are some impurities present the ore may contain more sesquioxide than would be indicated by the formula Fe_3O_4.

HEAT C.

Charge.	
Pig	99,050 lbs.
Scrap	23,200 "
Ore	29,500 "

In this case, as we have seen, the loss was about 800 lbs.

CARBON.

In pig, $99{,}050 \times 0.0375$	3,714 lbs.
In scrap, $23{,}200 \times 0.006$	139
Total charged	3,853
Present at tap, $116{,}650 \times 0.0034$	397
Oxidized	3,456

For the formation of CO this requires $\frac{3{,}456 \times 16}{12} = 4{,}608$ lbs. of oxygen.

PHOSPHORUS.

In pig, $99{,}050 \times 0.014$	1,387 lbs.
In scrap, 23200×0.0004	9
Total charged	1,396
Present at tap, 116650×0.00056	65
Oxidized	1,331

For the formation of P_2O_5 this requires $\frac{1{,}331 \times 80}{62} = 1{,}717$ lbs. of oxygen.

SILICON.

In pig, $99{,}050 \times 0.011 = 1{,}000$ lbs., practically all oxidized. For the formation of SiO_2 this requires $\frac{1{,}000 \times 32}{28} = 1{,}143$ lbs. of oxygen.

MANGANESE—PROBABLY OXIDIZED.

In pig, $99{,}050 \times 0.003$	297 lbs.
In scrap, $23{,}200 \times 0.008$	186
Total charged	483

For the formation of MnO this requires $\frac{483 \times 16}{55} = 140$ lbs. of oxygen.

IRON.

About 800 lbs. oxidized. For the protoxide it requires $\frac{800 \times 16}{56} = 229$ lbs. of oxygen.

ORE.

29,500 lbs. of Fe_3O_4 reduced to FeO give up $\frac{29{,}500 \times 16}{232} = 2{,}035$ lbs. of oxygen.

The total oxygen required is 7,867 lbs., therefore the oxygen coming from other sources than ore is 5,832 lbs.

HEAT D (slow).

Charge.

Pig	86,600 lbs.
Scrap	30,750
Ore	29,250
Loss about	2,300

Carbon

In pig, 86,600 × 0.0375	3,247 lbs.
In scrap 30,750 × 0.006	184 "
Total charged	3,431
Present at tap 110,700 × 0.003	332
Oxidised	3,099

Oxygen required is $\frac{3099 \times 16}{12} = 4,132$ lbs.

Phosphorus.

In pig, 86,600 × 0.014	1,212 lbs.
In scrap, 30,750 × 0.0004	12
Total charged	1,224
Present at tap 110700 × 0.0003	33
Oxidised	1,191

Oxygen required is $\frac{1,191 \times 80}{62} = 1,537$ lbs.

Silicon.

In pig, 86,600 × 0.011 = 953 lbs.

Oxygen required is $\frac{953 \times 32}{28} = 1,089$ lbs.

Manganese.

In pig, 86600 × 0.003	260 lbs.
In scrap, 30750 × 0.008	246
Total charged	506

Oxygen required is $\frac{506 \times 16}{55} = 147$ lbs.

IRON.

Oxygen required $\frac{2,300 \times 16}{56}$=656 lbs.

Total oxygen required is 8,054 lbs.

ORE.

Oxygen liberated is $\frac{29,250 \times 16}{232}$=2,014 lbs.

Oxygen required from other sources than ore is thus 6,040 lbs.

HEAT E.

(Melted soft, delayed two hours on phosphorus.)

Charge	
Pig	89,100 lbs.
Scrap	35,500
Ore	16,650
Gain of Fe	3,300

CARBON.

In pig, 89,100×0.0375	3,341 lbs.
In scrap, 35,500×0.006	213
Total charged	3,554
Present at tap, 123,600×0.0016	198
Oxidised	3,356

Oxygen required, $\frac{3,356 \times 16}{12}$=4,473 lbs.

PHOSPHORUS.

In pig, 89,100×0.014	1,248 lbs.
In scrap, 35,500×0.0004	14
Total charged	1,262
Present at tap, 123,600×0.00055	68
Oxidised	1,194

Oxygen required, $\frac{1,194 \times 80}{62}$=1,540 lbs.

SILICON.

In pig, 89,100×0.011=980 lbs.

Oxygen required, $\frac{980 \times 32}{28}$=1,120 lbs.

MANGANESE.

In pig, 89,100×0.003	267 lbs.
In scrap, 35,500×0.008	284
Oxidised.	551

Oxygen required, $\frac{551 \times 16}{55} = 160$ lbs.

Total oxygen required is.	7,293 lbs.
Fe, gain, $\frac{3,300 \times 16}{56}$	943

Net oxygen required=6,350

Ore liberates $\frac{16,650 \times 16}{232} = 1,148$

Required from other sources, 5,202 lbs.

USE OF LIME.

At an earlier time, lime was used altogether instead of limestone for the purpose of making a basic slag. This had the advantage of making the heats much quicker, and eight or nine hours was not an unusual time. On the other hand, by this means, the lining of the furnace, instead of being continually eaten away, kept building up, so that the charges had to be reduced from 115,000 lbs. to about 85,000 lbs. For making lime there are ten large kilns at the steel works, using coke-oven gas as fuel, after some of the sulphur has been eliminated by passing through purifiers. The supply of limestone near Sydney is considerable, as is also that of dolomite.

TEMPERATURES OF BATH AND FURNACE.

To control the temperature is one of the greatest problems which face the open-hearth steel-maker. When there is a good action on the heat there is comparatively little danger of melting down the roof, but in some cases the lime rises to the surface and lies there very quietly, reflecting a large part of the heat to the roof. In such a case it will be found very difficult to get the charge hot, and although the reduction of ore to metallic iron by carbon is an endothermic reaction if only carbon monoxide is formed, it generally pays to throw in enough to get a motion on the bath.

In many cases this is inadvisable because the percentage of carbon in the steel is already very low, when either cold pig iron is thrown in or some molten pig taken. The latter is of course much the better of the two. In general the charge will keep hot if the current of gas and air is a good one. In case there is a rolling motion the gas supply is too great for that of the air, and more air should be turned on if the furnace is hot enough to cause its complete combustion, which, however, will probably not be the case immediately after charging. It is common practice to leave a good current of air at all times, but this would seem to be rather doubtful economy.

As the gas and air do not mix until they enter the furnace, the end at which they go out is much hotter than that at which they come in. In fact, if a melter sees that the roof at the outgoing end is not too hot, he does not often trouble to look further. H. H. Campbell advises that the ports be constructed so as to have gas and air mix about five feet away from the furnace entrance, and from the above considerations it would seem advisable.

Ladle Additions.

A few words of explanation may be given regarding the addition of ferro-manganese, ferro-silicon and coke dust.

Recarburizing.—For rail steel about fifteen hundred pounds of ferro-manganese are always added, and as this contains not far from six per cent. of carbon, the actual amount of carbon added thus is about ninety pounds. This would theoretically raise a hundred thousand pounds of steel 0.09% in carbon, but in actual practice it is found that the rise is only about 0.05% or 0.06%. Hence for rails the steel must always be taken down at least this much below what is desired in the finished product. If more than this amount is required, coke dust is added in forty-pound bags, and each bag serves to increase the carbon content of the steel about 0.025% instead of the theoretical 0.04%, counting the coke as pure carbon. This cake is thrown into the ladle very soon after the steel begins to pour out, and the flame which rises is abundant proof that much of it burns away.

Ferro-Manganese.—The fifteen hundred pounds of ferro-manganese would theoretically raise the manganese content one per cent. or over, but in practice this is found to be only about eight-tenths of a per cent., which amount is desired for rail steel. Were it over one per cent. the rails would be too brittle, but this quantity has the power of making steel ductile at high temperatures. An addition of ferro-manganese in the ladle also tends to make the dissolved oxygen go into the slag in combination with the manganese added. The addition is begun practically as soon as the coke dust has been thrown in, and the endeavor is to distribute it evenly throughout the whole quantity.

Ferro-Silicon.—The effect of silicon on steel is not well known, though it may, like the ferro-manganese, carry some oxygen into the slag. However, with the basic slag of these furnaces, care must be taken to throw it all as soon as possible after the steel begins to flow, for if it were thrown into the slag the phosphorus would be driven back into the steel. In fact, the phosphorus percentage in the ingot is often greater than that of the bath at tapping. Ferro-silicon is not added for rail steel unless the orders specify it, and then in quantities to make about 0.15%.

REMOVAL OF CARBON.

It is of course well known that ore is the great oxidizing agent for carbon, yet there are still some things in the removal of carbon which are hard to understand. When a furnace is running regularly and making heats in fairly good time it is easy to gauge the quantity of ore approximately. At such times there is added about ten thousand pounds of ore for thirty thousands pound of scrap and eighty-five thousand pounds of pig. But if a heat remains in the furnace a great while because the lime refuses to rise well from the bottom the amount of ore required may be greatly increased, even in exceptional cases up to a total of thirty thousand pounds. This is largely due to the fact that the lime on the bottom does not take a great part in the reactions going on, and the basic iron oxide is utilized in its place to make the slag.

To reduce the carbon alone, when a heat is found to contain too much, lump ore is added, because, being of a density very nearly the mean of those of slag and steel, it will sink into the metal till about half covered by it. Hence the larger the pieces of ore the better the oxidization is likely to be. Fine ore might remain entirely in the slag and have scarcely any appreciable effect in bringing down the carbon content.

REMOVAL OF PHOSPHORUS.

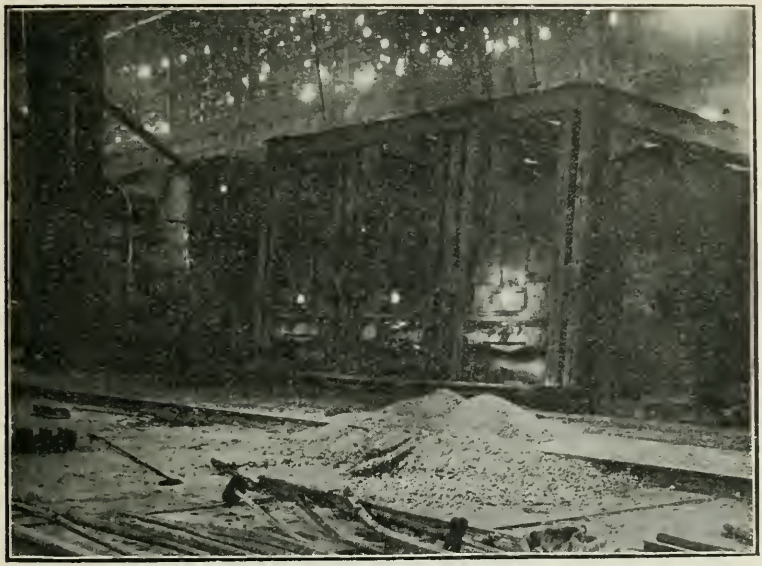
For phosphorus the method is very different. If the phosphorus be high it is desired to make the slag very basic, and that often without reducing the carbon further, hence fine rather than coarse ore is added, and this ore is likely to remain in the slag, where it is wanted. Lime may be added for the same purpose, but this is not often done; in fact, when thirty thousand pounds of limestone is charged there is scarcely any trouble with the phosphorus unless the lime refuses to rise from the bottom.

REMOVAL OF SULPHUR.

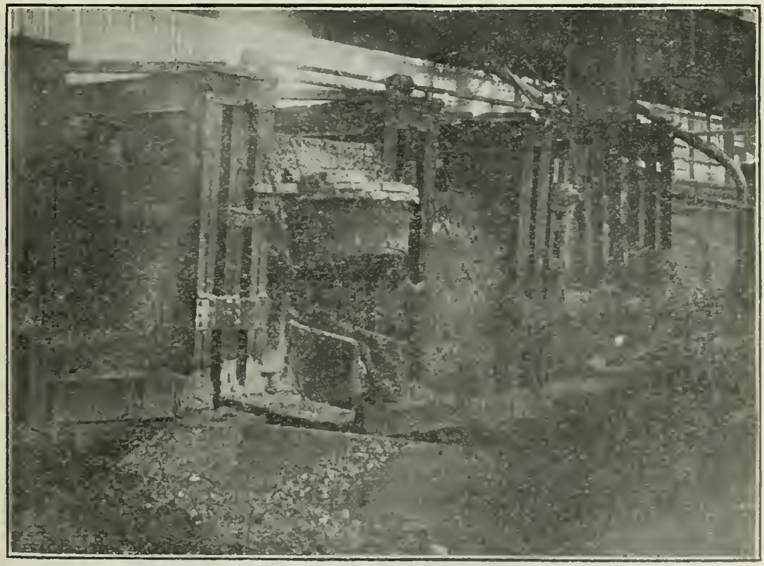
This element is decidedly more difficult to deal with, and it seems at present easier to keep the sulphur low in the blast furnace than to remove it when it has once got into the open-hearth furnace. It is certain that it cannot be removed without an extremely basic slag. Many methods have been tried, some advocating the use of calcium chloride and fluorspar. When there is any difficulty with it, at Sydney it is the custom to reduce the carbon content very low, and then to bring it up with pig iron. Whether the sulphur is burnt out by this repeated oxidising action or passes into the slag is not well known, but considerable quantities have sometimes been eliminated in this way. The process, however, is a tedious one, and is avoided whenever possible. It will have been noticed that considerable fluorspar is used at Sydney, though not with the definite purpose of removing sulphur. Any use of this flux has, however, the effect of making the phosphoric acid in the slag much less soluble, and thus preventing an economical use in the manufacture of fertilizer.

COMBINATION WITH BESSEMER CONVERTERS.

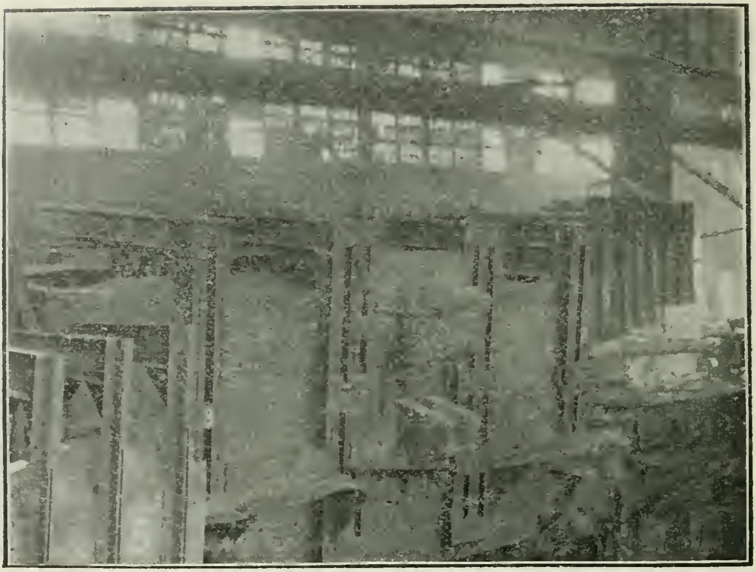
This is being contemplated at Sydney for the near future, and the probable advantages of such a method may be noticed here. H. H. Campbell says, in *The Manufacture and Properties of Iron and Steel*:—"The expense of the pig and ore process rests in the slow combustion of carbon, for it is impossible to hurry the work without causing violent boiling of the voluminous slag, producing scorification of the hearth, and possibly also a loss of metal through the doors." This difficulty may evidently be obviated by removing the carbon,—and at the same time the silicon,—in a Bessemer converter. The silicon goes first, and even the carbon may be removed before the phosphorus is materially reduced. It is hence possible to perform these parts of the present open-hearth work, now requiring hours of time, in a very few minutes in a converter, and this may be acid, for if the transfer of metal be made before the oxidation of the phosphorus begins, a basic lining will not be necessary. The indications, therefore, are that this method may prove very satisfactory, and that the time of a heat, and consequently the coat of steel, may be materially reduced. The heat reduced by the combustion of one per cent. of silicon and three per cent. or more of carbon will almost certainly be enough to make the charge sufficiently hot for the transfer, though the phosphorus percentage is probably not high enough to heat up the lime which would be necessary in a basic Bessemer converter, in addition to keeping the low carbon metal in a sufficiently fluid condition.



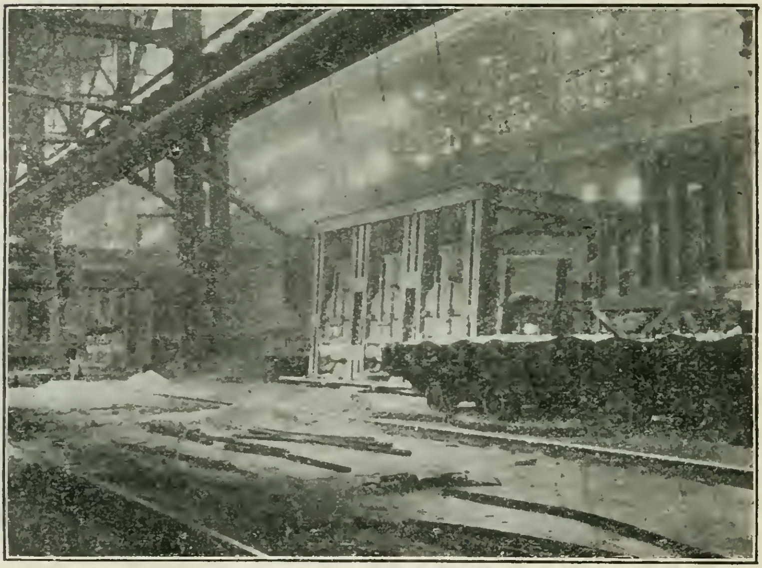
Front View of Furnace.



Rear View of Furnace.



FRONT OF OPEN HEARTH FURNACE, showing also charging boxes, part of charger, piles of burnt dolomite, coke oven, gas-pipe, etc.



BACK OF OPEN HEARTH FURNACE, showing charging basin, runner, rollers, etc.

UNDERGROUND MINING METHODS AT THE QUINCY COPPER MINE, MICHIGAN.*

By G. R. McLaren, School of Mining, Kingston.

The large deposits of native copper of which the Quincy is one, on Keeweenaw Peninsula, in Lake Superior, are well known, as they are now, and have been for some years, among the important sources of the world's copper supply.

Geology

The rocks are of the Keeweenawan series, and the ore bodies are of five different classifications:—

1.—Conglomerate.
2.—Amygdaloid.
3.—Contact.
4.—Fissure.
5.—Gash.

In the Conglomerate the copper occurs as a cement binding together the pebbles of the conglomerate.

In the Amygdaloid it is found partially or entirely filling the pores in melaphyr.

In the contact the copper occurs as irregular masses between igneous and sedimentary rocks.

In the fissure and gash veins, the copper is supposed to have been deposited in the same manner as in the Amygdaloid. They are widened by replacement of the wall rock.

In all the ore bodies the gangue material is calcite, quartz, zrolites, datolite, etc.

Origin of the Deposits

Geologists differ widely as to the origin of these deposits, some claiming that they are of igneous origin, others that they are due to electrolytic action. Another theory is advanced that they are due to surface alteration from sulphides on a gigantic scale. The best

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Student's paper presented in competition for Prizes offered annually by the Institute. This paper was awarded a prize of $20.

explanation given as yet, however is that there were large deposits of sandstone overlain with lavas and conglomerates, and above all a layer of sandstone. All were fractured and acted on by hot and cold waters which leached out the copper and stored it up in conglomerates, lava and veins. The copper is supposed to have been precipitated to the native state from copper salts by iron.

ONTARIO DEPOSITS

I might here call attention to the fact that in Ontario on the north shore of Lake Superior we have practically the same geological formation as in Michigan. Several discoveries have been made particularly at Point Mamainse and on Michipicoten Island. Some work was done here between 1848 and 1858 by the British North American Company at Prince's Bay, and by the Montreal Mining Co., and two English companies at Point Mamainse. After sinking a few shafts, the deepest being seventy feet, the work was abandoned as the veins seemed to peter out. At a later period work was resumed and three shafts of 100 ft., 200 ft., and 300ft. were sunk. However there is a large extent of country here not thoroughly prospected, and there seems to be no reason why we should not have some good bodies of the same copper on the north shore as on the south.

THE QUINCY

The Quincy, with which I intend to deal more particularly, is situated on Portage Lake beside and under the city of Hancock. It is an amygdaloid with sharply defined walls having in many places on the hanging wall a layer of gouge and often slickensided. Parallel to the main vein which is called the Pewabic, are two other veins of the same character, called the East Pewabic and the West Pewabic. The East Pewabic is really a foot wall branch only about 20 feet east of the main vein. This is also worked and yields good returns. The West Pewabic is 300 feet to the west and has been explored in several places by cross-cuts. In a few places this lode has yielded good returns, but in most places it is not highly mineralized enough to pay.

The wall rock is a melaphyr, and the gangue material consists of quartz, calcite, epidote, etc. Native silver is found in some quantity particularly in the upper levels.

The copper contents of the vein are about 19.3 lbs. of refined copper per ton of rock stamped.

SHAFTS

There are five incline shafts. The most southerly ore is No. 7 sunk to 57th level. 860 ft. north of No. 7 is No. 4 sunk to the 51st. level. 580 ft. next north is No. 2 sunk to the 62nd level and 4,168 ft., farther north is No. 8 sunk to the 44th level. The extreme distance between No. 7 and No. 8 is 7,541 ft., but the Franklin mine intervenes between No. 6 and No. 8. Below the Franklin No. 8 is connected with the other shafts. The extreme distance from the most southerly breast of No. 7 to the most northerly one of No. 8 is about $1\frac{3}{4}$ miles with a mile of ground still to go on the north. These figures are for 1905, when I last worked there. No. 7 shaft is sunk on a catenary curve and considerable comment was raised at the time of its sinking. Drifts were run over from No. 4 and below from No. 2 about 1,500 ft. away. Work was begun sinking from surface and raising from the 55th level and also at 3 levels between. It speaks well for Mr. Harris, the Engineer, when we see that all joined together as if the whole had been sunk from surface, especially as there is a cut off in the vein down to the 40th level in No. 7 shaft. The Quincy vein has a dip of pretty nearly 45° at the surface flattening to about 38° below. In No. 2 shaft which is one of the oldest, the shaft was started at an angle of 53°, but at the 53° level it was flattened to 38° to save the long cross cuts from the shaft into the hanging to reach the vein. The wear on the ropes, due to it rubbing on the hanging wall, is prevented by means of sheaves.

SINKING

The sinking of the shafts themselves is the hardest work in the mine and requires the strongest and most skilled workmen. The sinkers as well as all others of the underground men (except the timbermen) work day and night shifts alternate weeks.

The sinking is done by two men on a shift with usually a man to help muck the dirt for an hour or so after going down. When sinking, a pentice is left to protect the men from dirt falling down from the shaft above them. The full size of the shaft is about twenty feet wide by eight to nine feet high. About twenty holes are required to square a cut. The position of these holes is illus-

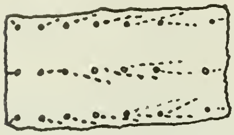
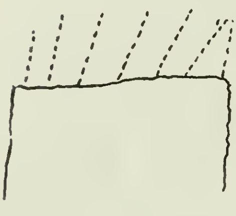
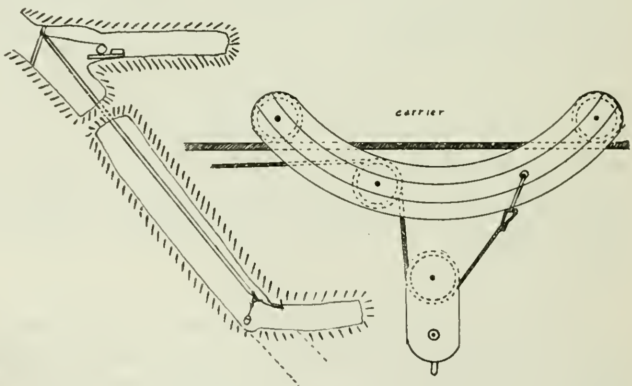


Fig 1



trated in Fig. 1. The time required to sink one lift of one hundred and twenty five feet is usually about three months and the cost about $20.00 a foot. Usually there is very little trouble with water as the mine is dry. A small depression is generally left atone side of the sink to hold it. The only trouble with the water is that it is slightly acid and is very hard on the men's clothes and hands. The dirt is hoisted from the sink by means of a small donkey engine working the apparatus, shown in Fig. 2. This consists of an inch rope (steel) fastened securely to stubs at either end and keeping it close to the hanging. On this runs a semi-circular piece travelling on pulleys. This runner is drawn by a half inch rope (steel) passing from the drum of the donkey engine up through a pulley fastened securely to the stub at the upper end

Fig 2.



and down to the semi-circular piece. The bucket is attached to this. The bucket is of sheet iron and holds about 400 pounds. It is used to hoist the water also.

SHAFT TIMBERING

The hanging wall in almost all cases is strong enough to hold till the entire lift is sunk, if not, temporary props are put in till the next level is reached, when the pentice is broken down and a double shift of timbermen is set at work. The shafts are all three compartment, two for skip roads and one for ladders and pipes. Hitches are cut in the foot and hanging walls between each of the compartments as well as at the sides of the shaft and 12″x12″ square timbers are put in. Lying on these and bolted to them are 12″x 12″ square timbers a foot shorter, and on these last the 12″ x 12″ caps are laid reaching clean across the shaft. (Fig. 3)

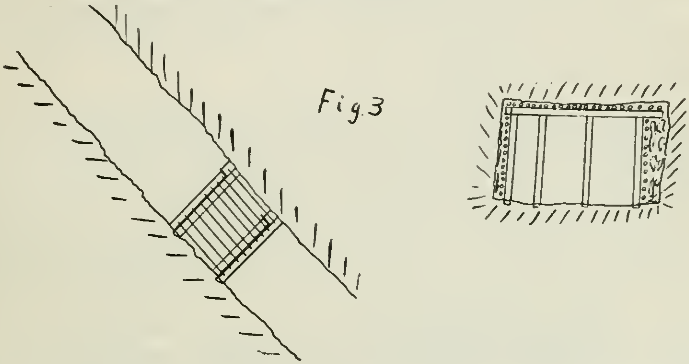


Fig 3

These sets are placed six ft. to twelve ft. apart according to the nature of the ground. If the ground be loose, lagging is placed from cap to cap to prevent loose rock falling from the roof, and from upright to upright to hold in the rock at the sides. Between the rock and lagging is filled with loose material such as broken pieces of timber, etc. The rails on which the skip runs are placed on 12″ x 12″ runners which are laid on supports. An engineer can save much time and labor for the timbermen by giving a sight with the transit so that rails can be driven in every upright to show the height to which the runners should be laid. In this way the track is even and gives less trouble both to the timbermen in putting them in and afterwards. Around the level mouth, a plat or platform of planks is always laid, care is taken to keep this clear of broken pieces, shavings, etc., for fear of fire. The shaft timbers are usually Florida pine which has been found to be the strongest and most durable.

LEVELS

The levels are 80 ft. apart at the top of the mine, and 125 ft. at the bottom. The change was caused partly on account of the change from hand drilling to machine work, and partly because the longer the d stance between the levels the greater the stoping capacity to the amount of drifting or dead work. Experience has shown, however, that more than 125 ft. would be to great as the hanging in the stopes would be to heavy and would require too much timber for supporting it.

WIDTH OF VEIN

The width of the veins varies from a maxium of forty feet at several points in the higher levels to a minimum of three feet at the 60th level in No. 2 shaft.

The average width at t e bottom is about 6.5ft., and the average of the whole vein from surface down about 18 ft. It has been obsreved by the miners that where there is a rolling of the vein the best copper values are to be found.

In the upper levels a great deal of mass copper was found but the values were bunchy. In the lower levels the copper is in a fine, state, but the values are more uniform. At present only about 15% of the values found is heavy copper. The fine copper is cheaper to treat as the heavy or mass copper must be cut underground by chisels to make it portable. The miners believe on account of the flattening at the bottom that the veins are clevice shaped and come to the surface elsewhere.

DRIFTING

As soon as the shaft is down, parties of men are sent drifting. It takes twenty holes to square a cut, and requires two men working three shifts to do this. A good drifter should make six feet every cut. The position of the holes is shown in Fig. 4. The

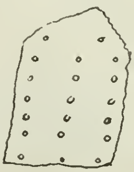


Fig 4

drifts are made about seven feet high by six wide. The miners muck back their own dirt to get room for posting up and lay sollers for blasting on, but the dirt is taken away by trammers. The sollers are merely planks laid on the bottom of the drift to make shovelling easy. The tracks for the cars are always kept up as close to the face as possible.

Cutting Out

Just behind the drifters comes a machine cutting out. The cutting out is really stoping from the drift up twenty feet into the vein. The amount of work a man cutting out does is measured from the track rail on the foot side up to the back.

Level Timbering

As the cutting out proceeds, the timbermen follow up putting in the timbers to make ready for the stopers. This timber consists merely of stulls and lagging. The stulls are put in by means of hitches cut in the foot and hanging, and are usually hemlock about two feet in diameter. (Fig. 5) Sometimes instead of hitches in

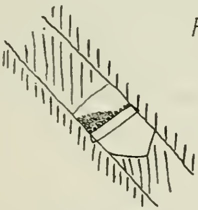


Fig 5

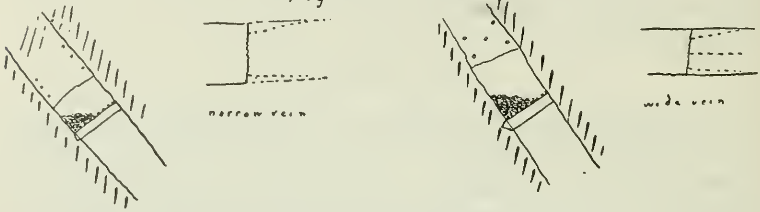
the hanging, the rock is merely smoothed and the timber jammed down, or caps of soft two inch plank are put on top. The stull is kept in place by wedges driven behind it in the hitch. The timber are placed six feet from centre to centre and are lagged with cedar poles. A mill hole for the dirt to be run through is left every 24 ft This work is done by six men and a boss. A day's work is to put in and lag three or four stulls.

Stoping

As soon as the timbers are in, stoping is commenced. Since the lagging is often not more than two or three feet from the face, great care must be taken when blasting not to blow out or break the timber. When this happens, the miners responsible may be charged with the loss. All stoping is overhand. The machines used are usually Rands, and they are worked from posts, rarely from tripods. Enough dirt is always left in the stopes on which to post up.

The holes when close to the timbers are always drilled with a light burden, and very little powder is used until the stulls are loaded with dirt. Six holes six feet deep is a day's work, but five six foot holes is commoner. Fig. 6 shows the position of the holes.

Fig 6



In the stopes as elsewhere two men work on a machine, both of whom receive the same pay and work chuck and handle alternate days. The man at the chuck is responsible for the number of holes drilled and for their breaking. The amount of ground broken, depends on the number of holes, their depth, the width of the vein and the skill of the miners. About six to eight three-ton cars will be an average day's work.

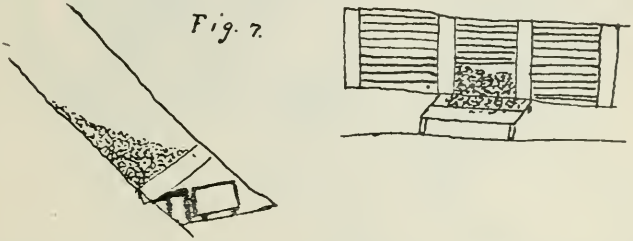
STOPE TIMBERING

The amount of timber placed in a stope, depends on the hanging. If it is good, no timber is put in, if poor, as little as possible on account of the cost. If poor, usually enough broken rock is left in the stope to keep up the hanging till the next level is reached, when the dirt is removed rapidly by a gang of stope cleaners and hanging is allowed to cave. Nowadays, to save timber, stopes thirty to sixty feet wide are run up with twenty-five foot pillars between. Then these pillars are worked till they become unsafe when they are left to cave in. In the upper levels, stopes two hundred feet long were common, as the hanging was better. In the longer stopes, a miner can break more ground per shift than in the shorter ones. If the hanging be very poor, the stopes are picked. Two men are put in each, who build up dry stone walls from the mill holes, and roof them with lagging. These men pick out the copper rock and throw it down the passsage to the mill hole and leave the waste rock to support the roof.

TRAMMING

The dirt runs or is shovelled down through the mill holes on to high sollers (Fig. 7) and is shovelled directly into cars by trammers.

Fig. 7.



These cars are of wood or iron, usually the latter, with a door at each end hinged at the top for convenience in dumping. They hold three tons of ore and a trammer is supposed to fill six cars in a drift, or eight cars from a high soller each shift. The tramming is all done by electricity. The wires are fastened to hangers in the hanging wall away from the timber. These wires are uncovered and are dangerous particularly to men carrying drills as although they rarely kill, a man will get a very bad fall if a drill touches the wire. This often happens as in places the wire is only five feet and a half above the level bottom.

The ore cars are drawn by motors weighing 5,500 lbs. These will draw six loaded cars at rate of four to five miles an hour. The power is supplied by the Hancock Electric Co. to a 100 K.W. transformer at the 59th level of No. 2 shaft, whence it is transmitted through the wires. The return current is through the rails.

CHUTES

When the cars reach the shaft they are dumped into chutes or ore bins. These chutes are the same width as the main shaft and parallel to it. They are five feet high and about ten feet back in the hanging wall. Usually they are sunk before the main shaft as it was found that blasting in the chutes loosened the hanging in the main shaft. Just above the mouth of the level, sinking in the chute is stopped and an opening is made into the shaft as shown in Fig. 8. This sudden turn takes up a great part of the pressure due to the

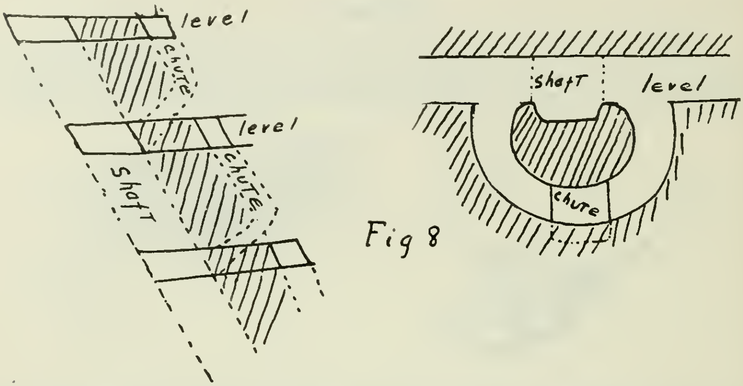


Fig 8

great weight of loose rock dumped into the chute, and lessens the pressure on the aprons by which the dirt is let into the skip. Fig. 9 shows these aprons and the windlass arrangement by which

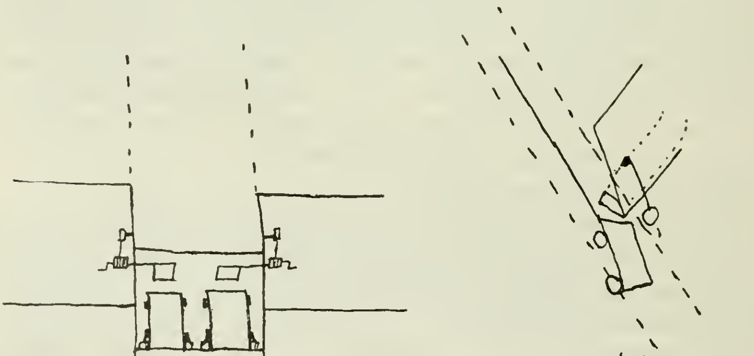
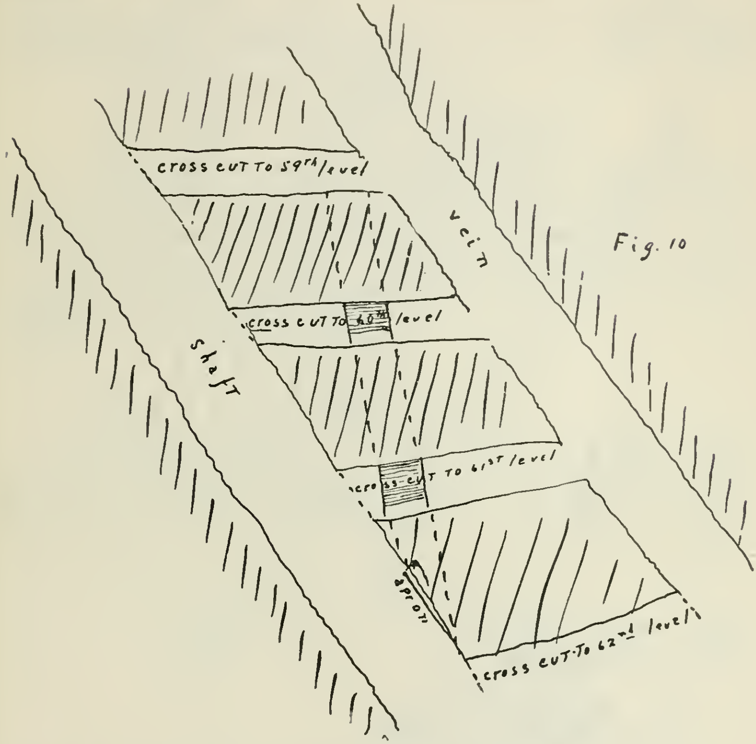


Fig 9

they are raised or lowered. It also shows the gates in which the skip rests. These will be described later.

Instead of being parallel to the shaft, which is the case only when the shaft is sunk on the vein, these chutes may be three or four levels long as shown in Fig. 10. These are used when the shaft is sunk in the foot wall as in the case of No. 2 shaft. Of



course with these there is always an opening for dumping ore into them from every intervening level. These chutes cost less for sinking and do not weaken the hanging of the main shaft, but they cause a great deal of dust in dumping.

Their capacity is from 300 to 500 tons of ore so that in case of accident to the skips, the work in the mine need not be delayed. In No. 2 shaft at the 62nd level the whole hanging has caved, and it is planned to sink a chute from the 58th level to the 62nd. The shaft from the 58th level will be sunk on the vein and the dirt hoisted by an electric hoist to this level, then dumped into the chute and hoisted through the other shaft to surface, as shown in Fig. 11.

On account of the time saved by the more rapid filling of the skips, it is claimed that these chutes add 25% to the hoisting

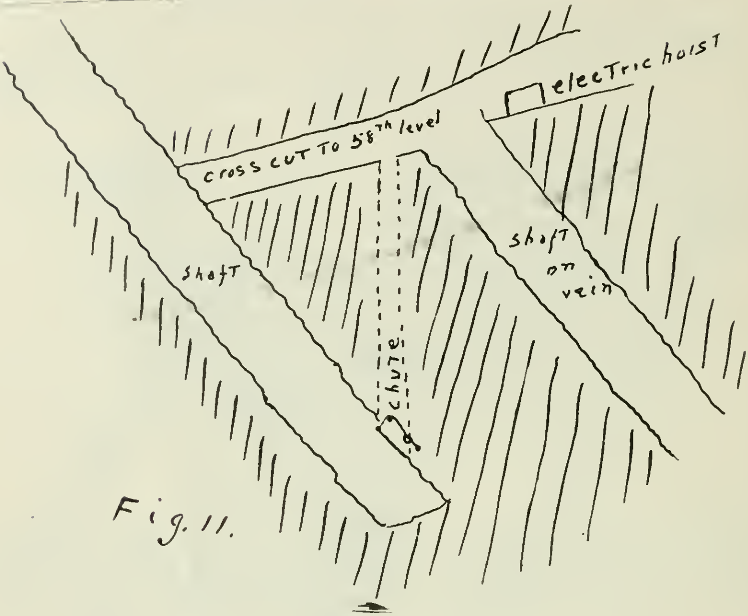

cross cut to 58th level
electric hoist
shaft
shaft on vein
chute

Fig. 11.

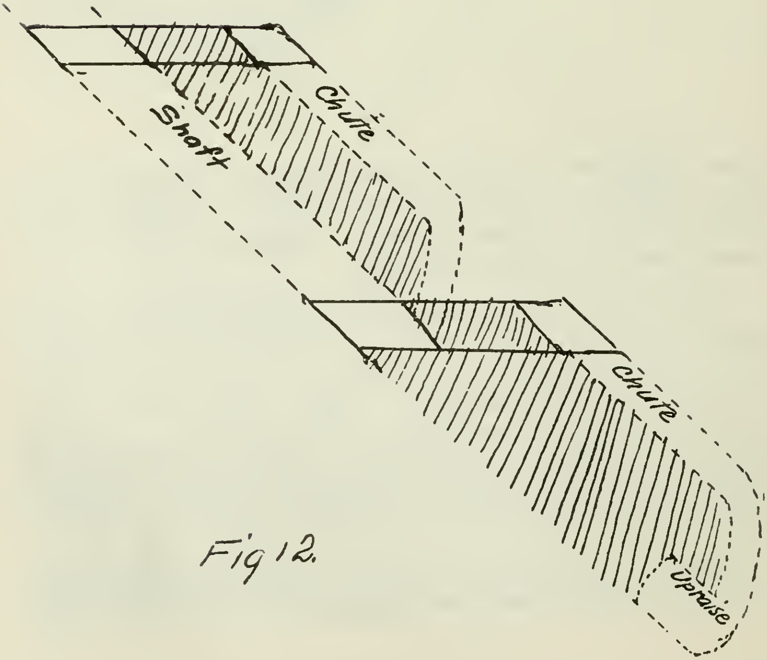

Chute
Shaft
Chute
Upraise

Fig 12.

capacity of the mine. Before they were in use the skip had to stop twice each trip to get its full load, as two cars were required to fill each skip.

SHAFT RAISING FROM CHUTES.

Sometimes instead of sinking the shafts from the level above, they are raised from where the chutes bale into the shafts. Fig 12. The ore is raised by the same scheme as in sinking (Fig. 2). This has the advantage of having no water difficulties, but it is slower and means a long pull up with the machine every morning. Ventilation and dust also give trouble.

GATES.

When dumping from the chutes there is necessarily a great strain on the ropes. To remove this strain, gates are put in vertically below the apron. At first a skeleton of hardwood was used (Fig. 13), but these broke too readily. Then they tried using

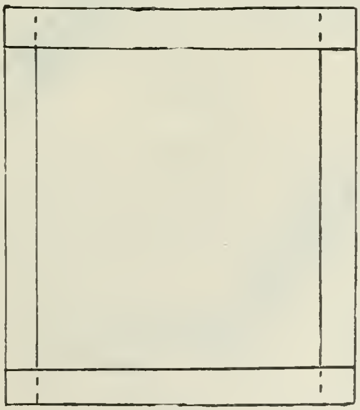


Fig 13

springs on the bottom of the skips to ease the jar on the hardwood skeleton, but this also proved unsuccessful. Now they use a piece of false top on the rail with a semi-circular piece below to fit the wheel of the skip (Fig. 14). The skip is drawn a few feet above the level, the false top raised and the skip assumes a vertical position as shown in Fig. 9, when the wheels drop into the gate.

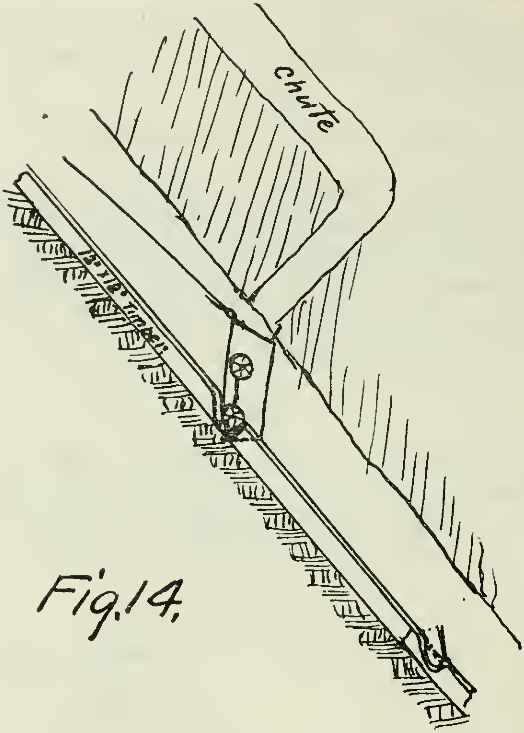


Fig. 14.

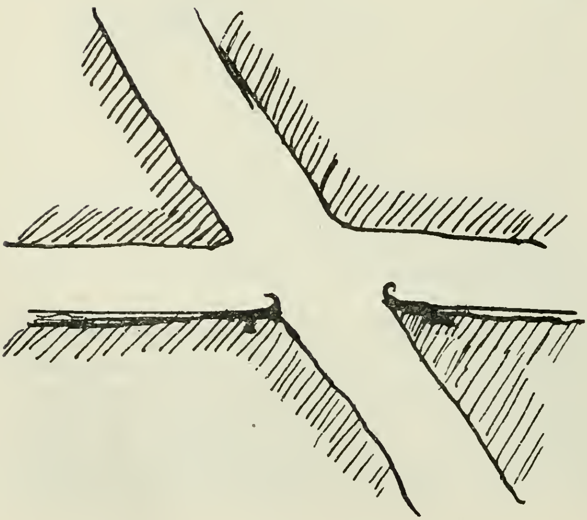


Fig. 15

The bottom corner of the skip rests on the foot wall of the shaft, so that there is practically no strain on the rope.

SKIPS.

The skips are of steel, hold seven tons of ore and are hoisted by 1½″ steel cable. The body of the skip extends below the wheels and about half way down the 12″ x 12″ runner, so that it is almost impossible for it to be thrown off the track. This precaution is necessary on account of the speed of hoisting which is 3,000 feet per minute. The hoisting is limited to this by an automatic cut off which also prevents overwinding.

CAR DUMPING INTO SKIPS.

In the higher levels where electric haulage is not in use, the cars are dumped directly into the skip. These cars are pushed directly to the shaft where the front axle is caught by a hook on the level floor. The body of the car is not attached to the rear axle so that the rear end of the car may be lifted and the dirt run out through the door into the skip.

ROPES.

The ropes used are 1.5 inch steel cable. They are protected both foot and hanging by wooden sheaves. A man in each shaft is employed in keeping these sheaves oiled, and in inspecting the rope daily. These ropes cost about $1.00 per foot and last about six months. Some idea of the strain on them may be gathered from the fact that the hoisting capacity of each shaft is 100 skips each shift.

HOISTING MEN.

The men are hoisted from the mine in man-cars holding thirty men. In appearance these cars resemble a flight of steps. The skips and man-cars are handled at the surface by cranes and are fastened to the ropes by an arrangement similar to a clevis. Only about four or five minutes is required to replace a skip by a man-car.

As the shafts are inclines there is no safety device.

UNWATERING THE MINE.

Very little trouble is experienced with water, except in the top levels. From these it is led by means of pumps and pipes to No. 4 shaft which is sunk from the 50th to the 51st level, but no drifting has been done on the latter. It is hoisted from here in 1,300 gallon skips to surface, whence it goes through a pipe down to the 7th level, and is led by an adit out on the hillside. On account of the heat in the lower part of the mine, drinking water is carried by means of iron pipes to every level.

VENTILATION.

The ventilation is good as all the shafts are connected by drifts. When a new lift is sunk in any shaft, drifts are run in at once on both sides. Then from the level above a winze is sunk to connect with a raise from the new level, thus giving a good circulation of air.

UNDERGROUND EXPLORATION WORK.

Almost all underground exploration work is done by cross-cuts or ordinary drifts. Very little diamond drill work is ever done.

SIGNALS.

The rope and bell system is used, the signals being rung by levers from the different levels. On account of the great depth there is a compensating set of weights at the 22nd level. The signals ring in the lander's office, and from him are communicated to the engineer. The following are the usual signals, but the timbermen and the bosses, each have private signals.

One bell, means to hoist up the skip.
One and a half bells, means to hoist a little.
Two bells, lower down.
Two and a half bells, lower down a little.
One bell, pause—then three bells, tools coming up.
Four bells, men coming up.
Four bells, pause—then four more, hoist very slowly.
Nine bells, hoist up man who has been hurt.

AIR BLASTS.

Before leaving the underground work, mention should be made of the air blasts here, which I believe only occur in the Quincy and Atlantic Mines. These are loud reports accompanied by a very heavy fall of rock. The shock is so great that it is felt all over the mine and even more strongly on surface. The cause is believed to be merely great falls of hanging wall rock driving out the air and giving a heavy displacement shock.

COSTS OF UNDERGROUND WORK AND WAGES.

Miner's wages $65 per month. Costs for powder, etc., vary from $87 to $150 according to the experience of the miner. (Almost no contract work is done except drifting and sinking).

Timbermen, $54 a month. Timber boss, $65 a month. Stope cleaners and pipe men, $50. Trammers, $60. Shute men, $60. Machine boss, $75. Under shift bosses, $85. Shift bosses, $110 to $125, according to the size and importance of their shift. The timber costs about $5.00 for each stull, and $5.00 for work. The total wages paid per month in the Quincy is over $90,000. About 1,700 men are employed between surface and mine work.

PRODUCTION.

The Quincy holds the record for the cheapest production of copper in this district, 5.7 cents per lb. of refined metal in 1894.

The cost per lb. at present is about 9 cents.

The following table gives the percentages of copper per ton of rock stamped, and the average cost per pound of refined metal, for six of the chief Lake Superior Mines for 1903.

Mine.	Lbs of Copper per ton of rock stamped	Cost per pound of refined Copper
Calumet and Hecla	50	7.5
Champion	30–35	
Franklin Jr.	15	11.
Wolverine	29.6	7.1
Osceola	20	7.7
Quincy	19.3	9.

The total production of the Quincy is about 1,100 tons of refined copper per month.

FORESIGHT OF THE DIRECTORS.

The Company is a very far-sighted one and no expense is spared for equipment so that the work may be done as economically as possible. But for this provision the mine would have had to be abandoned long ago on account of the small percentage of copper and the great depths from which the rock must be hoisted. One instance might be cited to show the wise provision the Company makes for the future. Originally, the Quincy owned the ground south of the Franklin. After the Franklin had proved that the vein carried good copper on its location, the Quincy bought the land north and west of it so that now the lower levels of the Quincy run directly beneath the Franklin as shown in Fig. 16. Both mines are working on the same vein.

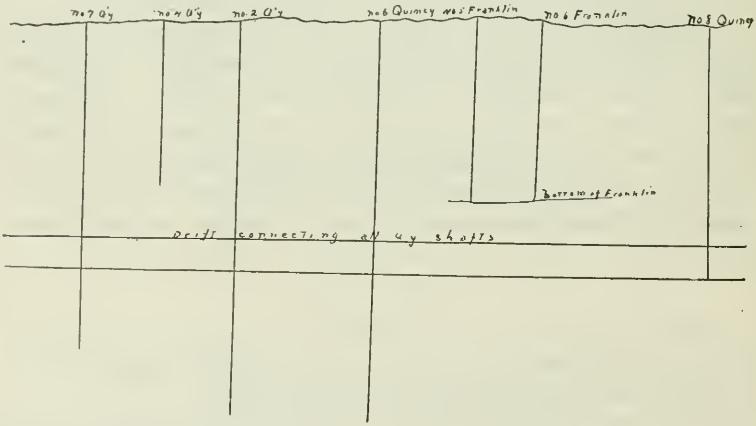
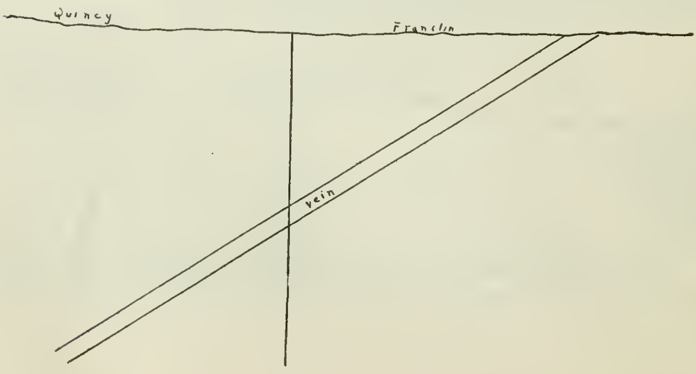


Fig. 16



SURFACE EQUIPMENT.

The surface equipment is very complete.

The Company have two large machine shops, in which they manufacture most of their own drills. The hoisting plant is very large and efficient. They have two large blacksmith shops, carpenter shop, central heating plant and three large drys for the men to change in.

They own their own mills and smelter and draw their ore to them in their own cars on the Quincy and Torch Lake Railroad, which they built and own.

They have three large docks for shipping copper and bringing in supplies.

They have a church for the men, three doctors, a druggist who supplies drugs free, and have an arrangement with the Hancock general hospital, for treating men injured in the mine.

For these benefits every single man pays a fee of fifty cents a month, and every married man a dollar. In fact both in the mine and on surface the best of care is taken of the men. Accidents do occur, but a large proportion of them is due more to the carelessness of the men than to the negligence of the mine managers.

THE CARIBOO CONSOLIDATED HYDRAULIC PLANT, BULLION, B.C.*

By W. J. Dick, McGill University, Montreal.

This property is located in the Quesnelle Mining Region—famous for its rich shallow placers, its many ancient river channels, and its immense deposits of high-grade auriferous gravels. It is situated at Bullion, Cariboo District, British Columbia, on the south-west side of the South Fork of the Quesnelle River, about four miles easterly from the town of Quesnelle Forks, and about one hundred and ninety miles by waggon-road from Ashcroft, a town on the Canadian Pacific Railway.

The property comprises thirty-four placer mining leases, aggregating two thousand five hundred and fifty four acres of land, and a block of pasture land containing three hundred and twenty acres.

The mining leases cover, for a distance of ten miles, the auriferous deposits of a system of ancient rivers, and also two placer mining leases situated on Likely Gulch, on the north side of the Quesnelle Lake.

The generally accepted theory as to the origin of the gold in the creeks of this district is, that it has been derived from the washing away, by these streams, of some old channels of the Glacial Age, but these old channels must, again, have derived their gold from a previous denudation of the country with a consequent concentration of values.

To quote from Dr. Dawson in the report of the Geological Survey of Canada, 1887 (p. 47 R),—"The deep, rich leads of the Cariboo evidently date from a period antecedent to that in which the country was for a time covered by a great ice mass, or are, in other words, pre-glacial and lie beneath the boulder clay, and other deposits due to the 'ice age'." "The wearing down of

*Student paper presented in competition for prizes offered by the Institute, and awarded a prize of $20.

the country-rock and natural concentration of gold had been in process from the close of the Miocene or Middle Tertiary Period (or perhaps, in some localities, even from an earlier date) to the Glacial Period. During the period of the Middle Tertiary, a great part of the Province included between the Coast Range and Gold Range became occupied by fresh-water lakes."

The old channels which afterwards drained these lakes do not necessarily follow the present streams, nor conform to the present topography of the country. The general area in which these old rivers flowed is fairly well bounded and defined, and to again quote from Dr. Dawson is "included between the Coast Range and the Gold Range." The exact courses of these old rivers have not been fixed, except at spots where they have been worked, as at the Cariboo Hydraulic, Horsefly Hydraulic and a number of other camps.

The ancient river, now being developed at Bullion, lies nearly parallel to the course of the South Fork of the Quesnelle River, for a distance of approximately two miles, and has its outlet at Dancing-Bill Gulch, through which a small stream flows into the river. The bed-rock of the old channel at its deepest part is from 165 to 175 feet above the level of the present river. The bottom of the old channel is from two hundred to three hundred feet wide, and the sides rise at an angle of about 45 to 50 degrees to a height of some four hundred feet. The width of the deposit on the surface is from one thousand to fifteen hundred feet, which would give about ten thousand cubic yards of gravel to each foot of advance up the channel. The old channel enters the South Fork of the Quesnelle River almost at right angles, that is in a northerly direction, and when followed up for some five hundred to six hundred feet was found to swing sharply to the left, that is, coming from an easterly direction, or parallel to the present river. The bottom of the channel or bed-rock is found to rise to the eastward at a grade of one foot per hundred, indicating the flow of the old river to have been from the east. At the hydraulic pit the steep south bank of the river rises to a height of from five hundred to six hundred feet, where it meets the north rim of the old channel, rising as sharply to the north, and forms a narrow razor-back ridge known as the "French Bar Bluff," which is all that separates the old from the new channel. A diagramatic sketch of the channel is as shown:—

(*a*) At surface, ten to twelve feet of surface gravel carrying a small amount of gold;

(*b*) underlying this a bed of very firm clay and rounded boulders, about one hundred and fifty feet in thickness, perfectly barren;

(*c*) bands of sand and fine gravel, auriferous, ten to twenty feet thick;

(*d*) lying on bed-rock, a great depth, of one hundred and fifty to two hundred feet of exceptionally rich gold-bearing gravel, coarse in kind, containing a large amount of cobble-stones and a fair amount of boulders, mostly of eruptive rock, both massive and stratified. The quantity of auriferous gravel available for hydraulic washing is estimated at 500,000,000 cubic yards, and the average gold tenure is estimated at twenty-five cents per cubic yard, making a total gold constituent of $100,000,000.

The water supply system consists of thirty-three miles of well-constructed canals, having a capacity for delivering at the mine five thousand miner's inches of water, under a head of 420 feet. (A miner's inch is 2,160 cubic feet, the quantity of water discharged in twenty-four hours under a head of seven inches through an opening one-half in. wide by two inches high, made in a board of two inches thick). The sources of supply are at Bootjack Lake and Polley's Lake, about nineteen miles distant, and at Morehead Lake, ten miles distant from the mines at Bullion. All the above named lakes have been converted into efficient storage reservoirs by the construction of substantial dams across their outlets. These reservoirs have an aggregate capacity for storing 1,016,000,000 cubic feet of water, which is equal to 470,370 miner's inches of water. Referring to the report of J. B. Hobson, Manager, an engineer of very considerable experience and with a thorough knowledge of hydraulic placer mining, it may be seen that the largest quantity of water used during those seasons provided the largest results.

PRODUCT OF MINE SINCE COMPLETION OF WATER SUPPLY SYSTEM IN 1898, COMPARED WITH PRECIPITATION.

Year	Precipitation In Inches	Water Used In Miner's Inches	Time Days	Run Hrs.	Cubic Yards Gravel Washed	Product
1899	28–65/100	353,056	144	8	1,952,535	$ 92,678.93
1900	30–67/100	460,878	171	13	1,843,938	350,085.77
1901	20–30/100	258,250	104	13	2,420,288	142,273.41
1902	23–40/100	179,520	65	15	690,442	61,395.19
1903	17–48/100	127,083	53	7	373,000	44,943.70
1904	24–39/100	225,198	88	16	1,461,341	85,936.30

Take the season of 1904, if the water supply had been sufficient to operate the mine 200 days (instead of 88) with 2,500 miner's inches of water, the season's output would have reached $193,800, which, after deducting from this the operating expenses and cost of development work—estimated at $150,000—would have left a net profit of $43,800. Increase the quantity of water used to 5,000 miner's inches for the same period, and assume the duty of water and grade of gravel to be the same as the past season, then the gross product would have been something like $380,000; deduct from this the estimated cost of operation ($200,000) and there is left a net profit of $180,000. Years of experience in hydraulic mining prove that it costs no more to discharge water through 10-inch nozzles; that the moving power and duty of the water increases more rapidly with the increase of the quantity of water used, and that the cost of mining is materially decreased by an increase of the quantity of water used. In view of this fact, the Company are constructing a canal to Spanish Lake, fifteen miles distant, from which it will be possible to obtain a supply of at least 5,000 miner's inches, throughout the open season of seven months.

ESTIMATES FOR PROBABLE COST OF CANAL AND PIPE LINE TO DELIVER 2,500 MINER'S INCHES OF SPANISH LAKE WATER AT THE MOOREHEAD POOLING RESERVOIR.

Construction of 15 miles of canal, at $9,000 per m.	$135,000
2,500 ft. of forty-inch pipe line across Poquette Pass, at $8.00 per ft., laid.	20,000
8,000 ft. of forty-inch pipe crossing the South Fork of Canal River, at $10.00 per ft., laid.	80,000
Timber crib and plank-sheathed diversion dam at outlet of Lake.	10,000
Total Estimated Cost.	$245,000

For a canal system as above, to deliver 5,000 miner's inches, would probably cost about twice as much. (It is found in practice that two 2,500 miner's inches canals may be constructed at the same cost as one 5,000 miner's inch canal.)

OPERATING EXPENSES, 1904.

Mining	$30,815.05
Explosives	21,148.20
Sluice Maintenance	16,681.15
Camp Maintenance, Fuel, Etc.	1,288.91
Lime and Camp Light Maintenance	605.73
Wagons, Stable, Horses, Etc	1,263.26
Mine Office, Insurance, Stationery and Miscellaneous	3,161.57
Bullion Expense (Royalty, Insurance, Etc.)	3,624.50
Management	6,712.41
Roads and Trails	64.47
Quicksilver (Loss for Season)	490.72
Lands and Leases (Lease, Rentals)	2,048.75
	$88,423.75

As has been already noted, the bed-rock in the pit rises on a one per cent. grade, while Mr. Hobson finds that five per cent. is the lowest on which he can run his sluices, consequently, four feet of elevation is lost for every one hundred feet advanced up the channel. The present sluice (four thousand feet in length) at its lower end is as low as it is possible for it to be and afford a proper dump for the gravel, and at its upper end it has arrived at the elevation of the bed-rock. Last season, 1905, will be the last in which bed-rock can be washed by means of this sluice, although the sluice can be extended for a long distance yet, and used to remove the upper benches and top burden. The lower bench, lying on bed-rock, will be removed by a tunnel driven through the rim rock (mentioned before and shown on slide). This tunnel starts at a point 1,500 to 2,000 feet above the present sluice termination, and runs on a five per cent. grade for a distance of about 1,200 feet, and is then under the hydraulic excavation, to which it will be connected by shafts. The dimensions of the tunnel are:—10 ft. x 10 ft. in the clear, and large enough to accommodate a sluice 7 ft. wide x 3 ft. deep, and a walk 2½ ft. wide placed on one side for the sluice tenders. No. 15 Gardner electric drills were used in this work and gave good satisfaction. By the aid of this sluice it will be possible to wash the rich alluvial deposit (about 150 to 200 ft. in depth) from top to bed-rock from one bench, thereby cutting off the heavy cost of maintaining a system of sluices 4,000 ft. in length.

These sluices are paved partially with ordinary end-wood sluice blocks, one foot thick, and partially with improved longitudinal steel riffles. It is the intention, I believe, to put in a system of under-currents for the recovery of flour quicksilver, fine gold, platinum and osmeridium that cannot be recovered in the ordinary sluices.

The following is an assay of the heavy concentrates that remain in the sluices after cleaning up:—

	Oz. per Ton.	Gross Value per Ton of 2,000 Lbs.
Gold	95	$1,900.00
Silver	180	90.00
Platinum	64	832.00
Palladium	61.4	1,769.00
Osmeridium	42	1,386.00
Copper	10.5	16.56
Total Value		$5,993.56

These concentrates cannot be recovered by the process of amalgamation, due, no doubt, to the minerals being enclosed in particles of pyrites, argentiferous galena, manganese and other metallic oxides. The platinum, palladium and osmeridium are found in minute metallic grains and enclosed in small fragments and nuggets of magnetic and chromite. These concentrates will be recovered by the system of under-currents placed at the end of the sluice, where everything of value will be separated from the tailings before going over into the dump.

The mine equipment consists of a portable hydraulic plant of four lines of thirty-six and twenty-two inch riveted steel pipe, aggregating 6,000 feet; six No. 8 hydraulic giants with deflecting nozzles, varying from six to ten inches in diameter; one steam-power hoisting and pumping engine for sinking shafts for bank blasting (on account of the compactness of the gravel it is necessary to loosen it up with powder, a shaft being sunk down a short distance ahead of the excavation, and levels run off from this along the direction of the channel which are filled with powder and set off, and in this way several hundred thousand cubic feet of gravel are loosened up at one time); one steam-power saw mill having a capacity for cutting daily about 4,000 feet of lumber. This mill is also equipped with a planing and matching machine, boring and framing machines, band saw, also emery wheel and grindstones operated by steam power, the use of which appliances results in a great saving of labor and a reduction in the cost of all wooden structures, as well as the cost of sharpening edged tools.

The melting plant consists of three retorts, fitted with iron Liebig condensers for distillation of mercury, having a capacity for treating twelve thousand ounces of amalgamated gold at a single charge; two furnaces for melting, and other appliances necessary for handling ingots of gold weighing up to twelve thousand ounces; also a complete assaying outfit for determining the fineness and value of bullion. The mine is also equipped with a complete outfit of mechanics' and mining tools, and implements of all kinds, sufficient for one hundred and fifty men; powder magazines; blacksmith shop for general forging, wagon work and horseshoeing; one pipe-making shop, fitted with tools and other appliances for making and repairing hydraulic pipes.

The Electric Light and Power Drill Plant comprises:—one 30 kilowatt General Electric Company's direct current dynamo, Form "H" multipoler type. One 40-h.p. Tubular Boiler and one 35-h.p. Erie Engine, used for driving the electric generator at times when it is not possible or convenient to operate the plant by water power. One 24-inch Tuthill water wheel, with automatic governor, and one 8-inch electrically driven Root Blower for tunnel work. The electric appliances used for lighting the mine include four General Electric Company's nine-inch hand-operated Projectors, one Benton search-light, and six long-burning Standard enclosed Arc Lamps. Those in use for lighting the camp and camp buildings are four long-burning Standard enclosed arc lamps, thirty 32-C.P. and fifty 16-C.P. incandescent lamps.

The rock-drilling appliances include:—four Gardner Electric Drill Company's No. 15 Electric Drills, with 2 h.p. 110 volt direct current portable motors, all complete with seven-foot flexible shafts, adjustable tripods, columns, etc., together with stock of extra parts sufficient to keep drills in running order for twelve months.

The telephone system includes three lines aggregating thirty-five miles, with instruments that place the Storekeeper and Manager in direct communication with the reservoir tenders, canal tenders, saw mill foreman, general blacksmith and foremen of the hydraulic pits. The mine is also connected with the Government telegraph line to Ashcroft.

The Company's camp equipment includes one general store, with store-room and meat house attached; boarding-house with store-room; one retort and melting house; bunk houses; hospital for surgeon; stables, office building, etc., making in all thirty-four camp buildings.

This makes the equipment of the property as complete and efficient as that of any hydraulic mining property on the Pacific Coast.

The total amount of gravel washed from the pit up to 1905 was 12,535,009 cubic yards of auriferous gravel. The Chinese companies who owned the property previous to the present owners recovered from the old workings gold valued at $900,000; the Consolidated Cariboo Hydraulic Mining Company recovered from 1894 to 1904, inclusive, gold valued at $1,208,734, making a total product of $2,108,734—an average yield of 16.8 cents per cubic yard for the total quantity washed from the excavation.

The Company's property is one of the largest, and the high grade of its auriferous alluvial deposit entitle it to a place among the richest hydraulic mines in the world.

THE OLDHAM STERLING GOLD MINE, NOVA SCOTIA*

By C. V. Brennan, McGill University, Montreal.

The Oldham Sterling Gold Mine is in the gold mining district of Oldham, in Halifax County, Nova Scotia. It is about 25 miles north of Halifax and 3½ miles east of Enfield, a small station on the I. C. R.

The district is one of the first known and richest in Nova Scotia. Gold was discovered there in 1861, and mining has been carried on after a fashion ever since that time.

The Oldham Sterling Gold Company, Ltd., was organized in 1862 by a party of English capitalist to operate in Oldham. A good deal of development work was done by them, but they were forced to shut down after spending $75,000, chiefly owing, it is said, to extravagance on the part of the management. The property passed into the hands of the late Mr. J. H. Grey, of Montreal, one of the chief shareholders of the old company.

During the eleven years from 1869—1880 Mr. Grey made returns to the mines office for gold to the value of $60,000, while during the three years 1873-1875, tributers on the property made returns for $20,000 more, but were not allowed to do further work. The property then remained idle until the death of Mr. Grey in 1902.

The present company was formed in the latter part of 1902 to take an option on the property for one year, and the results were so satisfactory that the purchase was completed. Since then it has been worked steadily, and over $65,000 worth of bullion has been taken out from what is known as the Sterling lead alone. Adjoining the property on the south are the famous Dunbrack claims of the Hardman and Taylor property, from which over $500,000 worth of bullion was taken in the early nineties.

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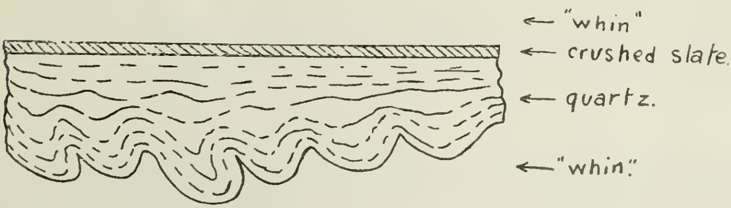
*Student's paper presented in competition for the prizes offered annually by the Institute, and awarded prize of $20.

The country rock of the Nova Scotia gold-bearing series is a quartzite or metamorphosed sandstone locally known as "whin." It is very fine grained, bluish-grey in color and very hard, the hardness in the present case seeming to increase slightly with depth.

The rock has regular planes of bedding, the quartz veins occupying the cracks caused by rupture along some of these planes.

The vein material of the Sterling lead is primarily a greyish quartz. The gold occurs free and usually in fairly large particles. From the 300-ft. to the 1,000-ft. levels the values have varied very little, returning about 2oz. 5 dwt. of bullion per ton, worth $19.65 per ounce. Associated with the quartz have been arsenical. iron and copper pyrites, in small quantities near the surface, but increasing largely in amount below the 700-ft. level. A considerable quantity of galena has been found with the pyrites below the 900-ft. level.

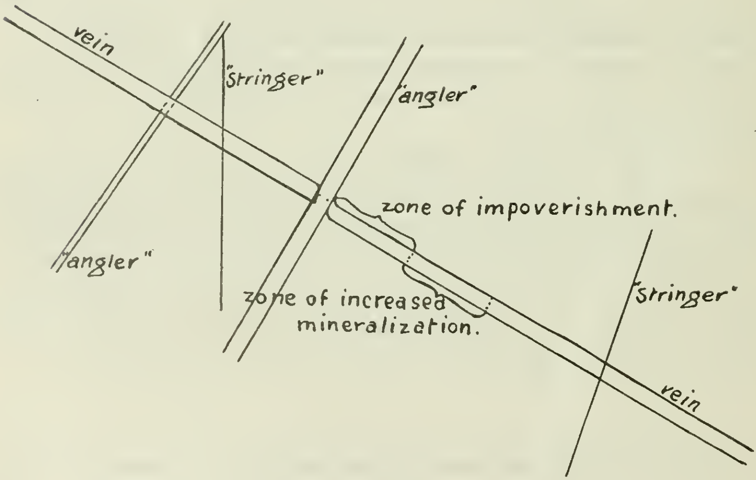
The vein varies in thickness from 3 inches to 10 inches, averaging about 5 inches, and is in a form known as a "barrel" lead. It is very smooth on top and is covered by a quarter-inch or so of fine crushed slate, which makes a very good plane of weakness to shoot to. The bottom of a section of the lead looks like so many half barrels of varying size laid in a row. A sketch will, perhaps, make this clearer. The barrels all run downward, but they



incline slightly toward the apex of the anticlinal from both sides. Down to 500 feet or 600 feet they were easi y taken off with gad and bars, but from 600 feet they have had to be shot off the footwall as described later.

The mine abounds in quartz stringers in size varying from ⅛-inch to 8 or 10 inches. They usually slant in the opposite direction to the lead and at a somewhat steeper angle, about 50° to the horizontal, as shown in the accompanying sketch. In some cases these "anglers," as they are locally called, pass through the vein without having any effect upon it, but a great majority of them especially if of large size, either impoverish or enrich the vein, and are then termed "robbers," or "feeders." The robbers are by far the more common, and they have a very noticeable effect upon the vein for about eight feet below where they cut it.

The vein then increases in value, and for a few feet here abounds in "mineral." This is shown in the following sketch.



The Oldham district, which comprises about 2,500 areas—an area being 250feet by 150 feet—is three miles long by one mile wide, but the greater part of this area is regarded as comparatively barren. It is traversed by an anticlinal whose axis passes through the middle of the district and runs approximately N. E. Roughly coincident with the axis through almost its whole length is a fault or break, the throw and depth of which is not yet known (1).

(1.) It has just been reported from the mine that the break has disappeared about the 1,100′ level, and so they can connect with the whole of the north leg. The work can now be carried up for 1,100′ by overhand stoping, no development work being necessary.

In the western part of the district the gold bearing quartz veins run almost parallel to the axis of the anticlinal, dipping away north and south at from 50° to 80° to the horizontal, but past the centre line, marked AB on the plan of the district, the axis of the anticlinal pitches downward at from 30° to 40°, and the veins turn in toward the centre quite sharply, their outcrops forming a kind of horse shoe. This part of the district is much broken up and intersected by faults, showing that great pressure must have been brought to bear at this point. It is in this shattered zone that most of the richest pay shoots are found. As shown on the plan, the Sterling vein comes into the centre at the point marked E, and it is here that the main plant of the Oldham Sterling Company is situated.

Unfortunately the richest part of the vein, and the only part now being worked, is very limited in length, being cut off on the north by the apex fault above mentioned, and on the south by another large fault, which diverges from the first at about 10°. At the surface the distance between these faults is only about 150 feet, but fortunately it increases with the depth, and at the 1,000 feet level on the slope of the present workings it exceeds 250 feet.

The shaft house is a well constructed frame building of which a photograph and a plan, with position of machinery, is given on page 438. In this building are installed a 100-h.p. tubular boiler, a 30-h.p. double cylinder steam hoist, a 4-drill straight line Rand compressor, a 4-drill straight line Ingersoll compressor and two receivers for compressed air. In other sections of the building are the smithy and the quartz bins.

The magazine, constructed of sheet iron, is placed about 300 feet from the shaft house. This distance is sufficient, as the amount of dynamite on hand is not usually large. By damming up the neck of a shallow depression of probably two or three acres in extent near the mine, an artificial pond has been formed, to which the mine water is pumped and allowed to settled. This gives at all times a sufficient quantity of fairly pure water for the boiler, and is much better than pumping the mine water direct to the boiler supply tank.

A simple device is used at the shaft head for making the skip self dumping. A sort of cradle, placed at the end of the slides, is so pivoted and counterbalanced that when the loaded skip comes upon it, it turns on its axis and the skip is turned over far enough to allow the rock to slide out into a car which carries it to the dump. When the weight of the rock is removed, the weights which counterbalance the cradle are sufficiently heavy to bring it back to its original position, and the skip can then be lowered.

The shaft or hoist track is a slope in the vein following the projection of the anticlinal axis on the right of the main fault. No rock pillars are left to support the roof, but the scaffolds run right into the shaft from both sides, the end stulls of the scaffolds forming part of the shaft timbering. It is divided in two by a line of posts, one compartment being for the skipway and the other for ladder way, pipe line, etc.

The hoisting system is somewhat crude, but very simple. The main shaft is down to the 1,000′ level and slopes from 33° to 40° to the horizontal. In this shaft round slides about 6″ in diameter and 20′ long are spiked to ties sunk in the footwall. These slides are the straight trunks of spruce and fir trees with the bark removed making a very good sliding surface especially when damp. They are placed about 2′ apart and a large sheet steel bucket or skip with a capacity of about ¾ ton slides on them. At every 30′ a small roller for the rope is placed between the slides.

At the 100′ level a drift 7 x 4 is driven east through the soft crushed whin and quartz in the break for 160′, and connects with a vertical shaft 15 x 8 and 130′ deep, which was sunk by the original company.

Owing to the very limited width of the workings and to the fact that the arched roof stands with very little timber, the overhand method of stoping has been found unnecessary, and a modified form of the underhand method adopted. The former would, of course, be less expensive under ordinary circumstances, owing to less handling of ore and waste, but in this case the economy would be more than counterbalanced by the expense of sinking the shaft and driving in levels and raises, as the extra cost could only be divided along a few hundred feet of level. Of course by this method practically no development work is done, but as the company is working with small capital the main object is to extract the quartz with as small an outlay as possible, looking to immediate returns.

The method pursued is first to take out about 4½′ of ground above the vein stuff, leaving the latter in place on the footwall for the time being. The sinking is first done in the line of the shaft, the aim being to keep the sump at the shaft bottom well ahead of the rest of the workings.

The waste is stoped out on either side for about 20′, making in all about 50′. 15′ scaffolds are then put in on either side of the shaft, which is left 10′ wide, and a large part of the waste rock from the side stopes above is stowed on them. As the stope just above is worked lengthwise the scaffold below is extended, but a mill way of 5′ is left between the end of the scaffold and the solid rock for the ore and any extra waste that cannot be retained on the scaffold, to slide down to bottom, where it is mucked out and sent to surface. A good deal more waste rock is sent up than is really necessary, due largely to carelessness in loading the scaffolds.

These latter are placed every 20′ on the slope and run directly across the face. Before a new scaffold is put in, all the ore above it is "stripped" and sent "on deck".

In the footwall a thin layer of crushed slate on top of the quartz makes an excellent plane to shoot to, but there is no trace of a plane of weakness in the hanging wall, and this necessitates the use of much dynamite.

In starting a new stope a sump about 10′ wide and 8′ deep is first blown out at the foot of the temporary slides. This acts as a reservoir for the water and allows of stoping being carried on without interference from that source. The usual square cut system is used in starting this sump. The stoping is carried on across the face from both sides of this reservoir, and goes up in steps on either side. About four and a half feet of the whin, measured perpendicular to the vein, is taken out. The holes are put in about 8′ deep, the top one looking toward the hanging, and the lower one in such direction that it will not quite touch the footwall. The direction and depth of the holes vary somewhat in order to take the greatest advantage of the set up, as the greatest loss of time is in getting the machine in place, and the attempt is made, as a general rule, to get 4 and often 6 holes in on the one set up. The machines when working steadily average about 30′ per shift. Columns are used altogether in the stopes.

There is one important point to notice in placing holes and blasting in the "whin" in this part of the Sterling lead. Experience shows that on the south side of the shaft, holes can be put in 3′ apart on the stope, and the rock moved with 2½ plugs of 1¼″, 50% dynamite, while on the north side the same amount of "powder" will only move 2½′ of the rock. The dynamite used is manufactured by the Acadia Powder Co. of Waverly, N.S., and costs 20c. per lb. The fuse is made by the same company, and is found very efficient.

At the present level all the quartz has to be "shaken" before it can be taken off the footwall. To do this, holes are put in under the lead at such an angle that the bottom of an eight foot hole will be in the solid whin about 2½′ under the quartz. As has been mentioned, the barrels all run downward, and the hole is put in so as to cut transversely under the barrels, but looking slightly downward. The hole is then shot three or four times with 1½″ to 2½″ of dynamite. This small amount of powder is not sufficient to break away the rock, but tends to lift and jar the barrels somewhat, and this jarring is carried along the barrels for perhaps four feet each way, each charge loosening them more. The lead can then be taken off with picks and bars.

At 1,000′ down the barrels adhere very firmly to the footwall and quite a lot of the whin has to be blown off with the vein-matter.

Almost all the stope holes are shot at the end of the night shift, and the ordinary fuse is used, but it is often convenient to shoot holes during the shift, especially in bringing off the lead, and for this purpose an electric battery is used, which does away with the danger of a delayed explosion.

Underground there are three duplex Northey pumps and one Cameron sinking pump, each with a sump to retain the water so that it is not necessary to work them all at once. For drilling there are two 2¾″ Rand drills, one 3⅛″ Ingersoll, two 3″ McKernan and one Baby McKernan. There are two sets of steel varying from 18″ to 8′ or 10′ for each drill. There are usually two and never more than three of these machines in use at once.

For illuminating purposes 9″ wax candles are used underground, and oil lanterns are used in the shaft house. For signalling from the bottom a wire rope is used, running on small rollers attached to the shaft stulls and connecting with a bell near the hoist on deck. The following are the signals employed:—

1 bell—Stop if in motion, or start if the hoist is stopped.

2 bells—Lower.

3 bells—Air on.

4 bells—Men going up.

5 bells—Start the upper pump.

6 bells—Air off.

The main expense of mining in Oldham is in the uncovering of the quartz. For every ton of quartz taken out over ten tons of "whin" have to be moved, and this means an enormous amount of dead work. The mine employs 28 men on the average. These are divided into two shifts of 10 hours each. The day shift comes on at 7 o'clock a.m. and goes off at 6 p.m., and the night shift comes on at 6 p.m. and works till 4 o'clock next morning. The shooting is usually done at the end of the night shift, and thus at least three hours are given for the smoke and fumes of the dynamite to get cleared away.

On the day shift there are 1 smith, 1 helper, 1 engineer, 2 deck-hands, 2 machine men, 2 helpers, 1 pumpman, 6 muckers and a superintendent. On the night shift, one engineer, 1 deck-hand, 1 pumpman, 2 machine men, 2 helpers and 4 muckers. The pay role averages over $1,300.00 per month.

The actual production from the present limited workings averages about 75 tons of quartz per month, yielding over 2 oz. in gold per ton.

The company owns four horses for hauling coal, wood and other supplies. Soft wood costs $2.75 per cord at the boiler, and soft coal about $4.75 per ton.

The average monthly costs of operations are shown by the following approximate figures for August, 1905.

No. tons ore produced..	100
Pay-roll	$1,276
Powder and caps	100
Fuel	175
Repairs and timber	100
Total expenses	$1,650

THE STERLING MILL.

The stamp mill is at the point marked C on the plan, about one-third of a mile from the shaft house and about 80′ below it. The ore is conveyed there in carts of one ton capacity. The mill is reached by a short trestle and the ore is dumped on the breaker platform. The breaker is a 10 x 7 Blake, made, as was nearly all of the milling machinery, by the Truro Foundry. It is fed by hand and reduces the quartz to pass a 2″ ring. The ore then passes into the ore-bins, which have a capacity of twenty tons, and from there automatically to feeders of the usual suspended Challenge type. The stamps weigh 1,000 lbs. They drop 4 inches 100 times per minute and crush through 40 mesh. The pulp passes over electro-silvered plates, 10′ long, into sluice boxes, and then down stream, no attempt being made either to concentrate or to save the tailings. (1)

The power is supplied by a 90 h.p tubular boiler placed in a fire-proof boiler-house at one side of the main building. This supplies steam to a 45 h.p. engine, belted to the main shaft from which the stamps, breaker and pumps are run. An engenious device is used for filling the tank that supplies water to the boiler and mortar boxes. The rod of a vertical jack-pump is attached to one of the driving pulleys in such a way as to form an eccentric of the latter, and this causes a stroke of the pump piston for every revolution of the pulley. The suction is in a stream in front of the mill and 15′ below it.

The mill is constructed in a most durable manner, the purpose evidently having been to get great strength and rigidity. The internal design is fairly good, although it might have been improved in several important points. There are no grizzlies, and everything has to go through the breaker. This is not a serious matter as the capacity of the breaker is largely in excess of that of the mill. The breaker is placed too near the throat of the ore-bins, and with fine damp stuff this tends to clog the machine. The mill was made as fire-proof as possible. The entire walls are covered with a fire-proof felt, the roof is of galvanized iron, and the boiler-room is sheathed with thin sheet iron plates.

There are three men employed in the mill, one fireman, who

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(1). Since the data for this paper were collected a Wilfley table has been installed in the mill.

looks after the engine and boiler, a boy to attend the breaker, and the amalgamator who is in charge.

As the mill is without concentrators or other devices for saving gold, it is necessary to catch as large a per cent. of the amalgam as possible in the mortar boxes without unduly reducing the duty of the mill. Another scheme has been adopted to gather the amalgam in the boxes, and has been found very successful. Instead of having the water fed into the mortar by one or more jets from above, a ½-inch nipple is put through the screen frame near the bottom, with a slant upwards, and the water for the mortar is supplied through this pipe. In practice it is found that a large proportion of the amalgam gathers just in front of where this nipple enters the mortar, and collects either in a hard, compact ball or in a form much like a doughnut. The plates are rubbed up with chamois cloths and the loose amalgam collected every evening or whenever the condition of the plates shows that it is necessary. The mortar boxes are cleaned and the sands panned at the end of each run, and if the ore is very rich the amalgam ball formed iu front of the jet may be taken out during the run without much loss of time, by removing the screen from the frame proper and digging the ball out from in front of the nipple.

Owing to the fact that the capacity of the mill is greatly in excess of the present output of the mine, it is customary to run by day only and to shut down completely for about half of each month. The amalgam is kept until the end of the run. It is then squeezed in a chamois leather bag and all the liquid mercury goes through, leaving a lump of hard amalgam. This runs from 40 to 60% gold, depending on the fineness of the particles of gold which make up the mass. The coarser the gold, the lower the per cent. of mercury retained. This mass of amalgam is broken up and made into several balls, which are placed together in a cast iron retort. This has an air-tight cover fitted with a curved iron pipe for the mercury vapours to pass off through. The retort is placed in a pot furnace and surrounded with coal. The iron pipe passes out of the furnace and downwards, the mouth being just over the surface of a pan of cold water. Waste is wrapped around the upper part of the pipe and a stream of cold water is caused to play upon it. This condenses the mercury vapours, the liquid mercury being caught in the pan below. When this operation is finished the retorted gold, or "gold sponge," as it is called, is taken out and weighed. It is then placed in a graphite crucible with carbonate of soda and again put in the pot furnace, where it is melted.

The molten gold is cast into ingots in cast iron moulds. The retorted gold is found to contain about 4% of mercury and other impurities, which are got rid of during the melting. The results of a small clean-up in July, 1906, may give a clearer idea of the relation between the amalgam and the gold.

Data from test run of 20 tons Sterling quartz:—

Hard squeezed amalgam	75 oz.
Retorted gold	43 oz. 15 dwt.
Smelted gold..................	42 oz. 10 dwt.

Value of gold, $19.67 per oz.

Here the amalgam went 57% gold, and the retorted gold had less than 3% of impurities in it. The gold is worth from $19.55 to $19.80 per ounce as it comes from the mill. A royalty of 2% on retorted gold, or 36 cents per oz., is collected by the Nova Scotia government.

The average duty is .8 ton per stamp per 10-hour shift, corresponding to a duty of two tons per stamp per 24 hours. An average of $2\frac{3}{4}$ ounces of mercury is used per ounce of gold recovered. A fair average of mill costs is given below.

Cost Sheet, week ending June 23rd, 1906:

Wages..................................	$27.00
Fuel, Oil, etc..........................	30.00
Screens, Mercury, etc....................	10.00
	$67.00

Tons crushed, 49, or a cost of $1.35 per ton.

The bullion is deposited at the Bank of Montreal, in Halifax, and from there forwarded to the U. S. assay office in New York City.

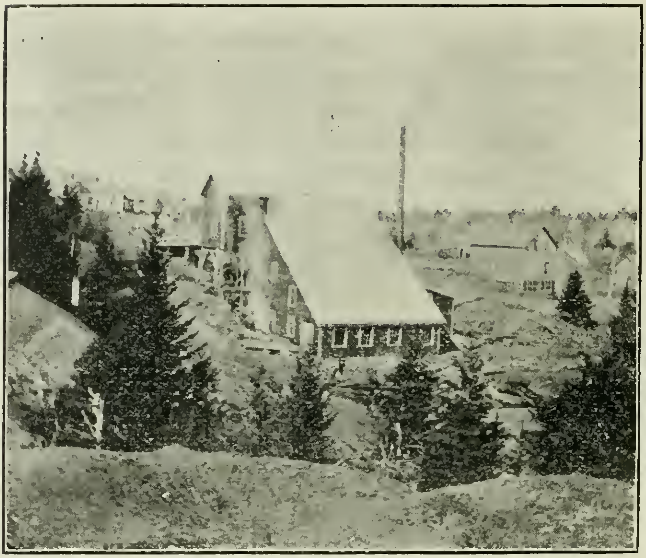
Following is a return sheet showing fineness of the gold and charges made against it at the mint from 30 t. quartz, 5th October, 1906.

U. S. ASSAY OFFICE AT N. Y.

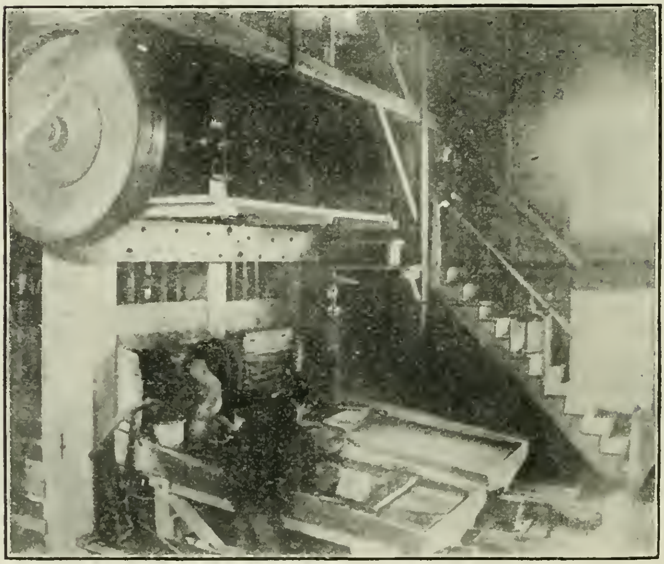
Au. before melting. . . . . . . 88.57 oz.		Fineness 957	
Au. after melting. . . . . 88.51 oz.			
Ag. 1.70	Ag. 61c.	Fineness 38	
Melting, Refining and Parting.			4.71
One-quarter per cent. commission			4.38

Au.	$1,750.99		
Ag.	1.70	Net	$1,743.70

The writer wishes to acknowledge the kind assistance given him while in Oldham by the manager of the Company, Mr. J. B. Forster and by the Superintendent, Mr. Martin O. Shaughnessy.



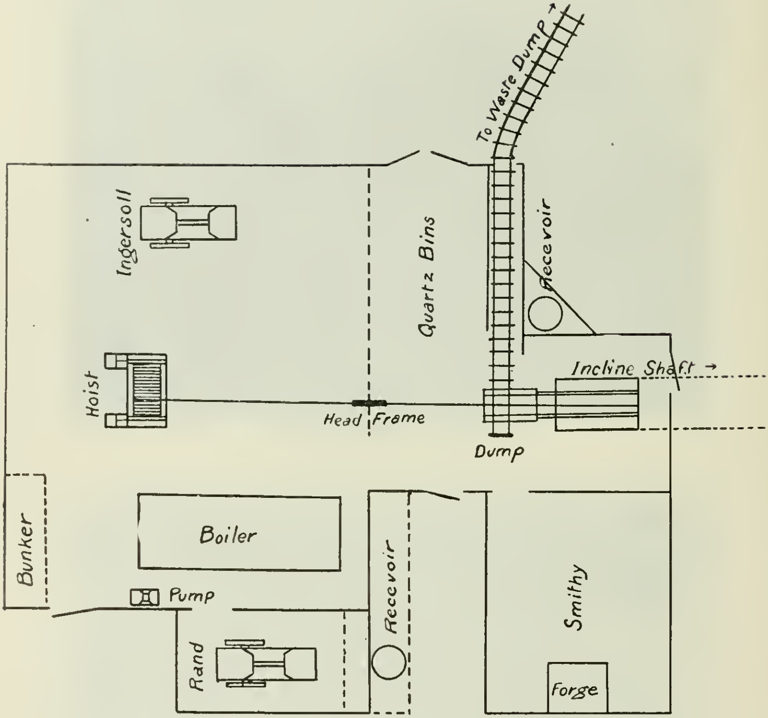
STERLING MILL.



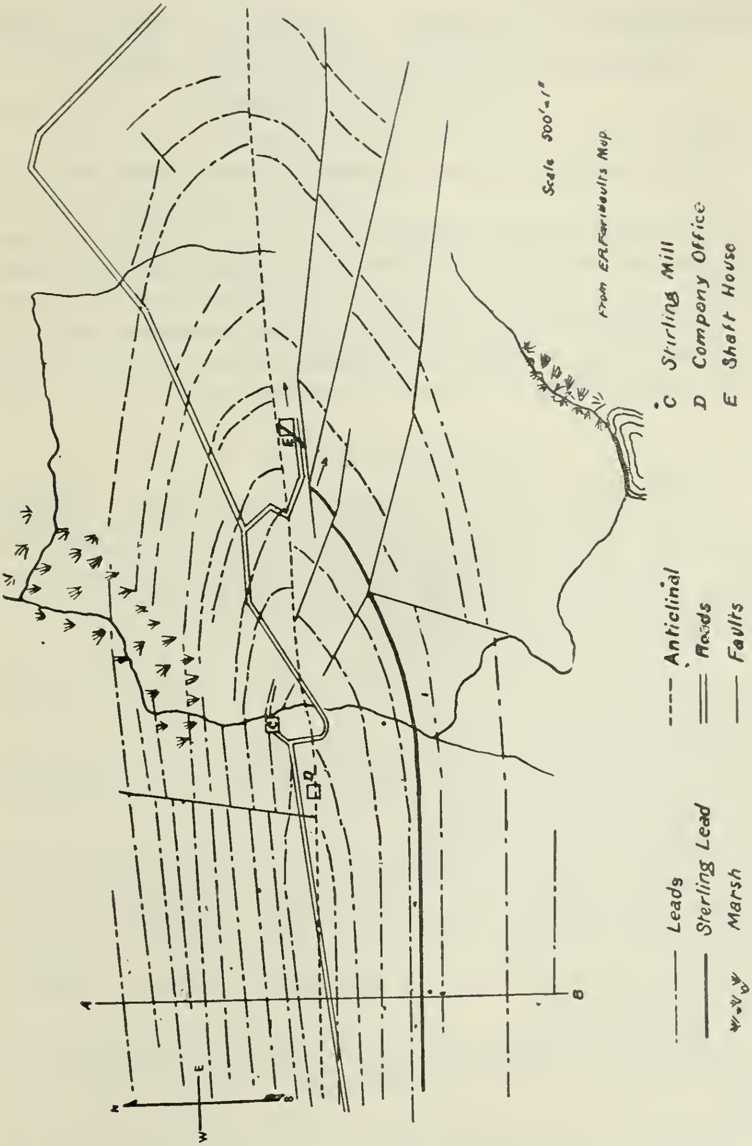
MORTAR PLATES—STERLING MILL.

STERLING SHAFT HOUSE.

GENERAL TOPOGRAPHY. OLDHAM.



PLAN
STERLING SHAFT HOUSE
OLDHAM N.S.
Scale 1"=10'


Scale 500'=1"
From E.R. Faribault's Map
C Stirling Mill
D Company Office
E Shaft House
Anticlinal
Roads
Faults
Leads
Sterling Lead
Marsh
A
B

THE USES OF CHEMICAL ANALYSIS IN IRON BLAST FURNACE PRACTICE AND SOME NOTES ON LABORATORY METHODS.*

(By George D. Drummond, McGill University, Montreal).

This paper will treat chiefly of the uses of chemistry to a blast furnace, and some methods of analysis used at the Midland Blast Furnace of the Canada Iron Furnace Co., Midland, Ont.

The Midland Furnace smelts Lake Superior ores with Connellsville coke and a description of the plant, before proceeding to the main objects of this paper, may be of interest.

Description of Plant.

The Midland Furnace of the Canada Iron Furnace Company is situated on Midland Bay, the most easterly point of Georgian Bay. The plant is on the water side, and the furnace elevator is about 200 feet from the dock. Boats drawing 21 feet can go up to dock safely, and have done so.

Furnace.—The furnace is 65 feet high by 13 feet bosh. It has a capacity of 100 to 140 tons per day. Hearth is 8 feet. Tuyeres are eight in number.

Hot Blast Stoves.—These are of the 2-pass type. They are 16 feet in diameter, by 65 feet high. They are on a substantial stone and concrete foundation.

Blowing Engines.—There are three blowing engines; two were built by the Ragor Machine Company, Columbus, O., the other by the McIntosh, Hemphill Company, Columbus, O. Two have a 6-foot by 4-foot air cylinder, and 34-in. steam. The third has 36-in. steam cylinder, and same size air cylinder. Engines are of vertical type.

Boilers.—There are eight 75-h.p. flue boilers, and two McDougall boilers of 120 h.p. apiece in use. Working pressure 90 lbs.

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*Student's paper presented in competition for prizes offered annually by the Institute. This paper was highly commended by the judges.

Boiler and Stove Stack.—These are of steel, diameter 10 feet, height 174 feet. Foundation is built of stone 20 feet. It is lined with fire-brick. Inside diameter 8 feet 6 inches.

Pumps.—Two Duplex pumps for circulation and fire requirements, also one Duplex for boiler feed.

Blacksmith and Machine Shop.—These are in a brick building 30 feet by 60 feet. In one end is the carpenter and machine shop, in the other, the blacksmith shop.

Cast House.—This is a brick building, heavily built; it is 150 feet by 140 feet. Floor is five feet above yard level, to obtain easy handling of pig iron.

Water Supply.—Water is taken direct from Midland Bay and pumped to a steel tank 12 feet in diameter and 40 feet high. Water is drawn from tank to tuyere coolers, cooling plates, and for general use around plant.

Laboratory.—The laboratory is a complete one in every respect. It is a one-story brick building with very high roof. The Building is electrically lighted.

Lighting Plant.—Lighting is done by electricity. There is a Canadian General Electric dynamo producing electricity.

Docks and Dock Equipment.—These are directly behind the furnace and extend several thousand feet, with 21 feet depth of water.

Two McMyler hoists handle the iron ore direct from vessel to stock pile, with grab buckets. These two McMyler hoists have a radial swing of 60 feet, and place material 120 feet back from water's edge. The grab buckets have a capacity of 4 tons.

The limestone and sand are handled with a small McMyler hoist with 60 feet boom, but it only takes two tons. Bucket used is similar to Brown hoist bucket.

The "McMylers" are also used to load pig iron and other material.

Pig Iron Disposal.—Pig iron is taken from the cast house to the yard on railroad flat cars, and piled.

In the study of the chemical phenomena of iron smelting, great credit is due to the English iron master, Isaac Lowthian Bell. As far back as May, 1869, he submitted to the Chemical Society of Great Britain, a paper dealing with this subject. In 1872, he published the "Chemical Phenomena of Iron Smelting." Before

1869 chemistry was used at many works, but it might be said that the systematic study of these phenomena was begun by Isaac Lowthian Bell. On this continent Mr. Andrew Carnegie was one of the first to systematically use chemical analysis in iron and steel works. To-day, every iron works recognizes the use of chemistry.

To manufacture iron three materials are necessary, fuel, ore and flux. In the Ontario furnaces the fuel, with one exception, is coke. Coke, ore and limestone, or dolomite, are the three materials used in this section. Charcoal is used at the following Canadian furnaces:—Deseronto Iron and Steel Company, Radnor Forges and at Drummondville, Que. The rest use coke, namely—four, Dominion Steel; one, Nova Scotia; one, Londonderry; one, Midland; one, Hamilton and two A. S. Co.

A brief outline of the requirements of the business may be given.

For the successful operation of an iron and steel plant the following considerations must be satisfied:—First, a good market at hand, secondly, raw materials must be cheaply assembled, and, thirdly, labor must be plentiful and not unreasonably costly.

Ontario and the Northwest give a good market, whilst labor is plentiful

The Lake Superior iron ore ranges, the Mesabi, Gogebic, Marquette, Menominee and Vermilion in the United States and the Michipicoten range in Canadian territory, are near Great Lake transportation, and from these ranges hematite ore is taken. The Mesabi, Gogebic, Menominee, Vermilion and Michipicoten have ore ports on Lake Superior, whence ore goes down St. Mary's River, thence by Georgian Bay to Midland. The Marquette range ore is shipped from Escanaba, Green Bay, Lake Michigan. It goes through Upper Lake Michigan, thence by Mackinaw Straits and Georgian Bay to Midland. This ore is carried in modern steel steamers of from 3,000 to 6,000 tons, types of which are the Canadian steamers "Neebing" and "Agawa." The ore is assembled from these points at an average freight rate of 45 cents; this is less than 1/10 of one cent per ton per mile. Thus it will be readily seen how cheap the assembling of iron ore is.

Handled from the mines by steam shovels into 50-ton steel hopper cars, drawn by 150-ton locomotives to immense ore dock pockets, loaded into steamer by gravity, and unloaded by automatic grab buckets, the whole process is wonderful. From the time the ore is mined until it lies on the Midland dock scarcely one quarter is not mechanically handled.

Coke is brought from the Connellsville district in Pennsylvania, and is transported by rail all the way, about 700 miles.

Limestone is brought from the Company's quarry, which is situated at Quarry Point on Midland Bay. Quarry Point is three miles from the furnace, and the limestone is brought in on scows by a tug.

Nowadays, the value set on iron ore, coal, coke and limestone is calculattd from the data determined by the chemist regarding the several constituents, and on the physical qualities supplied by the practical furnaceman or founder.

A brief note on the physical qualities of the ores and coke used will now be given.

The Mesabi ore, though exceedingly rich in iron generally and a good all round ore, is a very fine dusty ore physically. In a modern blast furnace it tends, under the big blast pressure of 15 to 25 lbs., to blow out as flue dust.

The other range ores, Menominee, Michipicoten, etc., are chiefly of the hard lumpy type, generally slightly poorer in iron and good chemical qualities of the Mesabi, but greatly superior for blast furnace working.

Physical Qualities of Coke.—Good coke can be recognized by the metallic ring given when two pieces are clinked together, and by its silvery lustre and large lumpy formation free from sulphur spots. The Connellsville coke used has the foregoing characteristics.

The writer will now proceed to describe the methods of analysis of the raw materials and products.

Sampling.

Sampling is as important as the actual chemical analysis itself, and a skilled man has charge of this section of the work. In sampling iron ore the sampler usually uses a large sized trowel, a hammer and a small pail. The steamship cargo is sampled hatch by hatch. First the upper portion is skimmed over, and small pieces of ore broken by the hammer and put into the pail. Then when the cargo is nearly unloaded the hatches are again sampled, and thus a sufficiently accurate sample is obtained. Altogether from each hatch about 75 lbs. are taken. The ore may be sampled very accurately from stock pile direct, after unloading. At Lake Superior ports the sampler simply takes pieces out of chutes as the ore rushes down, or takes pieces of ore from the cars one by one as they lie over the ore pockets.

The sample is then ground up in a small ore crusher, driven by a belt off the shafting of the repair shop. The sampler spreads it out evenly on the floor and then quarters it, saving the opposite quarters, which are mixed, and rejecting the others. This is kept up till a small sample is the result; it is then crushed in a mortar or mortar and pestle until it will all pass through a 100 mesh screen. It is then ready for analysis.

Limestone, coal and coke are all sampled in practically the same way, a large average sample obtained, and by successively quartering is reduced to the powdered sample (100 mesh).

Each cast is sampled thus:—A small mould is filled at the beginning of the cast, another at middle, and again another at the end. After standing a minute the moulds are turned over and each piece of iron plunged into water. On cooling, the pieces are drilled and about 10 grams taken from each. In the case of white iron, shot samples are taken. Molten iron is poured in drops into a bucket of water and the small globules of iron pounded up in a mortar so fine that it will go through an 80-mesh sieve.

The samples are put into envelopes, and their name, number, where from, and other details noted thereon. They are then handed to the chemist who has charge of that section of the work.

Slag Sampling.—Before every cast of the furnace, "flushes" or withdrawals of slag are made. At the last flush before each cast a mould is filled. At the end of the day, pieces of approximately the same size are broken off each and broken up fine by a mortar and pestle to go through a 100-mesh sieve.

METHODS FOR RAPID ANALYSIS OF IRON ORE.

DETERMINATION IRON.

Permanganate Method.

To .5 gram of ore add 15 C.C. $SnCl_2$ (stannic chloride), 15 c.c. H_2O and 15 c.c. HCl. The SnCl acts as a sort of catalizer;

put on a warm plate till dissolved, add $SnCl_2$ from burette till colorless, then add 25 C.C. saturated solution of mercuric chloride, $MgCl_2$, and manganese phosphoric acid, titrate to a sudden pink (it disappears if left to stand) with $KMnO_4$, reading 1% to 1 c.c.

Solutions used.—$KMnO_4$, approx. 5.646 gram.—1 litre (see stand). Manganous phosphoric acid. 160 grams manganous sulphate, dilute to 1750 c.c., 330 c.c. of 1.3 S.G. phosphoric acid, then 320 c.c. $H_2\ SO_4$. $SnCl_2$, made by nearly saturating HCl. 1.20 S.G., in C.P. granulated tin and diluting this solution with about five volumes of H_2O. $MgCl_2$ (manganous chloride) is a saturated solution.

BICHROMATE METHOD.

This method is slower than permanganate, and not more accurate; therefore, it is not much used in steel works laboratories.

Weigh out 1 gram of ore into a small beaker, adding 50 c.c. strong HCl, when ore is dissolved, it is ready for filtrating. If not all dissolved filter through No. 11 Cm No. 0 paper with hot HCl and H_2O. Fuse residue with sodium carbonate in a clean crucible, dissolve in HCl and add to original filtrate (trouble mainly occurs with magnetites). Heat to boiling point.

Titrating.—The purpose is to reduce the Fe by stannous chloride and then oxidize the reduced solution with potassium bichromate solution.

$SnCl^2 +_2FeCl_2 = SnCl_4 + 2FeCl_2$ (Reduction of Fe by $SnCl_2$).

Run in $SnCl_2$ till solution is colorless; more than one or two drops will spoil determination. Have a No. 6 beaker with 200 to 300 c.c. water and 25 c.c. $HgCl_2$ (mercuric chloride) in it ready. Iron solution being colorless pour it into large beaker. Mercuric chloride, takes up any excess stannous chloride, which would otherwise act on bichromate.

$SnCl_2 + 2HgCl_2 = SnCl_4 + 2HgCl$.

Reaction between the bichromate and the oxidizing iron is tested by potassium ferricyanide.

(If great excess of $SnCl_2$ has been used metallic mercury will be formed as a grey precipitate.

$SnCl_2 + HgCl_2 = SnCl_2 + Hg$

which will subsequently reduce the K_2Cr_2O solution, thus giving erroneous results.) (Cremer & Bicknell.)

Stir solution up well to make sure of complete oxidization, excess $SnCl_2$. Titrate immediately with the standard $K_2Cr_2O_7$ solution.

React.—$K_2Cr_2O_7 + 14HCl + 6FeCl_2 = 2KCl + 2CrCl_3 + 6FeC_2l + 7H^2O$

Potassium ferricyanide $K_2Fe_2\ (CN)_{12}$ gives a deep blue color with ferrous salts, but with ferric salts produces a yellow brown color. On a clean porcelain plate put drops of $K_2Fe_2\ (CN)_{12}$ solution, run in bichromate till drops of iron solution put on plate turn light green with the $K_2Fe_2\ (CN)_{12}$ solution. At end reaction there is no color. When drops show no greenish tint, but only a deeper yellow, oxidization is complete and the reading of burette is taken.

If ores do not dissolve, filter, save filtrate, fuse silica, with sodium carbonate, dissolve the fuse salt, precipitate iron and alumina with NH_4OH, filter, wash with hot H_2O six times, and dissolve by HCl into first filtrate. Titrate; this is to prevent salts precipitating mercuric chloride.

Solutions used.—$K_2Cr_2O_7$ (potassium bichromate)

8.8 grams powdered $K_2Cr_2O_7$ per litre.

1 C.C.—1% iron.

Standardize $K_2Cr_2O_7$ with iron wire.

$SnCl_2$—Solution made up as described above.

$K^2Fe_2\ (CN)_{12}$ solution—0.1 grm. $K_2Fe_2\ (CN)_{12}$ dissolved in 50 C.C. H_2O fresh each day.

PHOSPHORUS, MANGANESE, SILICA AND SULPHUR IN IRON ORES.

Determination of Phosphorus.

Weigh out two grms. into No. 1 beaker, add 30 c.c. HCl, evaporate to dryness to get SiO_2 out. Take up in as little HCl as possible, take down to syrupy condition, add HNO_3 and evaporate to syrupy condition again, add HNO_3 again, filter out SiO_2 and proceed as in iron. If a magnetite ore, fuse, with sodium carbonate, dissolve fused salt in HCl and H_2O, filter, add filtrate to first filtrate and proceed as before.

(NOTE:—The presence of arsenic in ore or steel introduces a possible source of error in the phosphorus determination, since arsenic may precipitate along with the phosphorus as ammonium arsenio-molybdate, and subsequently as magnesium ammonium arsenate. At temperature given for precipitation with molybdic solution, viz., 40 degrees C., there is no danger of arsenic being precipitated unless amount present is large.) (Cremer & Bicknell.)

DETERMINATION OF MANGANESE.

Weigh out .2 grms. into No. 1 beaker, add 30 c.c. HCl and evaporate to syrupy condition, add HNO_3, evaporate to syrupy condition, again add HNO_3 and proceed as in iron.

DETERMINATION OF SILICA.

Weigh out 1 grm. of ore into No. 2 beaker, evaporate to dryness in 30 c.c. strong HCl, take up in diluted HCl, filter through No. 11 or 42-½ c.m. No. 0 paper, wash with hot HCl, and water well. Fuse with sodium carbonate in a perfectly clean crucible for half an hour, dissolve in HCl and evaporate in a casserole to dryness. Filter through 11 c.m. No. 0 filter paper, wash with hot HCl and H_2O well, and burn and weigh as SiO_2.

DETERMINATION OF SULPHUR.

Treat 1 to 5 grms. with aqua regia (3HCl and $2HNO_3$) and evaporate to dryness in No. 3 or 4 beaker. 50 c.c. aqua regia is added to each gram of ore weighed out. Take up in hot dil. HCl, filter through No. 12½ c.m. and No. 590 No. 0 paper, washing well with hot HCl and H_2O. Evaporate the filtrate to dryness almost, or syrupy condition, but adding before 15 c.c. barium chloride (1-10). Salts form at the last; take up in hot H_2O, filter through No. 12½ c.m. and No. 590 No. 0 paper, washing well with hot HCl and H_2O. Ignite and weigh as barium sulphate $BaSO_4$.

All apparatus should be scrupulously clean by washing well in distilled H_2O.

Moisture.—Several crushed samples are taken of about 10 lbs. apiece; these are placed in shallow tins, weight of tin observed, and ore dried over steam pipe bath for a night. Loss of weight = moisture.

Determinations of alumina, lime and magnesia are done by the methods proposed by Cremer and Bicknell in their admirable chemical and metallurgical handbook.

Before leaving iron ores it may be well to state that flue dust, which is composed of fine ore, coke and limestone, is analysed in the same way as iron ore. This flue dust is blown down the Downcomer gas main to the dust catcher.

COAL AND COKE ANALYSIS.

Moisture.—10 grams of powdered material are placed in a hot air bath and dried at 100 degrees C. Cool and weigh. Loss of weight=moisture.

Volatile Matter.—1 gram of sample is placed in a closed platinum crucible and heated over Bunsen lamp for three and a half minutes, then over blast flame for three and a half minutes. Cool and weigh, the loss in weight less the moisture is the volatile matter.

Ash.—1 gram of coal or coke is placed in a platinum crucible, slowly heated and stirred with platinum rod. Stirring is kept up until the volatile matter is driven off, and the residue is granular. When residue is granular the combustion of carbon will be rapid. When carbon is cooled off allow crucible to cool and weigh ash.

Sulphur.—Weigh out 10 grams pure soda carbonate and 5 grams pure potassium nitrate into a small mortar. Weigh out 1 gram finely powdered coke and mix it up with the fusion mixture in the mortar. Fuse in a large platinum crucible over a moderate alcohol flame. Put the mixture in the crucible a little at a time and allow the fusion to become quiet before another addition. When all the mixture has been fused, dust out the mortar into the crucible and add a little potassium nitrate to oxidize any coke which may be unconsumed. Fuse a little longer and allow to cool. Dissolve in dilute HCl in a No. 3 casserole and evaporate to dryness, stirring occasionally when the contents become solid. The contents should be bone dry before proceeding. Take up in hot water and a little HCl, heat a few minutes, filter through an S-S 595 11 c.m. paper into a No. 2 beaker. Wash with hot HCl and water. Boil solution, add 10 c.c. barium chloride (10% solution) and evaporate to syrupy condition. Add hot water and a few drops of HCl. Boil a minute, allow to settle for ten minutes, and filter through double filters 11 c.m. No. 0 and 9 c.m. 590 S.S. Wash with HCl and hot water. Ignite and weigh as barium sulphate. Calculate amount of sulphur from this weight.

Limestone Analysis.

The determinations of silica, alumina, lime, magnesia, etc., are made in the same manner as in slags—see later.

We have dealt with the analyses of the raw material entering into the production of iron and steel. We shall now enter into the analysis of the products, iron and slag.

Analysis of Slags.

Silica.—To 1 gram of finely powdered slag in a No. 4 casserole add 10 C.C. water, mix thoroughly, add 15-20 c.c. HCl, evaporate to dryness, add 3 to 4 c.c. HCl and again evaporate to dryness. Filter on filter pump through 12½ c.m. No. 0 Munktells, washing well with hot dilute HCl and hot water, two or three times with each. Weigh as insolubles and subtract 1.00% to give approximate result. If accurate result is desired, fuse in clean crucible with fusion mixture and dissolve in hot HCl after fusing from half an hour to three quarters of an hour. Filter and weigh as before. Result is amount of silica. Save both filtrates for alumina, iron, lime and magnesia, if a very accurate analysis is required.

Alumina and Iron.—The filtrate from silica is put into No. 4 beaker, raised to boiling point and precipitated with ammonia twice, very carefully. The first precipitate is dissolved in HCl. Each time a slight excess of NH_4OH is required, this excess is detected by sense of smell. Filter through 12½ No. 0 paper, washing well ten times with hot water. After precipitating filter immediately, as it is liable to become gummy, and thus filter slowly. Weigh as alumina and iron. Multiply the iron in slag by 1.428 and substract. Alumina is the result. If iron is required dissolve out of crucible with HCl and titrate as in iron ores. Crucible must, of course, be clean.

Lime.—Save the filtrate from the alumina. Put into No. 5 beaker, and raise to boiling point. Precipitate with ammonium oxalate, dissolve with HCl, precipitate again, being especially careful to add ammonia in slight excess. Filter through No. 0 12½ Munktell's paper, and wash well with hot water. Take the paper out, spread it inside the beaker. Wash the precipitate down with hot water, and dissolve any lime that may be on the paper with dilute sulphuric acid. Add half No. 5 beaker full of hot water, add 10 c.c. strong sulphuric acid to dissolve the precipitate. Titrate, when almost boiling, to a first pink with permanganate. (A slight excess of ammonia used in precipitating the lime will bring down magnesia.)

Magnesia.—Put filtrate from lime precipitate into a No. 6 beaker. Evaporate to about 200 c.c., allow to cool as much as possible. Add a solution of microcosmic salts (100 c.c. water to a 3 grams of the salt) to magnesia solution and precipitate until precipitate stops forming with ammonia hydroixide. Allow to stand after stirring vigorously for 15 to 20 minutes, so that precipitate may crystall se thoroughly. This done, add NH_4OH to the amount of ¼ of the solution containing magnesia *precipitate.* Allow to stand twelve hours, filter through No. 0 12½ C. M. Munktell's paper, washing well two or three times with dilute ammonia water. Weigh. Decarbonise paper by slow heat of blast lamp, and when the paper is decarbonized turn on the full flame and burn for half an hour or so, according to bulk, when it should turn white. Weigh as MgO.

Sulphur.—Weigh five grams of slag into a beaker, add 200 c.c. hot water, and then run in a few c.c. less than the supposed required amount of standard iodine solution. Then add 20 c.c. HCl SG 1.20, and, after stirring well, a few drops of starch solution. If no blue color is produced add iodine solution with constant stirring, till a permanent blue color is obtained. The percentage of sulphur is then calculated from the factor of the standard iodine solution. (Cremer & Bicknell.)

Manganese.—Dissolve sample of two grams in 20 c.c. of water and 30 to 40 c.c. HCl. Filter out silica and proceed as in iron ore.

Phosphorus.—Dissolve sample of two grams into 20 c.c. of water and 30 to 40 c.c. HCl. Filter out silica and proceed as in iron.

Iron in Slag.—To two grams of powdered slag add 10 to 20 c.c. HCl and 40 c.c. of water. Heat on plate 30 minutes and do by potassium bichromate method.

Pig Iron Analysis.

Chromic Acid, Method for Silicon.—Weigh one gram of drillings into No. 5 porcelain casserole, adding 15 c.c. water and 25 c.c. silicon mixture. Evaporate till solution spits against watch glass. Add 15 c.c. chromic acid, and boil rapidly till greenish scum forms. Add ½ casserole full of hot water and boil till clear (one minute). Filter through 12½ or 11 c.m. No. 0 paper with a filter pump. Wash three times with water until clear, twice with hot dilute HCl. Wash with hot water twice. Ignite and weigh as silica.

(Notes.)—The chromic acid burns off carbon. Silica equals .4667 of its weight, Si. Other methods include HCl method, which evaporates to dryness, but has to burn off the carbon in crucible. The chromic acid, it may also be noted, is often left out, and when this is done the method is called the *sulphuric acid method.*

Hydrochloric Acid Method for Silicon.—Dissolve one gram of iron in 20 c.c. strong HCl. Evaporate to dryness and heat for one minute after it is dry. Take up with dilute HCl, filter through No. 0 12½ Munktell's, washing well with hot water and hot HCl. Ignite and weigh as SiO_2.

(Note).—The evaporation to dryness is longer, the carbons not being burnt out with chromic acid require longer to filter and burn.

Sulphur.—Weigh five grams of drillings. Transfer by glazed paper into an evolution flask. Put in a separatory funnel and fix in support. In a tall glass tumbler put 30 to 50 c.c. cadmium chloride solution and 150 to 200 c.c. water. Mix thoroughly, attach a delivery tube, resting on glass bottom of the tumbler. Run 50 c.c. water into flask, cork tightly, add 50 c.c. HCl slowly. When evolution becomes slow, boil with small Bunsen flame until delivery tube becomes hot with steam. Add 5 c.c. starch solution, dissolve precipitate with 50 c.c. HCl. Titrate immediately with iodine to a blue color.

Phosphorus.—Weigh out one gram if iron exceeds .20, two grams otherwise, into a No. 2 beaker or a casserole. Add 50 c.c. nitric acid, S.G. 1.14 for each gram. Boil until dissolved, the brown fumes will then have disappeared and iron ceased sizzling up from bottom. Filter into a 500 c.c. flask through 595 c.m. 12½ S.S. Wash with hot 2% nitric. Add 10 c.c. strong permanganate solution, (15 grams per litre). Boil till the brown precipitate comes down. Add ferrous sulphate in small crystals until the precipitate is dissolved. Boil three minutes. Add ammonia until a brown precipitate is obtained. Dissolve the precipitate with nitric acid S.G. 1.42 until solution is straw yellow. When the temperature of solution is from 85 to 90 degrees C. add 50 to 100 c.c. of molybdate solution. Shake well for 5 to 10 minutes, being careful to remove cork at first, several times. Use filter pump and double papers, Munktell's No. 0 12½ c.m. Wash with acid ammonium sulphate solution until a drop of wash gives no brown color with a drop of ammonium sulphate. Dissolve precipitate into same flask with dilute ammonium wash. Wash filter paper well with hot water, and add 15 grains powdered zinc and cautiously 25 c.c. sulphuric acid. It is well to have a beaker of cold water at hand if solution threatens to overflow. Filter into 500 c.c. flask, washing the first flask. Use folded 595 paper. Wash well with hot water. Titrate immediately with standardized permanganate, subtracting 8 c.c. for the zinc.

(NOTE.—Handy's method is sometimes used. See Cremer and Bicknell)

Manganese.—Dissolve two grams of drillings in a No. 2 beaker with 50 c.c. nitric 1.12, and evaporate to small bulk. Dilute to 500 c.c. in a 1000 c.c. marked at litre. Raise to a boil, add Z NO suspended in water, until the precipitate coagulates. Allow precipitate to settle. If top is clean, fill up to 1000 c.c. mark and shake well. Allow to settle. Filter through a folded 595 paper into 1000 c.c. flask and titrate to a pink with potassium permanganate. The precipitate should coagulate each time it is shaken.

(NOTE.—Sodium arsenite method is sometimes used, it is quicker.)

Graphite.—Dissolve 1 gram of drillings in 30 to 50 c.c. nitric acid 1.12, and filter on weighed paper S & S 590—9 c.m. is the preferable paper. Paper should be dried for one hour at 100 degrees C. and weighed between dried watch-glasses. Wash with hot water three or four times and with dilute caustic potash solution twice, two or three times with hot dilute HCl, and finish washing with hot water. Wash once with alcohol, dry at 100 degrees C. 1½ to 2 hours and cool in dessicator. Then weigh as silica plus graphite. Burn in weighed crucible and thus get the silica to subtract. Result of subtraction is graphite.

Combined Carbon.—Weigh out 5 grams of drillings, dissolve in 15 c.c. diluted HNO_3, cool in water (use test tube), then place test tube in boiling water for 20 minutes till dissolved (so that carbon will not pass off as CO, CO_2, etc.) Remove test tube. Dilute mixture till it is exactly the same color as standard. For instance, the standard iron run at same time and under same conditions is diluted to 57 c.c. Say the standard iron has .57%C, then each c.c.=.01. Therefore, if reading of an iron carbon diluted is 46 c.c. the percentage is 46 x .01=.46.

While diluting the solution should be shaken vigorously.

ANALYSIS OF REFRACTORY MATERIALS.

The analysis of the refractory materials used in lining, viz.: fire-brick, fire-clay, sand—for the various constituents—iron, silica, alumina, magnesia and lime, are conducted in the same manner as in slags.

TIME TAKEN FOR SOME DETERMINATIONS.

Silicon, in company with sulphur, is compleated within 20 minutes.

Phosphorus may be done inside an hour.

Manganese in 45 minutes.

The analysis of slag for silica, alumina, iron and lime takes about three hours.

The other determinations do not require to be accomplished quickly, and, as they are frequently run in company with others of the foregoing, the writer need not give any actual figures.

ROUTINE WORK IN THE LABORATORY.

The routine work of the laboratory may be shortly summed up as follows:—

Ores.—The different cargoes are analysed on their arrival. Every week the working face of the ores being used is sampled and analysed for Fe, SiO_2 and phosphorus.

Coke.—Volatile matter, carbon, sulphur, silica and ash determinations are made weekly. When coke of different kinds is arriving, sulphur and phosphorus determinations are frequently made, especially the latter if furnace is working on Bessemer iron.

Limestone.—An analysis for SiO_2, Fe, Al_2O_3, CaO and MgO, is run every week.

Iron.—There are six casts daily. Silicon and sulphur determinations are made on each. When the furnace is running on Bessemer iron, and if the burden is the same from day to day, one determination for phosphorus is made, the sample taken being the average of the six casts. If running on foundry iron, three phosphorus determinations are made daily. Determinations for manganese are made three times a day. Carbon determinations about once a day.

STOCK SOLUTIONS.

The following is a list of the various solutions used.

Silicon mixture—for pig metal.

700 c.c. strong HNO_3
840 c.c. H_2O
770 c.c. H_2SO_4

———

2310 c.c.

Chromic acid Solution.

240 grms. chromic acid
2000 c.c. water.

It is best to filter this.

FOR SULPHUR IN IRON AND STEEL—*Iodine for Titration.*

13 grams iodine
18 grams potassium iodide.

Add 100 c.c. water, let stand for a week, then add 1800 c.c. water. This solution may be used as a stock solution.

Titrating Solution.—Take 200 c.c. stock solution, dilute to 2000 c.c. with water, shake well during a day, allow to stand one day, then standardize with a standard iron. Keep in a dark place.

FOR SULPHUR IN IRON AND STEEL—*Cadmium Chloride Solution.*

50 grams cadmium chloride
1333 c.c. of water
1060 c.c. ammonia.

FOR SULPHUR IN SLAG—*Cadmium Chloride Solution.*

50 grams $CdCl_2$
50 c.c. of water
80 grams ammonia.

Keep this mixture in a glass-stoppered glass in a cool place. Have the cadmium chloride well in solution before adding ammonia.

FOR PHOSPHORUS IN IRON.

Manganese in Ore, Slag, Limestone, Coke.
Lime in Ore, Slag, Limestone, Coke.

Potassium Permanganate Solution.

2 grams $KMnO_4$
1000 c.c. of water.

Shake well four to five times a day for three days.

1 c.c. = .0034 Fe theoretically.
1 c.c. = .0010 M theoretically.
1 c.c. = .0017 CaO theoretically.
$Fe \times .2946 = Mn$
$Fe \times .5 = CaO$

FOR IRON IN IRON ORE.

LIME IN SLAG OR LIMESTONE

Potassium Permanganate Solution.

14 grams $KMnO_4$
2000 c.c. of water.

Shake well four to five times a day for a week.

FOR PHOSPHORUS IN IRON ORE, IRON, STEEL, COKE, LIMESTONE, ETC.

Molybdate Solution.

120 grams molybdic acid 300 c.c. of water 175 ammonia SGLO 75 nitric SG 1.42	In flask.

Add the above to this quickly,

500 c.c. HNO_4 SG 1.42 1200 c.c. of water	In Winchester.

Wash Solution.

2000 c.c. of water
50 c.c. H_2SO_4
40 c.c. ammonium hydroxide.

FOR IRON IN IRON ORE, COAL, COKE, IRON, STEEL, LIMESTONE, ETC.

Potassium Bichromate.

8.8 grams powdered $K_2Cr_2O_7$ per litre.
1 c.c. = 1% iron.

METHODS OF STANDARDIZING SOLUTIONS.

Standardizing of Permanganate Solution used for Iron and Lime.

Weigh out .3 grams pure iron wire, cleaning it well with sandpaper and cloth, into an Erlenmoyer flask. Dissolve in 1 to 10 sulphuric acid, add 1 gram zinc, boil till dissolved, titrate and filter while boiling hot. Divide number of c.c. taken to color solution pink and divide into .3 gram. Result = standard strength of iron, .5 or ½ of this result gives standard strength for lime.

STANDARDIZING OF PERMANGANATE SOLUTION USED FOR MANGANESE.

To standardize, take a standard iron, do as in regular iron, titrate and divide c.c. into standard results, result = strength for manganese.

Potassium Bichromate Solution used for Iron Determination.

Weigh out .5 grams of iron wire well cleaned, and proceed as in iron in ore. Divide c.c. of bichromate taken into iron in the .5 gram of the ore and multiply by 2. Result = strength for iron.

Iodine Solution used for S in Slag and S in Iron Determination.

Weigh out 5 grams of standard iron and proceed as in regular iron. Titrate and divide c.c. into percentage of S, and thus obtain value of each c.c.

Standard irons and ores used in standardizing above solutions are obtained from the American Foundrymen's Association. These samples have been analysed by different prominent chemists, and an average value obtained for each constituent.

The Midland Furnace may be said to be a merchant furnace, because it sells all the iron it makes. The output is sold to the foundry trade on an analysis and fracture basis, both acting as a sort of check on the other. The Bessemer iron made is sold on analysis only.

The uses of analysis to a blast furnace may be summed up.

(1). In buying ores, coke and limestone on percentage basis so much is given per unit, etc.

(2). In selling the product the analysis of the iron gives the foundryman or steel mill superintendent information for his own use.

(3). The calculation of a proper furnace burden, so that cheapest and best burden may be put upon furnace.

To illustrate above:—

(1). The ores are bought on unit system and analysis governs value of coke, in conjunction with physical qualifications. The same may be said of the limestone.

(2). A sheet shows how iron is graded by analysis.

(3). A burden is attached.

To illustrate (2) Midland Foundry Iron would run:—

No. 1.	No. 2.	No. 3.
Si – 2.50 – 3.25	2.00 – 2.50	1.50 – 2.00
S – below .040	below .050	about .060
P – about .60 to .80	P = .60 – .80	P = .60 – .80
Mn – .40 – .75	Mn .35 – .60	Mn .30 – .50

No. 4.	No. 5.	No. 6.
Si – 1.10 – 1.50	.90 – 1.10	below .90
S – about .075	about .090	over .090
P – .60 – .80	.60 – .80	.60 – .80
Mn – .28 – .40	.22 – .34	.22 – .34

A method of calculating a furnace burden is appended. The writer is indebted to Mr. Joseph Hartley for information regarding this method.

BURDEN CALCULATION.

In figuring out a burden we wish to determine the amount of limestone required to flux the impurities in the ore and coke, the composition of the metal, produced, the slag volume (the percentage of slag to metal produced) and the composition of the slag itself. By following up the sheet and reading the notes below, the method of obtaining these quantities will be readily understood.

A general outline of the theory and method of calculation may now be given.

We usually try a certain mixture and see how it works out as regards cost per ton of iron produced, slag volume, etc.

The governing factors of an ore are the iron, silica, manganese, phosphorus, usually.

The percentage of the ore used being known and the composition of the ore, we first calculate out how many lbs. in a hundred of the ore, the various constituents, silica, alumina, iron, etc., are. Knowing how much ore the fixed coke charge will carry we immediately calculate the amounts the various constituents are in the total charge. But in the ore and coke are several constituents, viz., alumina, lime, magnesia, and manganese, which are of value as fluxes. These must be given their value, so as to lessen the amount of limestone put on. Under "Equiv. of Bases," will be found the amount of silica in lbs. the fluxes in the ore and coke will take care of. Just below this the efficiency of the quarry limestone is figured.

The amount of limestone necessary to flux out the silica is now required. First of all we find the amount of silica required for the silicon in the iron, then the limestone required is figured.

Going back up the page the percentage and lbs. of silica, alumina, etc., due to limestone, are added on to the totals obtained for the ore and coke.

With information obtained we now proceed to calculate the theoretical Slag Analysis.

Then the Slag Volume and Iron Analysis can be calculated.

OUTLINE OF THEORY.

The efficiency of a limestone may be calculated by the following formula:—

% of SiO_2 x 1.86 = A

% of CaO x 1 = B

% of MgO x 1.40 = C

$$\frac{\%\text{ of } Al_2O_3 \times 1.63}{2} = D$$

% of S x 1.75 = E

Then efficiency = (B + C + D) − (A + E).

The object of this rule is to obtain the value of the bases in lbs. of lime per hundred.

The fluxing power of alumina is uncertain in practice, it is usual to use one half of its probable value.

By using this formula, the efficiency of the Quarry Point limestone is calculated. It may be noted that three different efficiencies have been used in calculating the amount of limestone to put on, and, therefore, three different amounts of stone are obtained. This was done because the limestone varied somewhat. This variation the furnace manager judged approximately by eye.

A certain amount of silica is required to make a 2.50 Si iron and, supposing that there is 95% of iron in pig metal, it is readily seen how the 184.7 lbs. is obtained. (Amount of Si in SiO_2=

.4679). Therefore, subtract 184.7 lbs. from the total of 872.91 lbs. silica in ore and coke and obtain quantity of silica to be fluxed. Every lb. of silica requires 1.866 lbs. CaO to flux it, and knowing that fluxes in ore and coke are equivalent to 327.4 lbs. lime, it can also be readily seen how the 1937 lbs. of lime are obtained, for in 100 lbs. of limestone there are 49.17 useful fluxing lbs.

Running out amounts of SiO_2, Al_2O_3, Mn, etc., for 1937 lbs. of limestone we can, on addition of SiO_2, Al_2O_3, etc., in coke, ore and limestone, obtain the Slag Volume or percentage of slag to the output of iron, and also the theoretical analysis of slag and iron.

The phosphorus and manganese in the pig iron produced is calculated by adding the total P and Mn by weight in the ores, coke and limestone, and on the basis of a yield of 3454 lbs. of iron, the percentage is obtained. In case of Mn the note below must be borne in mind.

. In determining value of bases in ore mixtures and coke charge it is assumed that 6/10% of manganese is reduced and that 4/10 passes into slag. Hence, by multiplying $\frac{22.78}{23.136}$ lbs. by .64 we obtain 14.81 lbs. as useful amount of Mn in MnO. The atomic weight of Mn=55, of O=16, therefore, one part of Mn is equivalent when oxidized to MnO, to $\frac{71}{55}$=1.29 parts MnO. It is known that 2.36 parts MnO will flux one part silica, or is equivalent to 1.86 parts lime. Therefore, 1 part MnO=$\frac{1.86}{2.36}$=.788 parts lime. Hence, having the weight of Mn in burden, multiply it by 1.29 to obtain equivalent weight MnO, then multiply by .788 to obtain quantity of lime it equals.

For all practical purposes we may take the silica, alumina, lime, magnesia, sulphur and manganese oxide as totalling 100.00 in calculating Slag Analysis.

The phosphorus is supposed to all go into iron, and this is practically true.

FOUNDRY IRON BURDEN.

ORES.		%	SiO_2		Al_2O_3		Fe		Mn		CaO		MgO		P		S		EQUIV. of BASES.
			%		%		%		%		%		%		%		%		
Helen	2560	40	11.83	4.73	.74	.30	50.55	2022	.120	.048	.29	116	.116	.046	.085	.0340	.078	.0312	Al_2O_3 230.08 / 2 × 1.64 = 188.67
Rowe	640	10	11.88	1.19	.90	.09	48.26	483	.430	.043	.23	023	.66	.066	.038	.0038	.006	.0006	Cao 102.53 × 1 = 102.53
Florence	960	15	6.04	.91	4.37	.65	50.27	754	.210	.032	1.51	.23	366	549	.261	.0392	.036	.0054	MgO 73.53 × 1.40 = 102.94
Port Henry	640	10	5.06	.51	.00	00	61.15	612	.200	.020	7.51	.750	.90	.090	1.383	.1383	.038	.0038	Mn 1028 × .7888 = 8.10
Roberts	960	15	11.06	1.76	112	17	54.08	811	.390	.058	.39	.066	.16	.024	.023	.0035	.005	.0008	402.24 Sulph. 42.57 × 1.75 = 74.50
Manganate	224	3.5	5.13	.17	3.95	.119	47.53	1.66	4.06	.140	235	.082	2.03	.071	.418	.0140	.038	.0013	327.74
Calabogie	96	1.5	0 3.36	.05	5.29	.08	57.80	.57	.32	.005	3.38	051	3.25	.048	.227	.0034	.272	0041	Quarry Lime Stone
Flue Dust	320	5	11.02	.55	5.89	.29	44.10	2.21	210	.010	1.81	090	59	.030	.050	.0025	.136	0680	Lime % 39.90 39.90
Ore	6400	100.		9.87 631.68		1.72 110.08		51.26 3281		.356 22.78		1.402 89.73		.924 59.13		.2387 15.28		.1152 7.37	MgO 11.31 × 1.40 = 15.83
Coke	4000		6.03	241.23	3.00	120.00	Yield	3454		14.81 7.97 1.29	32	12.80	36	14.40	.012	.48	.88	35.20	Al_2O_3 .53 / 2 × 1.64 .434 56.16
	2007			872.91 184.70		230.08				10.28		102.53		73.53		15.76		42.57	6.99
Stone	1937		3.66	688.21 70.90	.53	10.27					39.90	772.86	11.31	219.07	.010	.19	.092	1.78	Effic. = 49.17
	1878			759.11		240.33						875.39		292.60		15.95		44.35	SiO_2 3.66 × 1.866 = 6.83 S .092 × 1.75 = 16 6.99

Silica Reqd. = 3281 ÷ .95 = 3454 × 2.50 = 86.33 ÷ .46720 = 184.7 49.17 = 1937 lbs. Stone Reqd. = 872.91 — 184.7 = 688.21 × 1.86 = 1280.07 — 327.74 = 952.33 ÷ 50.78 = 1878 lbs
47.45 = 2007 lbs

SLAG ANALYSIS.

Silica	759.11	34.16
Alumina	240.35	10.81
Lime	875.39	39.40
Magnesia	292.60	13.18
Sulphur	44.35	1.99
Manganese	10.28	.46
Oxide	222.208	100.00

Slag Volume 64.33%

IRON ANALYSIS.

Silicon	2.50
Manganese	.428
Phos	.4617