TRANSACTIONS

OF

The Canadian Society of Civil Engineers.

VOL. V, PART I.

JANUARY TO JUNE,

1891.

Montreal:

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1891.

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CONTENTS.

CANADIAN SOCIETY OF CIVIL ENGINEERS.

LIST OF OFFICERS FOR THE YEARS 1887 TO 1891.

	1887.	1888.	1889.	1890.	1891.
President	T. C. Keefer.	S. Keefer.	C. S. Gzowski.	C. S. Gzowski.	Sir C. S. Gzowski.
Vice-Presidents	C. S. Gzowski. J. Kennedy. W. Shanly.	C. S. Gzowski. E. P. Hannaford. H. F. Perley.	E. P. Hannaford. H. F. Perley. P. A. Peterson.	E. P. Hannaford. J. Kennedy. H. F. Perley.	E. P. Hannaford. J. Kennedy. F. J. Lynch.
Members of Council	F. N. Gisborne. E. P. Hannaford. W. T. Jennings. S. Keefer. L. Lesage. H. D. Lumsden. A. Macdougall. H. F. Perley. H. Peters. P. A. Peterson. H. S. Poole. H. N. Ruttan. P. W. St. George. C. Schreiber. H. Wallis.	H. Abbott. F. R. F. Brown. F. N. Gisborne. J. Hobson. W. T. Jennings. J. Kennedy. L. Lesage. A. Macdougall. H. A. F. McLeod. M. Murphy. P. A. Peterson. H. S. Poole. H. N. Ruttan. P. W. St. George. C. Schreiber.	G. F. Baillarge. J. D. Barnett. K. W. Blackwell. St. G. J. Boswell. F. R. F. Brown. G. C. Cunningham. E. Gilpin. F. N. Gisborne. W. T. Jennings. G. A. Keefer. J. Kennedy. M. Murphy. B. D. McConnell. E. Wragge. J. E. Vanier.	W. P. Anderson. J. D. Barnett. F. R. F. Brown. K. W. Blackwell. C. E. W. Dodwell. W. T. Jennings. G. A. Keefer. H. G. C. Ketchum. T. Monro. G. H. Massy. P. A. Peterson. H. N. Ruttan. P. W. St. George. J. W. Trutch. E. Wragge.	W. P. Anderson. J. D. Barnett. F. R. F. Brown. K. W. Blackwell. C. E. W. Dodwell. H. E. Donkin. F. N. Gisborne. E. A. Hoare. Jos. Hobson. W. T. Jennings. T. Monro. P. A. Peterson. H. N. Ruttan. P. W. St. George. Sir J. W. Trutch.
Past Presidents and Hon. Councillors	....	T. C. Keefer.	T. C. Keefer. S. Keefer.	T. C. Keefer.	T. C. Keefer. Sir C. S. Gzowski.
Secretary	H. T. Bovey.	H. T. Bovey.	H. T. Bovey.	H. T. Bovey.	H. T. Bovey. C. H. McLeod.
Treasurer		H. Wallis.	H. Wallis.	H. Wallis.	H. Wallis.
Librarian	....	F. Chadwick.	F. Chadwick.	F. Chadwick.	F. Chadwick. W. McNab.

Canadian Society of Civil Engineers

SESSION 1891.

TRANSACTIONS.

Thursday, 15th January, 1891.

ANNUAL GENERAL MEETING.

COLONEL SIR C. S. GZOWSKI, President, in the Chair.

The Secretary having read the notice convening the meeting,

It was moved by Mr. A. Macdougall, seconded by Mr. P. A. Peterson, and resolved:—

"That the minutes of the Annual Meeting of the 23rd January, 1890, be taken as read."

The President read a telegram from Mr. H. F. Perley regretting his inability to be present at the meeting.

The following Annual Report was then read:—

ANNUAL REPORT.

The Council has much pleasure in presenting the following Report of the work of the Society during the past year:—

ROLL OF THE SOCIETY.

The membership of the Society has steadily increased, the elections comprising *eleven* members, *six* associate members, *fourteen* associates and *twenty-three* students. *Five* associate members have been transferred to the class of members, *one* associate to the class of associate members, *one* associate member to the class of associates, and *four* students to the class of associate members, while from various causes *ten* have been removed from the list, the net increase for the year being *forty-four*.

The resignations were:—

Member—R. C. Boxall.

Associates—R. R. Dobell, E. R. Faribault, H. Russel, C. E. Saunderson.

Student—F. McMaster.

The deceases have been:—

Members—Samuel Keefer, Past President, Thomas T. Vernon Smith, John Page and Edward Wasell.

The total number on the list at the present date includes *seven* honorary members, *two hundred and seventy-seven* members, *one hundred and five* associate members, *seventy-four* associates, and *one hundred and seventy* students, or *six hundred and thirty-three* in all.

In the list of deceases will be observed the name of Mr. John Page, who for more than half a century was intimately connected with the Public Works of the Dominion of Canada. Again, only a few days ago the sudden death of Mr. G. H. Henshaw was reported. Mr. Henshaw took a most active interest in the formation of the Society, and was the author of the first paper read before the Society, the subject being Frazil Ice.

With reference to a further increase in the membership, attention is particularly directed to the circular on the subject recently issued by the Council.

ANNUAL MEETING.

The Fourth Annual Meeting was held on Thursday, the 23rd January, 1890, Colonel Gzowski, A.D.C., President, being in the chair. The morning session was devoted to the transaction of the business of the Society, and in the afternoon the President delivered the annual Address, which was afterwards published in full in the Transactions. Amongst those present were His Excellency the Right Honourable Lord Stanley of Preston, Sir William Dawson, Sir Donald A. Smith, and other distinguished Canadians.

In the evening a Society dinner was held at the Windsor Hotel, which was honoured by the presence of His Excellency Lord Stanley, and many guests, both ladies and gentlemen.

SPECIAL GENERAL MEETING.

On the occasion of the elevation of the President to the rank of Knight Commander of the distinguished Orders of St. Michael and St. George, the Society deemed it a fitting opportunity to present to him a congratulatory address. A Special General Meeting of the

Society was called for the 30th September, and the following address was read by the Secretary:—

COLONEL SIR CASIMIR S. GZOWSKI, A.D.C., K.C.M.G.,

President of the Canadian Society of Civil Engineers.

DEAR SIR,

We, the members of the Canadian Society of Civil Engineers, beg leave to offer you, on your return to Canada, our hearty congratulations on your elevation to the distinguished Order of Knight Commander of St. Michael and St. George.

Her Gracious Majesty Queen Victoria had already honoured you by appointing you to be one of her Aides-de-Camp, in recognition of the valuable services you had rendered in connection with the volunteer forces of Canada. Her Majesty now gives a further proof, in this new honour, of her desire to recognize in you the spirit of patriotism and self-sacrifice in the public service.

As members of the Canadian Society of Civil Engineers, we may congratulate ourselves on the fact that our President has been thus distinguished, knowing as we do from our intercourse with you how well you deserve and how worthily you will wear the honour.

In conclusion, we congratulate you on your safe return to Canada, and trust that you and Lady Gzowski may long be spared to grace the high position you have won.

Signed on behalf of the Society,

HENRY T. BOVEY,
Secretary.

MONTREAL, 30th September, 1890.

Speeches congratulating the President were made by Sir Donald A. Smith, Messrs. T. C. Keefer, Past President; W. Shanly, E. P. Hannaford and John Kennedy, after which Sir Casimir Gzowski replied as follows:

GENTLEMEN,

The Address Professor Bovey, the Secretary, has read to me from the members of the Canadian Society of Civil Engineers, accompanied by most cordial and too kind expressions from several members of the Society, my old personal friends, is an unexpected event, and has taken me by surprise.

Words fail me to convey to you the gratification at such evidence of good feeling from the Society towards me. I am greatly touched by it, and thank you from the bottom of my heart for the address and the good words that accompanied it.

Thank you also very sincerely for the hearty congratulations in the address on the new honours Her Majesty has most graciously personally conferred upon me while your President. Your appreciation of Her Majesty's gracious act is very gratifying.

Members may rest assured that the interest I take in the welfare of the Society shall continue undiminished, and I will consider it a privilege to aid towards its progress.

Accept my best thanks for the good wishes you express towards Lady Gzowski and myself.

C. S. GZOWSKI.

ORDINARY MEETINGS.

During the year 1890, fourteen Ordinary Meetings of the Society have been held, at which the following papers were read:

On "The Screening of Soft Coal," by J. S. McLennan; on "The Manufacture of Natural Cement," by M. J. Butler; on "Columns," by C. F. Findlay; on "Irrigation in British Columbia," by E. Mohun; on "The Sault Ste. Marie Bridge," by G. H. Massy; on "Generation and Distribution of Electricity for Light and Power," by A. J. Lawson; on "Developments in Telegraphy," by D. H. Keeley; on "The Errors of Levels and Levelling, Parts I and II," by Professor C. H. McLeod.

STUDENTS' MEETINGS.

There have been four Students' Meetings, at which papers were read on "Stand Pipes," by R. S. Lea; on "The Cornwall Canal," by E. S. Mattice; on the "Sewerage System of Brockville," by C. H. Ellacott; on "Aluminium," by W. K. Hatt; on "Locomotive Shops, Small Jobs and their Difficulties, and how to overcome them," by T. H. Wingham; on "Cable Railways," by P. H. Middleton.

PAPERS.

The Council has repeatedly impressed upon members of all classes the necessity of contributing Papers to be read before the Society, and also of taking part in the several discussions. The usefulness of the

Society must largely depend upon the character of its publications, and the highest standard in these cannot be attained until each individual member is ready to give the benefit of his experience.

The President recognizing the importance of this subject, and desiring to stimulate members to a friendly rivalry, has again shown his great interest in the Society by offering to endow a silver medal to be awarded for the best paper of the year. This offer has been gratefully accepted by the Council, and the conditions under which the award will be made are specified in the Gzowski Medal Rules appended to the end of this Report.

It is sincerely to be hoped that this generous action on the part of the President may do much to secure the desired end.

SOCIETY'S ROOMS.

An important event in the history of the Society has been the vacating of the rooms at McGill College, and the occupying, on the 28th May, 1890, of the new rooms over the Bank of Montreal, at the corner of St. Catherine and Mansfield streets. The appointment of an Assistant Secretary has rendered it possible to keep the rooms constantly open, and they have, up to the present, been available for the use of members every week day afternoon and evening. The evening attendance, however, has been practically nil, and the Council has decided that it is not justified in the extra expenditure required to keep the rooms open during the evening. It has therefore been decided that the Assistant Secretary shall be in attendance daily from 9 a.m. to 12.30 and from 2 to 6 p.m., and on Tuesday evenings from 8 to 10, as well as on such other evenings as may be required for the special business of the Society. In the near future, the rooms will doubtless prove increasingly useful and attractive.

LIBRARY.

During the year 1890, a considerable number of donations to the Library of the Society have been received, among which mention should be made of the following :—

From the President, Col. Sir Casimir S. Gzowski, a donation of over 200 volumes of valuable engineering works, among which may be mentioned the following :—

Public Works of Great Britain, 1 vol.
Britannia and Conway Tubular Bridges, 1 vol.
Professional Papers Royal Engineers, Vols. I. to X.
Brees' Railway Practice, 4 vols.

Van Nostrand's Engineering Magazine, 18 vols.

Civil Engineers' and Architects' Journal, 14 vols.

American Railroad Journal, 56 vols.

Weale's Bridges, 3 vols.

Truan's Manufacture of Iron, 2 copies.

Life of Telford, with Folio Atlas of his Works, 2 vols.

From Walter Shanly, M.P., a presentation copy of The Victoria Bridge, Canada, and Rennie's British and Foreign Harbours.

From W. O. Buchanan, C.E., copy of Britannia and Conway Tubular Bridges, presented to him by the author, Robert Stephenson, C.E.

Donations have also been received from Sir Chas. A. Hartley, from Messrs. H. F. Perley, Dodwell & Hogg, G. A. Mountain, W. P. Chapman, F. W. Cram, F. H. Reynolds, N. B. McTaggart, H. E. T. Haultain, T. S. Russell, and from Professor Egleston.

Since the last annual meeting the following scientific societies have been added to the list of those with which the Society exchanges publications:—

Nova Scotian Institute of Natural Science, Halifax.

The Junior Engineering Society, London, England.

The Cleveland Institution of Engineers, Middlesborough, England.

The American Institute of Electrical Engineers, New York.

The American Institute of Architects, Chicago.

The Industrial Engineers of Barcelona.

The Massachusetts Institute of Technology, Boston.

The Library Committee is in correspondence with several other scientific societies, and expects to add to this list before many weeks.

Arrangements have been made to have the following periodicals laid on the table as they are published:

The Engineer.

Engineering.

Engineering News.

Railroad Gazette.

Railroad and Engineering Journal.

The National Car and Locomotive Builder.

Another donation of more than ordinary interest has been received from Mrs. S. Keefer, widow of the late Samuel Keefer, Past President. Mrs. Keefer has presented to the Society the Gold Medal awarded to her late husband, at the Exposition Universelle Internationale, Paris, 1878, for his design of the Clifton Suspension Bridge over the Niagara Falls. The bridge had a clear span of 1268 ft., and was erected in 1869.

BUILDING FUND.

The Building Committee regret to have to report a continued lack of interest on the part of the great majority of the members of the Society in the augmentation of the "Building Fund," the total receipts, during the past year, having amounted only to the insignificant sum of $50 (fifty dollars).

The Committee, when asking for subscriptions from members, is constantly met with the response that they will subscribe when the building has commenced. If this is to be the position taken by all those who have not yet subscribed, the Committee is of the opinion that the Society will never have a building of its own, as it would be folly to commence such a work without having first secured the money. The Committee hopes, however, that the number of those who put forth such an excuse is small and will become smaller, and that the great body of the members of the Society will make an effort to build up the fund to the required dimensions.

The Society is largely indebted to the generosity of the President for the rooms it now occupies, and surely, when he has done so much, the members should shew their appreciation of his interest by doing something towards increasing the "Building Fund;" and believing that they will do so, the Committee hopes that the next annual report will shew a very large increase in this important fund, upon which the future success of the Society so much depends.

FINANCES.

The income for the year ended on 31st December, 1890, amounted to $3,817.87, and the general expenditure reached $3,591.13, leaving a balance of $226.74, which, together with the balance of $2,502.89 brought forward from the year 1889, gives a total balance of $2,729.63 to be carried forward. A statement of the income and expenditure of the Society is given on page 8.

ABSTRACT OF RECEIPTS AND EXPENDITURE FOR THE YEAR ENDING DEC. 31st, 1890.

Balance from Dec. 31st, 1889		$2,502 89	
GENERAL RECEIPTS.			
Subscriptions :—			
Arrears	$ 156 00		
Current	2,514 00		
Advance	573 00		
Extra on Local Cheques	2 47		
		$3,245 47	
Donation by the President, Sir C. S. Gzowski, A.D.C., K.C.M.G		300 00	
Contribution by the Bank of Montreal towards furniture		100 00	
Extra "Transactions," etc., sold		48 25	
Donations to the Library		27 00	
Bank Interest to Dec. 31st		97 15	
			$6,320 76
BUILDING FUND.			
Balance from Dec. 31st, 1889		$2,715 48	
Additional Subscriptions		50 00	
Bank Interest to Dec. 31st		82 65	
			$2,848 13
			$9,168 89

GENERAL EXPENDITURE.		
Cost of "Transactions"	$861 50	
Advance proofs of papers	58 50	
Extra copies of papers for sale	55 65	
Printing and Stationery	341 18	
Postage, Messengers, Telegrams and Cabs	318 76	
Secretary and Assistant	350 50	
Stenographer	105 00	
Janitor and other labour	109 75	
Office Furniture and Rent of Chairs	750 83	
Rent of Rooms (half-year)	275 00	
Telephone Service	38 13	
Bank Commission	7 99	
Legal opinion and Drawing Lease	15 00	
Diplomas	225 30	
Removing to New Rooms	29 75	
Gas	3 16	
Insurance on Library and Furniture	13 50	
Extra dues returned to Toronto branch	16 00	
Charges on Books, etc	15 63	
		$3,591 13
BALANCE.		
General Fund	$2,729 63	
Building Fund	2,848 13	
		$5,577 76
		$9,168 89

Examined with books and vouchers, and found correct.

(Signed), JOHN KENNEDY,
G. H. MASSY,
Auditors.

(Signed), HERBERT WALLIS,
Treasurer.

RULES FOR THE AWARD OF THE "GZOWSKI MEDAL."

A silver medal, to be called the "Gzowski Medal," shall be struck each year from the annual proceeds of the Fund provided for that purpose, by Col. Sir Casimir Gzowski, A.D.C., K C.M.G., President of the Society, which medal shall be awarded according to the following rules for papers presented to the Society:—

1. Competition for the medal shall be open only to those who belong to the Society.

2. The award of medals shall not be made oftener than once a year, the medal year shall be the year ended June last, previous to the Annual Meeting at which the award is to be made.

3. The papers entered for competition shall be judged by a Committee of five, to be called the Gzowski Medal Committee, which shall be appointed by the Council as soon after the Annual Meeting of the Society as practicable. Members and honorary members only shall be eligible to act on this Committee.

4. Papers to be eligible for competition must be the *bona fide* productions of those who contribute them, and must not have been previously made public, nor contributed to any other Society in whole or in part.

5. The medal shall be awarded for the best paper of the medal year, provided such paper shall be adjudged of sufficient merit as a contribution to the literature of the profession of Civil Engineering, but not otherwise.

6. In the event of the Committee not considering a paper in any one year of sufficient merit, no award shall be made; but in the following year or years, it shall be in the power of the Committee to award the accumulated medals to the authors of different papers which may be deemed of sufficient merit.

7. The medals shall be suitably engraved by the Society, and shall be handed to the successful authors at the Annual Meeting, or be given to them as soon afterward as possible.

(Signed), HENRY T. BOVEY,
Secretary.

It was moved by Colonel Sir C. S. Gzowski, seconded by Mr. John Kennedy, and resolved:—

"That the Report of the Council be received, approved and printed in the Transactions."

It was moved by Mr. A. Macdougall, seconded by Mr. E. A. Hoare, and resolved:—

"That Messrs. Walter Shanly, Montreal; E. Wragge, Toronto; E. Gilpin, Jr., Halifax, N. S.; W. D. Barclay, Winnipeg; St. George Boswell, Quebec; T. C. Keefer and Sir Casimir Gzowski, Past Presidents, be elected the Nominating Committee for the year 1891."

Messrs. G. H. Garden, A. Rhodes and F. Chadwick, having been named by the President Scrutineers of the Ballot for the Amendment to the By-Laws, after a careful examination of the ballot papers, reported as follows:—

By-Law 6, line 7, etc.—Strike out the words "who are neither elective officers nor candidates for office."—*carried by* 68 *per cent.*

The following were nominated by the President as Scrutineers of the Ballot for the election of Officers and members of Council for the year 1891: Professor C. H. McLeod and Messrs. W. McNab and T. Drummond.

The Scrutineers having examined the ballot papers reported that the following had been duly elected as:—

President.

Colonel Sir Casimir S. Gzowski (*re-elected*), Toronto.

Vice-Presidents.

Edmund P. Hannaford, Montreal; John Kennedy, Montreal; Francis J. Lynch, Ottawa.

Treasurer.

Herbert Wallis, Montreal.

Secretary.

Henry T. Bovey, Montreal.

Librarian.

Francis Chadwick, Montreal.

Members of Council.

William P. Anderson, Ottawa.
John D. Barnett, Stratford.
Francis R. F. Brown, Montreal.
Kennet W. Blackwell, Montreal.
Charles E. W. Dodwell, Montreal.
Hiram E. Donkin, Port Hawkesbury.
Frederick N. Gisborne, Ottawa.
Edward A. Hoare, Quebec.
Joseph Hobson, Hamilton.
William T. Jennings, Toronto.
Thomas Monro, Coteau Landing.
Peter A. Peterson, Montreal.
Henry N. Ruttan, Winnipeg.
Percival W. St. George, Montreal.
Sir Jos. W. Trutch, Victoria, B.C.

It was moved by Mr. F. R. F. Brown, seconded by Mr. John Kennedy, and resolved :—

"That the thanks of the meeting be tendered to the scrutineers for the able manner in which they have performed the duties entrusted to them, and that the ballot papers be destroyed."

It was moved by Mr. John Kennedy, seconded by Mr. A. Macdougall, and resolved :—

"That the best thanks of the Society be presented to the President, for the interest which he has always evinced in the welfare of the Society, and for the practical aid which he has so generously given towards promoting its success."

It was moved by Mr. E. Wragge, seconded by Mr. H. A. F. MacLeod, and resolved :—

"That the thanks of the Society be presented to Professor Bovey for his services as Secretary during the year 1890."

It was moved by Mr. W. P. Anderson, seconded by Mr. E. G. Henderson, and resolved :—

"That the thanks of the Society be presented to Mr. Herbert Wallis for his services as Treasurer during the year 1890."

It was moved by Mr. H. A. Gray, seconded by Mr. Robt. Forsyth, and resolved :—

"That the thanks of the Society be presented to Mr. Francis Chadwick for his services as Librarian during the year 1890."

The above-named gentlemen made suitable replies, thanking the Society for its expressions of approval.

The President then read a statement showing how many Diplomas had been distributed and how many were still in hands.

The following report of the Gzowski Medal Committee was read by the President :—

"We, the undersigned members of the Committee, appointed by the Council to award the 'Gzowski' medal for the year ending with Part I, Volume IV, of the Transactions of the Society, beg to report unanimously in favour of the paper on Bridge Calculations by H. E. Vautelet, M.Can.Soc.C.E.

(Signed) "E. P. HANNAFORD.
"JOHN KENNEDY.
"PETER A. PETERSON.
"K. W. BLACKWELL.
"HENRY T. BOVEY."

The President then presented Mr. Vautelet with the medal, congratulating him on his success. Mr. Vautelet replied, thanking the

President for his gift, and stating that he should always prize it highly.

Mr. Hannaford then explained the programme for the following day (Friday), and stated that a special train would leave the Grand Trunk Railway Station at 10 o'clock A. M. for the accommodation of those members who desired to take part in the excursion.

It was moved by Mr. A. Macdougall, seconded by Mr. P. A. Peterson, and resolved :—

"That in future the Annual Meeting extend over two days, and that the President be authorized to appoint the scrutineers on the first day."

The meeting was then adjourned.

EXCURSION.

THE VICTORIA BRIDGE.

On Friday, 16th January, 1891, the day following the Annual Meeting, the members of the Society met at the Grand Trunk Station, and proceeded by special train to the Victoria Bridge.

The details of the structure were explained by Mr. Hannaford, the chief engineer of the Company, and are so well known that only the principal features need be given, and which briefly are as follows:—

Length of iron work........................	= 6592 ft.	being 25 spans
Length of bridge proper, including abutments..................................	= 7072 "	" "
Approaches extending into the river.....	= 2072 "	" "
Total length shore to shore...............	9144 feet, or 1.73 miles.	

Construction; Iron tube, size averaging 16 feet in width up to 19 feet 10 inches in height. Height of bottom of centre tube above river, summer level, 60 feet. Grade of approaches 1 in 100, and of iron work 1 in 130, centre tube level.

It was found some years since, when soft coal in engines was substituted for wood, that the gases had a deleterious effect on the structure, causing rust. Mr. Hannaford proposed (and the management accepted his plan) to open 20 inches in the centre of the top of the tubes, immediately over the smoke-stacks of the engines, making a continuous aperture, and allowing the fumes from the smoke-stacks to be sent through the opening, the stacks being only about 9 inches from the top of the roof cross plates of the tubes. The effect was all that could be desired, and the portion of the bridge completed is well lighted and ventilated,—in fact, as was aptly said, the structure was given *lungs*. Rather more than half the bridge has been ventilated in this manner.

Care was taken that before any of the top plates were opened increased section was added to the structure, to more than compensate for the portion to be cut away, and the new portions were put over the sides of the tubes, adding strength in the right place.

It has been found that in the portion ventilated, the cost of maintenance is less than formerly. The work is progressing, being done in yearly stretches by the Company's men.

It was explained that the deflection caused by a heavy coal train, filling the centre tube of 330 feet span, was about $\frac{1}{10}$ of a foot.

The members appeared impressed with the solidity of the structure. The piers are founded on the rock, and are of great size, being from 16 feet to 24 feet in thickness and about 33 feet in length at their tops, to which must be added their ample saddlebacks and huge masonry cutwaters, sloping 1 to 1, thus giving dimensions not equalled on the continent in a work of its kind.

It was also explained that the deflections of the centre tube, 330 feet span, were taken at intervals of time, and a record kept, giving both its lateral and vertical movements; that the tube is a vast thermometer, as it varies in height with the temperature, the difference in vertical movement between extremes of summer and winter (+ 86° Fah. and — 25° Fah.), in repose, being $\frac{5}{8}$ inches, the summer level being lower than winter level. The lateral movements are due to wind and sun attraction, the bridge direction being about east and west, the buckling of the tubes is towards the sun. The maximum range is $1\frac{3}{4}$ inches due to sun and wind, and the whole series of readings show conclusively that the tubes are elastic and preserve their original features.

It was pointed out to the members that the vast field of ice which covers Laprairie Bay, to a thickness of from $2\frac{1}{2}$ to 3 feet, cements the piers of the Victoria Bridge like molten lead, and exercises a pressure against the piers, which but for their solidity would move them bodily. The creeping of this vast field of ice up the cutwaters of the piers was apparent, and proved the resisting strength of the bridge beyond doubt.

The running ice in Spring attacks the bridge with a speed of about 4 miles per hour, but the cutwaters of the piers turn the frozen mass as easily as a plough does its furrow. The ice no sooner leaves the St. Lawrence than the rafts make their appearance, and it is very rarely a season passes without leaving marks of broken and wrecked masses of timber against the piers of the bridge. Sometimes it occurs that these rafts are broken apart by the piers, and are wrecked on the shores of the river. The bridge has been open for traffic 32 years, and stands to-day, for wear and tear, a marvel of solidity and strength.

After visiting the bridge the members were taken by special train to Point St. Charles, and lunch was provided by the Society.

GRAND TRUNK RAILWAY WORKSHOPS.

The party visited the Locomotive and Car works of the Grand Trunk Railway, and were shewn round by the Mechanical Superintendent, Mr. Herbert Wallis, treasurer of the Society, and by his assistants, Mr. F. W. Wanklyn, M. Can. Soc. C.E., and Mr. McWood, M. Can. Soc. C.E.

There were under construction at the time a number of engines for fast passenger service, having cylinders 18 inches diameter and 24 inches long, with four coupled driving wheels 6 feet diameter, and working at a boiler pressure of 160 pounds per square inch.

The boilers are of steel, and have butt joints with double riveted inside and outside strips, the fire-boxes being also of steel, and the crown sheets are supported by direct stays to the saddle plate. The tubes are of charcoal iron, and are $1\frac{3}{4}$ inches outside diameter.

The tyres on all the wheels are fastened by Mansell retaining rings, and the outside connecting rods are of the fluted type with solid bushed ends. The boilers are covered with silicate slag wool, and finished with refined iron clothing plates. The equipment includes the quick action Westinghouse air brake and sight feed steam lubricator. These engines haul trains of 300 tons gross weight, on a consumption for coal of one-sixth pound per ton per mile.

Covered shops for the repairs of locomotives occupy nearly 200,000 square feet, and for the repairs of cars 175,000 square feet, and the number of men employed reaches 2,000. The output of iron from the foundry is about 4,000 tons, and of brass over 200 tons per annum. The Company is just about erecting a rolling mill to use up the iron scrap.

The members enjoyed the limited time allotted them in examining the various labour-saving machinery and the self-contained locomotive and car-building shops of the Company.

The members after luncheon were sent to the Dominion Station of the Grand Trunk Railway by special train, where they were met by the Officers of the Dominion Bridge Co.'s Works.

DOMINION BRIDGE COMPANY, LACHINE.

On leaving Point St. Charles the Grand Trunk special train proceeded to Dominion Station on the G.T.R. Main Line, and the visitors walked up the siding to the shops of the Dominion Bridge Company. These works are situated about eight miles from Montreal, contiguous to the main lines of the Grand Trunk and Canadian Pacific Railway companies, from both of which lines sidings are run into the works. Access by water is gained by the Lachine Canal which skirts the south side of the Company's property, enabling ocean steamships to load direct from the Company's tracks by their steam derricks on the canal bank, as was done last year when the iron for the Grand Narrows

Bridge, C.B., was loaded on the S.S. "Inverleith." The Company operates about two miles of sidings with its own locomotive and rolling stock.

The main shop is 515 feet long by 125 feet wide, built of stone and brick; the roof of iron, consisting of heavy trusses capable of sustaining a load of ten tons, is supported inside by seven columns. The shops have a capacity of about 800 tons a month. The heating and annealing furnaces are fed by gas supplied by a "Swindell" producer.

The shops are thoroughly supplied with suitable heavy machinery, operated by one automatic condensing engine. Artificial light is supplied by a combined system of arc and incandescent lighting, the dynamos being driven by an independent high-speed engine.

Among other work in different stages of construction, the visitors were shown a 107 foot double track lattice span for the Grand Trunk Railway, completely assembled in the shop prior to shipment.

After inspecting the shops, the visitors were conducted to the testing room, in which is one of the celebrated "Emery" Hydraulic Testing Machines, the only one in Canada. This machine has a capacity from 75 tons down to ascertaining the tensile strength of wire. The visitors then viewed the template room, which is 120 feet, enabling templates for all spans to be laid down full size. Proceeding to the drawing room, refreshments were partaken of, and the visitors left on a special train drawn up in the yard, supplied by the courtesy of the Canadian Pacific Railway Company.

Mr. F. R. F. Brown, M. Can. Soc. C.E., superintendent of the Dominion Bridge Company's works, explained the different features, and Mr. G. H. Duggan, M. Can. Soc. C.E., of the Bridge Company's Staff, worked the testing machine with a sample of steel in which the members showed much interest.

THE DOMINION WIRE WORKS.

Leaving the works of the Dominion Bridge Company, the Dominion Wire Manufacturing Company's Works, at Lachine, were next visited by the Society.

The buildings cover about 5 acres of ground. They are substantially built of stone and brick. There is one large Compound Condensing Engine 400 horse-power. In addition there are seven other engines, giving an aggregate power of about 700 horse. These are driven by a fine battery of steel-boilers. The works are very carefully planned so as to avoid re-handling of the metal.

Rolled steel, iron, copper, and brass rods are the raw materials for these mills, and are imported from England, Germany and the United States. The annual tonnage output per year is about 6000 tons, and the yearly consumption of fuel about 5000 tons of coal and coke. The coal is "Bituminous," from Nova Scotia. The coke is brought from Pennsylvania.

In addition to drawing all sizes of wire from 7-16 diameter down to No. 30 gauge, this Company tins and galvanizes as well. They are large consumers of their own wire, manufacturing barbed fencing, wire nails, hay-bale ties, brass and iron wood screws.

This Company was the first to enter into the manufacturing of wire in Canada, and from a small beginning have developed as above stated. They are continually adding to their plant and machinery, and are well situated for freighting, being on the banks of the Lachine Canal, and having spurs from the Canadian Pacific Railway and the Grand Trunk Railway, which run into their works.

Adjoining the Dominion Wire Manufacturing Company's works are the Dominion Wire Rope Company's works, who manufacture all kinds of wire rope for mining, ship-rigging, etc. They have some very ingenious and complete machinery. Both of these works are under the control and management of Mr. F. Fairman, A. Can. Soc. C.E.

The Dominion Wire Manufacturing Company have recently added a large wing to their works, for the purpose of manufacturing electrically pure copper wire and brass wire, and are now in full operation.

THE ST. LAWRENCE BRIDGE.

Leaving the Wire Works, the Society was furnished with a special train by the Canadian Pacific Railway, and visited the St. Lawrence Bridge.

The spans are as follows :—

3	spans of	80 feet each, centre to centre	of piers.
1	do	120	do
8	do	242	do
2	do	269	do
2	do	408	do

3,652 feet between abutments.

The bridge is approached at its south end by a long and high trestle work in course of being filled in.

The paper on the foundations of this bridge by G. H. Massy, M. Can. Soc. C. E. (Vol. I Transactions Can. Soc. C.E.), gives the current of the river at from 2 to 6 miles per hour at low water and from 4 to 9 miles at high water, the difference in level between high and low water being about six feet. Of the 16 spans, 14 are "decks" and the two larger ones are "through," affording a clearance headway for navigation of 60 feet at summer level.

The day was cold, and the exposed position of the bridge rendered a detailed examination out of the question. The forming of ice was seen to advantage. Beneath the clear water of the river immense fields of congealed water like drawn out wool were visible, and an enormous supply of ice was in process of preparation at the site of the bridge. Mr. Massy's paper gives the details of piers and foundations, and Mr. J. W. Schaub, M. Can. Soc. C.E., in his paper on the steel superstructure (Vol. I Transactions Can. Soc. C.E.), gives the details of the work.

Mr. P. A. Peterson, Member of Council, Can. Soc. C.E., and chief engineer of the bridge, accompanied the party, and explained many features of interest. The bridge was commenced in the spring of 1886, and the first train crossed the bridge on 30th July, 1887. The cost of the bridge was rather under one million dollars. There are 7,641 cubic yards of masonry, 4,721 cubic yards of concrete, and 8,315,965 lbs. of steel in the bridge.

The party returned to the city by the Canadian Pacific Railway, thoroughly enjoying the trip and the welcome accorded to the Society.

Thursday, 22nd January.

K. W. BLACKWELL, Member of Council, in the Chair.

Paper No. 47.

THE INTERNATIONAL COLLIERY,

BRIDGEPORT, CAPE BRETON.

By C. B. Kingston, Stud. Can. Soc. C.E.

The operations of the International Coal and Railway Company are being carried on in the great Cape Breton Coal Field. The general disposition of the coal in this region, and the particular arrangement of the various seams, are very clearly shown on maps made from surveys by the Geological Survey of Canada, and also from surveys made under the direction of the Provincial Department of Mines and Works.

It is not necessary to say more of the geological formations of the neighbourhood than is enough to define the situation of that part of the coal field wherein the company is carrying on its work. Mr. Rutherford, late Inspector of Mines for the Province of Nova Scotia, in one of his reports, divides this field into three districts, the Sydney district on the north, the Cow Bay district on the south, and between these the Glace Bay district, in which is the area of the International Company.

This division is based on the presence of two anticlinals which separate these basins, one more distinct separating the Cow Bay from the Glace Bay district, and one less distinct between the Glace Bay and Sydney districts. Besides the International, there are three other collieries in active operation in the district,—one working the same seam, and two working different seams of coal, whose relations to one another have been pretty definitely decided.

The lease held by the International includes an area of four square miles, and contains four fine seams of coal within a workable distance at the surface. At present the upper seam, known in the neighbourhood as the Harbor Seam, is alone being worked.

GENERAL SKETCH OF WORKINGS.

The seam which dips due east at an angle of five degrees was originally opened by a pair of slopes. In course of time it was con sidered advisable to sink a shaft some distance from the outcrop, in order to lessen the labour and expense of hauling the coal, which at the time was being worked altogether to the rise of the shaft.

The mine is worked on the "Bord and Pillar" system, the bords or rooms being driven six yards wide, and the pillars left seven yards thick, cross cuts seven feet wide being made between the bords every twenty yards.

The old workings from the slopes, upon which the shaft had to be sunk, made it impossible to open the mine in the regular way by leaving four large pillars of coal for the support and protection of the shaft mouth, necessitating a great deal of heavy timbering, of which a description will be given in connection with the shaft. The rise coal, *i.e.*, that coal lying west of the shaft, which could be brought down to the pit bottom by the natural grade, was very soon worked out. The coal had then to be worked to the deep (east of the shaft), and hauled up against the grade. The main body of the work is at present carried on from a single pair of deeps, from which the levels are broken off. These deeps were driven due east from the shaft, and the levels turned off north and south. The coal is being worked out in blocks six hundred feet long, the workings of each block constituting what is known generally as a "Landing."

The main deeps are driven down six hundred feet, then in the middle of this block a pair of levels twelve feet wide are turned off at right angles to the deeps. From these levels in turn two more roads, known as "Headway" roads, are turned off at right angles.

From these headways the bords or rooms are broken off, and are driven at first back towards the main deeps, those to the rise of the levels being carried through to the deeps, those to the deep of the levels being carried back part of the way only, a heavy pillar being left next to the deeps to form a lodgment for water, the use of which will be explained in connection with the pumping of the mine. When this has been done the bords are carried beyond the headways away from the deeps. There are six of these landings at present, three on the north and three on the south side of the main deeps.

Coal Cutting.—The coal is mined or undercut to a depth of four feet, sheared down one side from the roof to the floor, a hole drilled near the roof, and the block blown down with powder. The face of the room is taken down in two shots nine feet wide. The shearing is done in the middle of the room, and the shots kept always two feet in advance of one another. By this means a shot which is mined out four feet needs only two feet of shearing, which greatly lessens the labour. The drill hole is begun a little below the roof and slanted upwards until it strikes the stone. This gives the man more room to handle the drill, and also gives the blast more leverage on the lump.

Plugging the coal, that is, blasting it when mined without shearing, is forbidden except in very few cases; for, unless it is practised with great care it jars the pillars, and renders them unsafe. The blocks, which contain from four to seven tons, are next broken up with picks, and loaded into the tubs. Short, straight picks, having very fine points, slightly chiselled, are used. Each man has a set of six picks of different weights, which he brings up to the forge every night, where they are sharpened and carefully tempered, the steel points being left blue; as, if they are tempered white, they become too brittle, and break in the coal, where there are bands of shale.

UNDERGROUND HAULAGE.

This very important branch of the mine has received much attention.

Roads.—The roads are laid exactly like an ordinary railroad. The small steel rails are laid on wooden sleepers, and ballasted with broken stone. The gauge is thirty-two inches. Where steam power is used, rollers are placed in the middle of the track, thirty feet apart, for the wire rope to run upon. Constant care is required to keep the roads in good condition and free from loose stone and coal which may throw the tubs off the rails.

On the roads where horses are employed, the stone ballast becomes quickly broken up, and forms heavy mud, which works up from their feet to the sides of the track. This must be carefully shoveled away, for, besides blocking the rails, it rubs the grease off the journals of the wheels and increases the weight of the load. The roads have also to be carefully drained, as the pit water injures the horses' feet.

A double track is laid on the upper part of the main deep where the trains of tubs, or trips, pass one another. There are single tracks on the levels which are widened in places for sidings where the trips pass. Single tracks are laid on the headways, and in each bord, where the tubs travel singly. As the bords advance, the headway roads are moved up into the cross-cuts nearer the face, the level road is advanced, and fresh sidings put in if necessary. This lessens the number of rails required in the bords, and is usually done each winter when the mine is not working. In laying out the roads, care is always taken to use the grade as far as possible with the load.

Haulage.—The tubs of coal are drawn by horses, one at a time, from the bords, along the headway to the level. Here they are coupled in trains of alternately four and five tubs, and drawn by heavier horses along the level to the main deep. A train of four and one of five tubs are coupled together here and attached to the rope from the engine. The trip of nine tubs being then drawn up the deep to the pit bottom is again broken up, and the tubs raised in the shaft one at a time. The plain rope system of haulage is employed on the deep, the empty trip carrying down the rope, which runs off a loose drum thrown out of gear and governed by a brake band.

Rope.—Lang's patent woven wire rope, three-quarter inch, is used.

Engine.—A horizontal cylinder, $10'' \times 24''$, with 60 lbs. of steam, drives a small spur wheel, gearing with two large wheels attached to two drums. These can be thrown in and out of gear. One drum is thrown into gear when a full trip is being drawn up, while, at the same time, the other drum is thrown out of gear and governed by a brake strap while the rope is being drawn off by an empty trip running down. The engine is on the surface, near the shaft, down which the ropes pass into the pit. The space being limited, the wheels have to be set one below the other, for which reason the drums are set one a little below the other to allow the ropes to clear each other. The drums are four feet in diameter and three feet six inches long, carrying each about three thousand feet of rope.

The engine being placed near the shaft, the rope leaving the drum has a lead to the first pulley of only fifty feet, which sometimes causes the rope to coil badly on the drum.

Signals.—The engineers on the surface are kept informed of the position of the trips below by means of a carefully arranged set of signals. These are made by fine wire ropes running on carefully oiled pulleys, and attached to right-angled levers by means of which a heavy weight is raised and allowed to drop on a metal plate. A signal is given when the trip is attached to the rope, and all is clear for it to start. When the trip reaches the top of the deep, and passes on to the level ground at the pit bottom, known as the "bank head," it signals itself by striking a lever arm standing up in the centre of the track, which causes a bell in the engine-house to ring. The signal wires pass along beside the road, so that in the event of anything happening to the trip, whoever sees it can at once signal the engineer to stop the engine.

A stout iron bar, known as a "bogey," is attached to the hind end of the last tub on the trip, and allowed to drag behind it. By its means the trip is thrown off the rails and stopped at once in the event of a rope breaking, or a coupling giving way.

On the bank head, where the rope is knocked off, a pulley is placed, having one side of its block loose, attached to a balance weight. The block is drawn down and hooked on to the rope on the trip coming up. When the rope is knocked off, the weight draws the pulley and the rope with it, up to one side of the roof out of the way of the trip, which runs of its own accord to the pit bottom.

A slanting road is cut from the pit bottom to the top of the bank head, into which the empty tubs are shoved as they come down from the surface, and are made up into trips of nine tubs to run down to the landings.

The rope, which passes along the bank head from the shaft and round the angle to the edge of the bank at the top of the deep, is drawn down into the end of this slanting road, and attached to the back of the empty trip, which is then shoved on to the deep, and allowed to run down the grade, its speed being regulated by the brake strap on the drum.

This rope is passed over a large pulley, running loosely in a frame suspended from a long bar across the roof. This keeps the rope clear of the rails as it swings across the road when the trip runs from the slanting road at the side on to the deep. When the trip is fairly on the deep, the rope is lifted out of this pulley and allowed to run on the wooden rollers in the middle of the track.

Horses.—Light horses are used in the rooms where single tubs are drawn, and heavier ones on the levels where the load is four or five tubs. A good deal of trouble is caused by the pit water, which works into any cuts or scratches on the horses' feet, producing lameness. On returning to the stable at night their feet are washed and greased with a mixture of tallow and kerosene to protect them from the acid water.

Each horse carries a pair of shafts which are hooked to the tubs. Their heads are protected from blows against the roof by heavy leathern caps lined with felt.

Tubs.—The coal cars, or tubs as they are called, are boxes built of inch and a quarter pine, bound on the corners with $\frac{1}{8}''$ angle iron and round the top and middle with bands of $\frac{1}{4}''$ iron. (Plate I, Figs. 1 and 2.)

These boxes are bolted strongly to a heavy frame, the side pieces of which ($6'' \times 4''$ in section) project three inches beyond either end of the box, and, being bound with iron, act as buffers.

A small iron loop is attached to a band of iron running across the box at each end, about one foot from the bottom, into which the shafts hook.

The couplings are made by an iron bar, attached to the lower part of the carriage, having a hook at one end, and four six inch links at the other. The wheels are of steel, and are turned, and pressed on to the axle so that they run perfectly. They are very light; the pair of wheels and the axle together weighing only eighty-five pounds. The wheel base is eighteen inches, so that they are easily handled, and will run on a sharp curve. The boxes are 4′ 11″ × 3′ 3″ outside measurement, and hold from 1800 to 2000 lbs. of coal.

TAIL ROPE SYSTEM OF HAULAGE.

An interesting example of this system of haulage has recently been started in the mine. It having been found necessary to lighten the strain on the present hauling engine, and at the same time to increase the output of the mine, it was determined to utilize an old level running south from the shaft. Driving down from this level at a point about 2000 feet from the shaft a lower landing of the south side workings was reached. There was already a slight grade from the turn off on the level down to the shaft mouth which helped the full trips coming in, but in order to bring the empty trips back a tail rope was required. The road turned off the level was graded down from the level to the landing, so that, after a certain point was reached, the tail rope was not needed, and could be knocked off, allowing the trip to run down alone, drawing the hauling rope after it.

The engine used for this system is set in the pit at the entrance to the level, and is supplied with steam from the surface. It is a small horizontal engine having two cylinders 8″ × 12″, and two drums, one carrying 3500 feet of a locked wire rope used for the direct haulage, and 5200 feet of the woven wire rope used for the tail rope.

The tail rope passes with a lead of seventy-five feet to a steel pulley, having a deep flange, running loose on a spindle 30″ long to allow the rope to coil properly on the drum; then one hundred and twenty feet to a similar pulley running on an 18″ spindle, being supported in the interval on wooden rollers 15 feet apart. From here the rope passes, supported by wooden rollers, 30 feet apart set between upright sticks of timber, to a large horizontal steel wheel of four feet diameter, placed in the angle at the back of the triangular pillar on the outside of the curve. From this wheel it passes 300 feet to a horizontal wheel of the same description set in a box under the track. This wheel is inclined carefully at such an angle that the rope when passing down to it, and when leaving it, will run clear of the ties. Where the rope leaves the roof to pass down to this wheel, a steel deep flanged pulley wheel is substituted for the rollers, and where the rope passes from the road to the wheel and from the wheel to the road again, steel rollers are used instead of wooden ones to prevent accidents from wearing.

When the full trip coming up reaches this point, the end at the tail rope is attached to the back of the last tub and drawn into the shaft. Here it is taken off, and being attached to an empty trip draws it up the grade on the level, over a distance of flat bottom on the curve, to the head of the down grade, the hauling rope being drawn out behind. Here the tail rope is knocked off, and the empty tubs run down with the hauling rope to the landing. The wheel beneath the track is set in such a position that the tail rope runs on clear of the tubs, and runs off near one of the rails, so that the end of the rope when knocked off cannot get foul of the hauling rope.

The hauling rope passes from the drum along the centre of the track supported at every 30 feet by a wooden roller. On the curve, which is a very sharp one, the rope runs on nineteen upright steel sheaves, 10 feet apart, set on a heavy plank laid close along the outer side of the inner rail, so as to answer the further purpose of supporting the rail. These sheaves, which are 8″ diam. and 10″ high, are sunk slightly in the plank so as to prevent the possibility of the rope catching beneath them. At either end of the curve, and a short distance from the point where it leaves the tangents, a small upright sheave is set in the middle of the road. The passage of the tubs on the curve is protected by heavy guard rails of wood.

An interesting feature of this system is the introduction of a patent locked wire rope, made in England, and known as "Elliot's patent locked wire rope." The wire used is of a section of two diamonds set on edge, and when twisted these wires lock into one another, making a perfectly solid rope with a smooth surface which runs easily on wheels and rollers, and does not hold dirt. The rope is made in two pieces, an inner and an outer, in each of which the wires are twisted in an opposite direction. This rope is very strong, a $\frac{1}{2}''$ rope doing the work of a $\frac{3}{4}''$ woven wire rope. It is also very durable, as each wire wears evenly. All these ropes are carefully greased to keep them from rusting.

A new shackle is used for the end of this rope which avoids the weakening of the latter by rivets. The shackle is a piece of round steel tubing tapering towards the rope. The rope being passed into it, the ends of the wires are turned back, and the whole made solid with molten lead. From twelve to fifteen tubs make the trip on this system.

THE SHAFT.

The shaft is a very shallow one near the outcrop, being only 80 feet deep. It passes for the greater part of this depth through solid stone; only about twenty feet at the top requiring cribbing, which rests safely on the stone head. The shaft is 12′ × 8′, eleven feet being taken up with the cages and buntings, leaving one foot for the steam-pipes for the pump and underground engine, and the ropes from the main deep. The cages travel on two pitch-pine spears or guides, one rising as the other drops. The ropes run off a single drum, being coiled on in opposite directions. This drum is driven directly by two cylinders 18″ × 48″, with 45 lbs. of steam. The man driving this engine is governed by a careful code of signals.

Timbering of the Shaft Bottom.—The shaft having been sunk upon the old workings, it was found necessary to use a somewhat elaborate system of timbering for its support and protection. Fourteen inch hemlock timber was used, round for the uprights, but partially squared for the roof pieces. There are three sets of timber in the roof, supported by uprights on either side of the road. The spaces left between the pieces are large enough to allow a complete new set to be put in before removing the old ones, when they have to be changed. A four inch cap of oak is placed on each support to prevent the end wood of the upright from crushing the ends of the cross-pieces.

This careful timbering was necessary, because the close, hard stone immediately above the seam was removed to give the required height about the shaft bottom. Through the rest of the mine very little timber is required for the support of the roof, and where it is needed an upright post, with a cap, is quite sufficient owing to the closeness and hardness of the roof stone.

VENTILATION.

The mine is at present ventilated by means of a furnace, the area of whose bars is 6 × 6 feet, raised two feet from floor, and having a heated column of 130 feet. As tested by the anemometer this furnace passes, on an average, 32,000 cubic feet of air per minute. The pit is ventilated in two sections, one-half from an intake on the north side, and the other from an intake on the south side. Care is taken, by means of frequent cross-cuts, to keep the current close up to the faces of the bords where the men are working, and all the stoppings are carefully looked after to see that no air is lost by leakage. Although very little gas has been met in the seam, the whole pit is carefully examined with safety lamps each morning to see that any gas which may have accumulated during the night has been driven off. The furnace having been found insufficient for the increased extent of the mine, a fan is about to be introduced which will supply a much larger amount of air.

PUMPING.

The division of the mine into landings makes it easy to deal with the water in the pit. The rooms driven back from the headways towards the deep on the lower side of the levels are not carried through to the deep, but a pillar of coal is left which, with the wall between this landing and the next below, forms a lodgment which will hold all the water made in the landing. The lower room in the landing is narrow, and is given a slight grade down towards the deep. By this means the water is made to press into the angle of the lodgment. At this point a hole is bored through the pillar to the deep, and the water held back by a wooden plug. Near the lowest landing on the pit a large lodgment, known as the "sump," is cut in the solid coal, from which the pump draws the water. At night, when the men have left the pit, the plugs are taken out of the different bore holes, and the water is allowed to run down to the sump through channels cut in the floor. It is then pumped up to a water level, near the outcrop, whence it runs off into the sea.

By means of these separate lodgments in the landings the water is kept well under control, and, in the event of any accident happening to the pump, the water could be held back for a month or more. The pump is set on the second of the main deeps, which is not now used for hauling coal, and is about one hundred feet above the sump. The water is drawn up through seven-inch iron pipes and discharged through five-inch wooden pipes. Owing to the acidity of the water, the latter are found to be more durable. They are prepared by the "Wykoff process."

The pipe, which is two inches thick, is bored out five inches, it is then bound spirally with hoop iron, and the whole rolled in the borings mixed with pitch to protect the iron from the water. The pipes are joined together by means of a spigot fitting into the end of each length, and can be separated by sawing this spigot through.

The pump is direct acting, of the Knowles pattern, having a cylinder $26'' \times 30''$ and running 22 strokes a minute with a pressure of 25 lbs. at the receiver. The plunger, which is 8″ in diameter, is made of Babbitt metal, a soft compound made especially for resisting the action of the acid water, and containing $65\frac{1}{2}\%$ lead, 25% tin, 5% copper, $4\frac{1}{2}\%$ antimony. In order to keep a smooth surface on the plungers, they are continually coated with a mixture of tar and tallow.

A very efficient means of destroying the exhaust steam has been adopted here. Instead of exhausting into the sump, as is usually done, the exhaust pipe is led into a small upright box, into which is directed, by pipes, the water from one of the upper landings. This water falling upon the steam as it leaves the exhaust pipe kills it completely.

COAL CLEANING.

The tubs of coal, as they are raised in the shaft, are at once weighed, and then dumped through shoots into cars below. A tipping cage, or tumbling cage, as it is called, is used for upsetting the tubs, and sending the coal into the shoots. One of these tumbling cages is shown in Fig. 3, it is built of $\frac{1}{4}''$ iron web plates, riveted to iron angles, $2'' \times 2\frac{1}{4}''$ with $\frac{1}{2}''$ rivets, and $2\frac{1}{2}''$ spaces. It swings on an axle fastened to a $30'$ wheel, bolted with six $\frac{1}{2}''$ bolts to the side of the cage. When the cage is inverted, the weight of the tub, as it falls forward, is taken up by a cross bar attached on either side to $1\frac{1}{2}'' \times 1\frac{1}{2}''$, $\frac{1}{4}''$ angles riveted to sides of the cage on the inside.

An iron door, swinging loose, is put in above this cross-bar, so that when the coal falls forward from the inverted tub it is directed by the weight of the door into the shoot without being broken up unnecessarily. The tipping of the cage is controlled by a brake strap and lever on one of the wheels, to which the axles are fastened. The weight of the full tub when the brake is taken off upsets the cage, and allows the coal to fall out. A heavy weight bolted to the bottom of the cage, as shown in the figure, brings the cage and empty tub back into position, when the brake is again put on.

Holes are cut in the bottom of the cage (see Fig. 5), through which the wheels of the tubs are greased while the coal is being emptied. A triangular piece of plate is riveted to the side of the cage, which projects beyond the cage resting on the floor when the cage falls back into position, and holding it level with the floor. The rails in the cage are turned up at the end to catch the forewheels of the tub.

If the coal is being shipped just as it comes from the mine, or as "Run of Mine," it is turned into the shoots, of the form shown in the cross section in Fig. 4.

These are of iron and swing on an axle, their swing being controlled by a break strap. When the coal is emptied into the shoots, they are held up against an iron plate suspended from a beam above, which prevents the coal running through while it is examined, and all splint and "bras" coal, i.e., coal containing iron pyrites, is taken out. The brake is then loosened and the shoot tipped by the weight of the coal, which runs off into a car standing on a track below, the shoot falling back into its former position.

If it be required to remove the finer coal and dust, the iron plates which formed the bottom of the shoots are removed, exposing a screen of $\frac{1}{2}''$ bars with $\frac{3}{4}$ inch spaces, through which the finer coal and dust, known as slack, pass into a wooden shoot below, and slide back into a car standing on a second track. The larger or round coal passes over the screen into a car on the first track. The slack is sometimes subdivided into three finer grades of coal, stove coal, nut coal, and duff or dust. For this work the conveyer and elevator, shown in Figs. 4 and 5, are employed.

The slack which passes through the first screen instead of running directly into the car is directed through a door further down the shoot, (shown as hooked up, in the cross section) and then back into a small metal trough passing along beneath the screens. Here it is taken up by iron plates fastened on an endless chain worked by a small donkey engine, and conveyed to an iron box at the end of the trough. From this box it is raised in small iron buckets fastened between two endless chains driven by a small horizontal engine on the bank frame, and emptied into a screen with $\frac{1}{2}''$ spaces, over which passes the stove coal.

From this screen the finer coal and dust pass on to a netting of heavy iron wire of $\frac{3}{8}''$ square mesh, which is shaken from side to side by a right-angled lever having its arms one on either end of a long rod, and deriving its motion from an eccentric on the shaft of the small engine used for raising the buckets. The duff or dust being shaken out, the nut coal passes over the netting into a shoot which leads it to a car below. This shoot, and that used for the stove coal, are made with a bend in the middle to prevent the coal being broken by a long straight drop. The duff is found to answer in the furnaces, so that nothing is wasted. The steam used by the small engine on the bank is held in a receiver packed with asbestos, which is not shown in the diagram.

SHIPMENT OF COAL.

The coal after being cleaned and put into the cars is brought along the Company's line of railway thirteen miles to their pier on Sydney Harbour. The plan of this pier is very simple.

There are three tracks; those on the outside being used for full and the middle one for empty cars. The full train is run on to one of the side tracks, and then, being broken up, the cars are moved singly by horses. The shoots on the body of the pier are led through holes between the rails. The car being drawn over the hole, the bottom is allowed to drop, and the coal, falling into the shoot, runs down to the hatch of the vessel. The empty car is then run on to the empty track in the middle by means of the turntables used for the jetties. At the head of the pier, and on the jetties where the larger vessels are loaded, the shoots must be thrown out some distance beyond the pier, and a piece of swinging track is used to run out the cars over the shoots. These drops and shoots are supported by chains, and are raised and lowered by means of a winch on a small truck, which can be moved from one to another. The pier is built on cribwork filled solid with stone.

The bents are sixteen feet apart, twenty feet high, of fir timber 12" square. The planking is laid crosswise, a second row being placed lengthwise between the tracks for the horse road.

The International is a bituminous caking coal, containing about 58% of fixed carbon and 35% of volatile combustible matter, leaving a moderate amount of ash. It has been carefully tested for steam purposes, gas purposes, and locomotive use, and in each case has proved to be of first-class quality. The annual output is something over one hundred thousand tons for the eight months during which the mine is worked.

From the drawings accompanying this Paper Plate I has been prepared.

Thursday, 29th January.

The following candidates having been balloted for, were declared duly elected as:

MEMBERS.

WILLIAM HASKINS, JOHN FRANCIS O'ROURKE, WILLIAM GEORGE MCNEIL, FRANK EDWIN PRINCE TURNER.

ASSOCIATE MEMBERS.

CHARLES ARTHUR MILLICAN, JOSEPH HOLLAND TESSIER.

ASSOCIATES.

HENRY E. WILFRID DORVAL, WILLIAM GILLESPIE REID.

STUDENTS.

JAMES EDWIN ALEX. MOORE, ROBERT LEONARD SHERRATON.

The following has been transferred from the class of Students to that of Associate Member:—

THOMAS SIMPSON RUSSELL.

The discussion of Professor McLeod's Paper on "The Errors of Levels, etc., Part II," occupied the evening.*

* Printed in Vol. IV, Part II, pp. 299 to 323.

Thursday, 12th February.

J. KENNEDY, Vice-President, in the Chair.

Paper No. 48.

AN ENLARGED WATER-WAY BETWEEN THE GREAT LAKES AND THE ATLANTIC SEABOARD.

By E. L. Corthell, M. Can. Soc. C.E.

The object and scope of this paper should be clearly stated at the outset. The object is to discuss the question of the feasibility of making an enlarged water-way from the great agricultural and manufacturing centres of the West, bordering on the Great Lakes, and tributary to them, to the sea ports on the Atlantic, and to the commercial ports of the Old World.

By an enlarged water-way is meant one capable of transporting freely, and with the least possible delays, the largest freight carriers now to be found upon the Great Lakes. Any project for a commercial route that will not transport economically and with speed vessels weighing, with their cargoes, 5000 net tons, with a draught of 20 feet, will be at once eliminated from this discussion. It would be a waste of time and of public thought to propose, or even dwell upon, any project that is not fully abreast of the commercial times. Again, let it be understood at the outset, that no narrow channel, even with the draught of 20 feet, is to be considered as at all adequate for the wants of commerce, or in consonance with the principles of this discussion. Careful and thorough investigation, comparing the cost of transportation by the present methods of rail and barge and ship canals, has made it evident that nothing but unrestricted channels of the very largest dimensions for laden vessels of large tonnage will at all compare with the celerity, economy and other and numerous advantages of transportation by rail, particularly in the United States and Canada.

A glance over the history of the last half century will show that all water-way channels of an artificial nature have been far behind the demands of the rapidly increasing commerce and tonnage of vessels of the Great Lakes. This has been appreciated by the commercial men most conversant with the conditions, but to the general public the necessity for larger channels has not always been apparent, and appeals for appropriations by Governments for such enlarged channels have been met with opposition.

Without regard to state or national lines, commercial men of Canada and of the northwest of the United States have generally been in accord on the subject of an enlarged water-way to the Atlantic seaboard. As long ago as 1863 a National Ship Canal Convention was held at Chicago, and 5000 delegates from all parts of the United States were in attendance. The special object of this Convention was to advocate the enlargement of the canals between the Valley of the Mississippi and the Atlantic.

In 1865 it was urged by an able advocate of water-way enlargement that the commerce of the Northwest had increased to so great a magnitude, that it had outgrown the Erie Canal and demanded a through route, not only to the Atlantic seaboard for its vessels, but to Liverpool; and it was asked: "Why should the lake cities with their wealth and resources not import for themselves and transact their own business? The ocean is the prerogative of no state of the Union, and the West will seek the channel which conducts its commerce with the least cost and delay."

Before the canals through New York State and Canada were even laid out, the inland seas of the continent were regarded as of so great importance, that a full and adequate ship canal from them to the ocean was looked upon as absolutely necessary. To obtain this has been the dream of commercial men during the last three-quarters of a century. That it has not been realized is due largely to the fact, that the natural water-way lies through two countries that have, as political divisions, nothing in common. There has not existed the union of action necessary to fully carry out the great projects desired by commerce. These projects have therefore never been taken up as a connected whole and pushed forward to legitimate conclusions.

It is well known that between the important ports on Lakes Michigan and Superior and Liverpool there are over four thousand miles of water navigation, and that only about 71 of them are restricted by natural obstacles in the channels. The object of this paper is to ascertain, if possible, how these natural obstacles placed here and there in the pathway of commerce may be removed, and steamships may be built on the Great Lakes to ply between their ports and the ports of the Atlantic seaboard and of the Old World.

The scope of a paper discussing so broad a subject, and one, withal, so important to the commerce and industry of great nations, must not be too circumscribed. The discussion must not be limited to certain special questions, but must canvass the entire situation, and, if possible (being given the privilege of selection), point out the best route and give convincing evidence of its superiority.

The question is not one that interests engineers alone, and there are other than engineering principles involved. We are led at once into an important commercial discussion and into the whole history of the great Northwest, particularly of the vast country tributary to the Great Lakes and the St. Lawrence River. It has to be borne in mind, also, that artificial lines of transportation—that is, constructed highways of commerce—have covered the country in every direction; that the methods of transportation upon these constructed highways have been vastly improved over those of a quarter of a century ago, and that still greater improvements will be made in the near future. We shall, therefore, be obliged to take up the subject something as follows: —

1st. Its historical features, showing the development of commerce and the increasing capacity of the channel-ways by water and by land;

2nd. The physical conditions of the present and proposed routes;

3rd. The financial and political questions involved;

4th. The commercial features of the subject.

In reference to the historical, a brief sketch will be of interest, showing the changes in the dim history of the past made in the Great Lakes, adapting themselves finally to present conditions for the benefit of man. Briefly, though not perhaps bearing directly upon our main subject, a sketch will be given of the commercial improvement southward of the Great Lakes to the Gulf of Mexico. We will then take up the present canals and channels built between the Great Lakes and the Atlantic seaboard in relation to their history; the history of the railroad system and the growth of railroad transportation will be briefly outlined. It will be necessary, also, to give a brief history of the harbour improvements upon the Great Lakes, and then in some detail the history of commerce shown by the increasing size of vessels, the increase in tonnage and the movement seaward on the Great Lakes of the productions of the Northwest. A history, also, of the gradual reduction in freight rates, both by railroads and canals on East and West routes, must be given. It will be necessary to trace briefly the growth in population, productions and commerce of the country tributary to the Great Lakes, and particularly of the more important lake ports, such as Chicago, Duluth, Cleveland, Buffalo, Toronto and Montreal. In discussing the physical features it will be necessary to state the topographical conditions of present and proposed routes, with estimates of costs and the capacity of these routes when completed, and give a comparison of the length of routes now existing and projected. The author having found it necessary to discuss the feasibility and desirability of constructing at certain points on the routes ship railways, a general sketch and brief argument in favour of the practicability of such a method will need to be given, and a comparison made between this method and that by ordinary canals and railroads.

The financial and political subject will embrace the question of what it will cost each of the two Governments to carry out the plans proposed, or the cost to private companies of constructing the proposed routes; and under this subject the relations of the two Governments to each other, so far as relates to commerce, must be briefly stated.

In discussing the commercial features it will be necessary to predict the effects upon the various large ports of the Great Lakes and the St. Lawrence, and, also, of the Atlantic seaboard, of completing and putting into operation the water-way, or the water-ways, recommended; and to state also the probable changes in methods of transportation which will take place, and also the change in the methods of trade with the Atlantic seaboard and with Europe, when steamers of 5000 tons displacement weight, when laden, are built on the Great Lakes, and put in direct trade between lake ports and the ports of the Atlantic seaboard, Great Britain and the Continent.

Great and astonishing changes have taken place in comparatively recent geological times in the basins of the Great Lakes. There are well defined high water marks to indicate, at least, that the three great Northwestern lakes were probably 200 feet higher than they are today; that there was a still greater lake, now Lake Winnipeg; that the immense overflow from all these lakes flowed southward to the Gulf of Mexico; and that great areas of country now inhabited and cultivated by man were at that time submerged to a great depth.

The great valleys of the Illinois River, the Minnesota River, and the Upper Mississippi as well, now occupied by comparatively small streams, prove conclusively that at a comparatively recent period there flowed southward great volumes of water, and that Lake Winnipeg drained southward, although now draining northward. A hypothesis was advanced, and an endeavour made to sustain it, by the late General Warren, to account for this remarkable change in the drainage of the continent. He attributed it to a great cyclic change in the continental slopes which depressed the northerly part of the continent and raised the southerly, as, for instance, the Florida Peninsula, as well as Cape Cod and other formerly submerged portions of the Atlantic Coast. This great southerly current of the vast interior basins of fresh water of the continent was hemmed in on the south by an ancient barrier, which evidently crossed the Mississippi near Grand Tower, Ill.; but the waters gradually cut their way through, and thus largely drained the great inland sea. Either by this means or by the changes in the continental slopes, the waters were drained from the land, and the conditions were slowly changed until we have the Great Lakes of to-day.

At Chicago is the lowest line in the cross-section of the trough or "thalweg" through which the waters of the lakes flowed southward. The bottom of this trough is only about 8 ft. above the present level of Lake Michigan, with a natural drainage and a steep slope down the Illinois River Valley from the immediate suburbs of the city. At this location has been built within the last half century the second city of the continent, and at this point, connecting the lake with the tributaries of the Mississippi River, there was projected in 1670 a canal to the Illinois River. It was proposed by one of the earliest pioneers—Joliet—to dig a canal across the Chicago Divide for commercial and military purposes. In 1804 Albert Gallatin, secretary of the Treasury of the United States, spoke of the national character of this proposed waterway. In the first comprehensive report on internal communication, DeWitt Clinton and Gouverneur Morris in 1808 to 1825 urged the "proposed ship canal" as an extension of the Erie Canal to the Mississippi, in order to open up water communication by the lakes from the Hudson River to the Gulf of Mexico. The Congress of the United States assisted in the project, and made a land grant of 284,000 acres in 1827 for the construction of the work. The first canal was opened for navigation in 1848. In 1865 the State of Illinois provided for its completion; it was completed by the city of Chicago for drainage purposes in July, 1871, but the flow through it proved insufficient for the purpose, and in 1881 the State required the city to erect pumping machinery of a capacity of not less than 60,000 cubic feet per minute, which was put into operation in 1884. The original canal was six feet deep, sixty feet wide at surface, thirty-six feet wide at bottom in earth, and forty-six wide in rock, with locks, one hundred and ten feet long, eighteen feet lift and six feet on the miter sills.

The rapid growth of the city requires a much more adequate drainage for its sewage than is now provided. This is necessary to prevent the pollution of the only source of its water supply, and to carry the sewage away from the city as quickly as possible. A channel for drainage purposes as well as for navigation purposes has been authorized by the State Legislature. Nearly the entire area of the city has, under the State law, been organized into a drainage district. The law requires (and this requirement it may be stated was demanded by the towns and cities located along the Illinois River) a continuous flow of not less than 300,000 cubic feet per minute, with a current not exceeding three miles an hour and 600,000 cubic feet per minute, when the population of the district draining into the channel exceeds 1,500,000, with a requirement for a still larger volume when the population exceeds the number last named. It is specified that the water shall not be less than eighteen feet deep through the channel, and that the width of the channel shall not be less than one hundred and sixty feet at the bottom. By a joint resolution the Legislature requests the United States Government "to aid in the construction of a channel not less than 160 feet wide and 22 feet deep, with such a grade as to give a velocity of 3 miles per hour from Lake Michigan at Chicago to Lake Joliet, a pool of the Des Plaines River immediately below Joliet, and to project a channel of similar capacity and not less than 14 feet deep from Joliet to La Salle, all to be designed in such manner as to permit future development to a greater capacity." It is apparent from the rapid growth of the city, that long before these works, so great in magnitude, and costing probably twenty-five or thirty millions of dollars, shall have been completed, there will be at least 2,000,000 of people in the drainage district. The normal growth of the city will, no doubt, make the population as great as this before the year 1900. The large quantity of water to be sent through this channel into the Illinois River Valley will, it is expected, raise the low water level of the Illinois River about 7 feet, and that of the Mississippi River at St. Louis at least one foot, and probably six inches at Cairo at the junction with the Ohio River. On the Mississippi River itself the United States Government is expending large sums of money in deepening and rectifying the channel for navigation, with the ultimate purpose of obtaining a minimum depth of 10 feet at low water between New Orleans and Cairo, a distance of about 1000 miles by the course of the river. As is well known, it has expended a large amount of money in removing the obstructions at the mouth of the Mississippi, and has created by the works there a channel 30 feet deep between the river and the Gulf of Mexico. This result was obtained in 1879, and the channel has increased rather than diminished in size since that day through the jettied channel. As incidentally of interest, it may be stated that the United States Government is about to connect the navigable waters of the Illinois River with those of the Mississippi River by a canal across the country from Hennepin on the Illinois River to Rock Island on the Mississippi River. This is not to be a ship canal but a boat and barge canal. The depth on the miter sills of the locks is to be 7 feet, the width at surface of the water 80 feet, and the locks are to be 170 feet by 30 feet. There will be 37 of these locks. The height to be surmounted from Hennepin going westward to the summit in a distance of 20 miles is 208 feet. The difference in level between this summit and the Mississippi River at Rock Island is 102 feet, the length of the canal will be 77 miles. The entire distance between Chicago on Lake Michigan and Rock Island on the Mississippi River, by way of the Illinois River and the Illinois and Mississippi canal, will be 193¼ miles. The plans are made for the work, and construction is expected to begin soon.

One question in relation to the proposed drainage and water-way channel between Chicago and the Mississippi River is, what effect, if any, will the abstraction of so large a volume of water from Lake Michigan have upon the level of that lake and of Lake Huron and upon the volume flowing through the Detroit River into Lake Erie? This is an international question, and should be briefly considered in connection with the general subject which we are discussing.

On September 8, 1888, a paper by Mr. George Y. Wisner, civil engineer, was read before the Western Society of Engineers, entitled: "Levels of the Lakes as affected by the proposed Lake Michigan and Mississippi Water-way." Mr. Wisner had had at that time about 20 years' experience on the rivers, harbours and lakes of the Northwest, and was connected with the Great Lakes surveys. The facts which he gave and his discussion of the subject were reviewed by several hydraulic engineers of the country. This discussion in printed form accompanies the present paper for the purpose of information. It is not intended here to do more than to state the general opinion on the subject as given by those who took part in the discussion. The opinion as stated by Mr. Wisner was that "probably the low water level of the lake would never be affected to exceed 2½ in. by withdrawing 10,000 cubic feet per second from Lake Michigan for the proposed water-way. The lowest stage occurs in Winter when navigation is closed." "The annual rise of the lake usually covers a period of about four months, and consequently the variation in the yearly fluctuation of the lake surface, due to withdrawing such a volume of water, could not exceed one inch." "When we consider that hourly fluctuations of the lake surface of from 6 to 30 inches in amplitude are constantly taking place, it is evident that the withdrawal annually of a volume of water from Lake Michigan, equivalent to 3 inches in depth over the surfaces of the two lakes, would not be appreciable in any ordinary set of gauge readings, and would certainly have but little effect upon the depth of water in the connecting water-ways." Somewhat similar artificial conditions have been produced by the deepening of the St. Lawrence rapids below Ogdensburg from 10 to 16 feet, adding from 6 to 8 per cent. to the free channel of the river. The question was considered at that time, and was referred to the United States Engineer Department, and the conclusion from the investigation was, that the effects would extend to no great distance, and that the level of Lake Ontario would not be impaired. The deepening at the Lime Kiln Crossing of the Detroit River where the depth has been increased from 13 to 20 feet, and at the St. Clair Flats which have been deepened from 9½ to nearly 20 feet, are cases generally similar to what is practically the deepening of the channel now existing between Lake Michigan and the Illinois River, and yet no injurious results have been experienced or are they anticipated. We may, therefore, dismiss any fears that may exist in regard to the deleterious effects of this channel-way upon the harbours and the connecting water-ways of the lakes.

Taking up again, after this diversion, the general features of our subject, with the intention of following it through in its logical order, we should look upon the Great Lakes, so called, or really inland seas of fresh water of immense magnitude, as simply the enlargement of the St. Lawrence River into which they pour their surplus waters. This chain of lakes, or the river, has its source in Eastern Minnesota at the head of St. Louis River, and almost coincident with the source of the Mississippi and the Red River of the North. The river ends at Cape Gaspé at the head of the Gulf of St. Lawrence.

We are contemplating the most magnificent inland navigation in the world. The basin of its drainage is 457,000 square miles. Lake Superior, the largest body of fresh water on the globe, has an area of 31,200 sq. miles. It is 412 miles in length and 167 miles in breadth, with a maximum depth of about 1000 feet. Its surface is 602 feet above mean high tide of the ocean. The outlet of this lake is the St. Mary's River, 55 miles in length. The difference of elevation between Lake Superior and Lake Huron is 22 feet, of which 18 feet is in the St. Mary's Rapids which are one half mile in length. Lake Huron is 265 miles long, 101 miles broad, with a maximum depth of 702 feet, and is 581 feet above sea level. The area of this lake varies, by different authorities, from 15,760 square miles to 23,800, depending upon what areas of adjacent bays are included. Lake Michigan, connecting with Lake Huron by the Straits of Mackinaw, is 345 miles long, 84 miles wide, and 581 feet above sea level. Its area is 22,450 sq. miles. Lake Huron discharges southward through the St. Clair River, 33 miles in length, Lake St. Clair 21 miles, and the Detroit River 18 miles in length, and then into Lake Erie which is 250 miles long by 60 miles wide, with an area of 9960 sq. miles. Its maximum depth is 201 feet. It is 573 feet above tide and is 326 feet above Lake Ontario, which is the next enlargement eastward of the St. Lawrence chain. The Niagara River between these two latter lakes is 33 miles in length; Lake Ontario, the most eastern of the lakes, is 190 miles long, 54 miles in width, and has a maximum depth of 738 feet, and is 247 feet above the sea. Its area is 7240 sq. miles. From the city of Kingston at the eastern end of Lake Ontario to the ocean the distance is 1164 miles, though Cape Gaspé, which is considered the mouth of the St. Lawrence River, is 400 miles from the ocean.

The St. Lawrence between Ogdensburg and Montreal is obstructed by rapids at several places, which have been improved either by removing the obstructions in the natural channels or by flanking them with artificial canals. From Montreal to the Gulf of St. Lawrence a navigable depth for ocean vessels exists by nature, except at a few points where the channel has been improved by dredging to over 27 feet and to ample width. The improvement in the St. Lawrence River from Lake Ontario to the Gulf of St. Lawrence has been made by and at the expense of the Canadian Government.

The historical features will embrace a sketch of each of the following constructed works: the St. Mary's Falls Canal, between Lake Superior and Lake Huron; the St. Clair River and Lime Kiln Flats improvements between Lake Huron and Lake Erie; the Welland Canal, joining Lake Erie and Lake Ontario; the Trent River navigation, between Lake Huron and Lake Ontario; the St. Lawrence River improvements; the Erie and Oswego Canals, in New York State; the Lake Champlain and Hudson River Route in New York.

In the "physical features" will be included a brief history of the following projects: the Ottawa Ship Canal between Georgian Bay and Montreal, the Georgian Bay and Toronto Ship Canal, and its successor the Hurontario Ship Railway, the Niagara Falls Ship Canal and Ship Railway on the United States side of the river, the Michigan Peninsula Ship Canal and Ship Railway, and the projected Ship Canal via Lake Champlain.

A sketch of the railroad history will be briefly given.

The Map Plate II shows the present and proposed routes.

ST. MARY'S FALLS CANAL.
(Commonly called the Sault Ste. Marie.)

As early as 1837, the project of building a ship canal around the Falls of St. Mary's River was discussed in the Legislature of the State of Michigan. The matter was brought before Congress in 1840, but was opposed, one of its opponents—the distingushed Henry Clay—speaking of it as "a work beyond the remotest settlement in the United States, if not in the moon." This was only half a century ago.

The first step taken by the General Government of the U. S. towards the improvement of this water-way was in 1852, 750,000 acres of public land being donated to the State of Michigan, to enable it to construct the canal, and a right of way 400 feet wide granted through the Military Reservation at the Falls of St. Mary's River, on which to build the work. The conditions were that the canal should be at least 100 feet wide with a depth of 12 feet, with locks 250 feet long and 60 feet wide. The canal was opened to commerce in 1855; the locks (two in number) were 220 feet long and 70 feet wide. In 1882 nearly $2,500,000 had been expended on the canal and its approaches. The prism of the canal had been changed from a uniform width of 100 feet to a width varying from 500 feet at the upper entrance to 108 feet at the narrowest part and 270 feet immediately below the locks, and the depth from 12 feet to 16 feet at a mean stage. A new lock had been constructed 515 feet long and 80 feet wide with 17 feet of water on the miter sills. These dimensions, however, proving inadequate for the rapidly increasing size and draught of vessels, Congress in 1886 provided for a still larger lock, based upon a navigation of 20 feet depth through the canal and its approaching channels. The new lock is to be 800 feet long between the gates and 100 feet wide, with 21 feet depth of water on the miter sills. The estimate for an enlargement of the canal and the construction of this lock is $4,738,865. The lock overcomes a height of 18 feet. This lock is now under construction.

ST. CLAIR RIVER IMPROVEMENTS.

The next obstruction to be overcome is between Lake Huron and

Lake St. Clair. A canal through what is called the St. Clair Flats was projected in 1866 for the purpose of obtaining a straight channel (in place of the tortuous natural channel), 13 feet deep, 300 feet wide and about $1\frac{1}{4}$ miles in length, each side being protected by timber dikes resting on piles; the cribs thus formed being filled with material dredged from the channel and backed by dredged material. In 1873 the channel was deepened to 16 feet by dredging a width of 100 feet on each side of the channel axis. Here also it was found necessary to deepen and enlarge the channel for the enlarging commerce. The project now contemplates a double row of sheet piling to a depth of 26 feet along the channel face of each of the old dikes, dredging the area between the dikes to a depth of 20 feet, and continuing the channel above and below the canal to the same depth in the river and in the lake. On this work there has been expended nearly $700,000.

The Lime Kiln Crossing at the mouth of the Detroit River is also being deepened to 20 feet. The depths demanded by and obtained for the increasing commerce through these channels have been as follows:—

1858 ...... $9\frac{1}{2}$ ft.	1871 ...... 12 ft.
1874 ...... 13 "	1885 ...... 16 "
1890 ...... 20 "	

WELLAND CANAL.

The history of this important artificial water-way connecting Lakes Erie and Ontario, by flanking Niagara Falls and surmounting a height of about 326 feet, is too varied in its nature and has too many details to burden this paper with more than a brief summary. It is nearly three-quarters of a century since the building of this canal was taken under serious consideration. The first project was to build a canal and railroad combined, that was in 1824, but the railroad feature was dropped, and the work began with wooden locks 110 feet long, 22 feet wide, with 8 feet of water on the miter sills. Water was let into the canal in 1829, and two vessels were taken from Lake Ontario to Port Robinson on the Welland River in that year. The financial embarrassments of the Company, however, compelled it to obtain a grant from the Canadian Government, one of the requirements of which was the extension southward to Lake Erie on nearly the same line as now exists. The canal was open to the passage of vessels in 1833. The channel was narrow as well as the locks. In 1841 the Government appropriated some money towards the enlargement and improvement of the canal and to make the structures permanent. According to the decision of 1843, the locks were to be made 150 feet long by $26\frac{1}{2}$ feet wide, with 9 feet on the sills, with $11\frac{1}{2}$ feet of water on the sills in the entrance locks. The estimated width of the straight parts of all the reaches was to be not less than 26 feet. This enlargement fully doubled in capacity both the prism and locks of the original design. In 1880 another enlargement more than trebled the size of 1843, the width being 100 feet at the bottom. The tonnage of vessels that could pass through the canal at that time was fully six times greater than that which could pass through the original canal in 1841. There were at that time (1880) 27 locks, each 270 feet by 45 feet. But these dimensions proved entirely inadequate to the size of vessels, and another enlargement took place, the locks of which are 270 feet by 45 feet with 14 of water on the miter sills. These are the dimensions of to-day. The length of the canal is now $26\frac{3}{4}$ miles. There are three guard gates and 25 lift-locks. The total rise, or lockage, is $326\frac{3}{4}$ feet. It may be interesting to know that there has been expended on this canal up to the present time, or to 1889, $23,787,950.30 according to the official reports.

TRENT RIVER NAVIGATION.

This canal, or series of canals, and open navigation of rivers and lakes, is mentioned simply for the reason that at times in the past it has been suggested as a possible route for a large ship canal. This navigation is a series of disconnected water stretches, extending from Trenton at the mouth of the Trent River at the Bay of Quinté, Lake Ontario, to Lake Huron, but this route has never been used for anything except local traffic, as it has a depth of but 5 or 6 feet. The entire length of the route is about 201 miles. The beginning of the work dates back to 1837. The total lockage of the Trent Valley route is 1044 feet. The impracticability of transferring this circuitous route over an undulating country into a ship canal of adequate dimensions to carry the traffic of the Great Lakes to the seaboard is apparent without any argument.

THE ST. LAWRENCE IMPROVEMENTS.

These improvements have consisted partly in dredging and removing obstructions from the natural channel, but mostly in the construction of canals to flank the very troublesome and dangerous rapids which exist at places between Kingston and Montreal. The canals are the Lachine near Montreal, Beauharnois, Cornwall, Farran's Point, Rapide Plat and Galops, their combined length being 43¼ miles—Lachine 8½, Beauharnois 11¼, Cornwall 11½, Farran's Point ¾, Rapide Plat 4, and Galops 7⅝ miles. In 1841, when the system of canals between Montreal and Lake Ontario was designed, it was intended to obtain a depth of 9 feet, but on account of fluctuations in the river itself the depth in the canal could not always be maintained. At times it fell in some of the canals to 6 ft. 7 inches.

In 1871 it was decided to enlarge the canals on the St. Lawrence, to afford a navigable depth of 12 feet throughout, and then again shortly afterwards it was decided that the ultimate depth should be sufficient to accommodate vessels of 14 feet draught. Work has been carried on since that time with this object in view, the locks are to be 270 feet long between the gates, 45 feet wide, and with a clear depth of 14 feet on the sills. This work has not been entirely completed, but for the purposes of this paper and the estimates which will follow for a still larger water-way, the work is assumed to be entirely performed. In round numbers it may be stated that the entire amount expended on the St. Lawrence system from Lake Erie to Montreal is about 41¼ million dollars, and it may be estimated that it will require to obtain a depth everywhere in the river and in the canals of 14 feet 12¾ millions more, or about $54,000,000 in all, not including the cost of the construction of the canal at the Sault Ste. Marie and other necessary improvements. Therefore, to obtain, between Lake Superior and Montreal, a full depth of 14 feet, it will cost, all told, about $60,000,000.

ERIE AND OSWEGO CANALS.

While it is not probable, and perhaps not possible, that the Erie Canal can ever be made to perform a greater part, or as great a part, in the development of the country than it has already performed, yet on account of its past usefulness it is necessary to briefly sketch its history.

It extends from Buffalo on Lake Erie to Albany on the Hudson River, a distance of 350.5 miles, with 71 locks 7 feet deep, 110 feet long and 18 feet wide. The total lockage is 657 feet. This was in 1865, and the total cost of the canal up to that time had been $38,-977,830.

The Oswego branch of the Erie Canal leaving Lake Ontario at

Oswego is 38 miles in length, and it descends 155 feet from the Erie Canal to Lake Ontario with 18 locks 110 feet long by 18 feet wide. The total cost in 1865 had been $3,077,429. Improvements and enlargements have been made from time to time.

The entire expenditure on the Erie Canal up to 1886 had been $133,000,000.

LAKE CHAMPLAIN AND HUDSON RIVER.

The present route of this canal is from Sorel on the St. Lawrence River, 46 miles below Montreal, up the Richelieu River through the St. Ours Lake to the Basin of Chambly, thence up the Chambly Canal to St. Johns and the River Richelieu to Lake Champlain, the distance in Canada being 81 miles, thence up Lake Champlain. At Whitehall, the southern end of Lake Champlain, the Champlain Canal is entered, and connection is obtained with the Hudson River. The total distance to Albany, 7 miles of which is by the Erie Canal, is 265 miles. The total lockage from the St. Lawrence River to the summit level of the Champlain Canal is 136¼ feet upwards, and the total lockage down to Albany 150 feet. The total distance to New York by this route is 411 miles. The canal is generally of very moderate proportions, being about 36 feet wide at the bottom with 7 feet of water on the sills.

RAILROADS.

One of the most important factors in transportation during the last half century has been the railroad. Its growth, especially in the United States, has been almost marvelous. Its effect upon the cost of transportation has been to continually reduce it, principally by competition with waterways and among the various lines of railroads. The methods have become so nearly perfect, and the cost of transporting goods so greatly reduced, that the ordinary barge canal, which before the advent of the railroad played so important a part in the development of the country, will not in any sense compete with it. Over one half of the entire mileage of canals of half a century ago has been abandoned, many of the old canal beds have been used for railroad tracks,—those that do exist are for special purposes, and most of them survive by the generosity of the States, which have removed all tolls from them and have maintained them at the public expense. It is not intended by this statement to depreciate the immense value which these former means of transportation have been to the country, but to state that a better method has come, and that the only possible means of competing with this better method is to make one better still.

Since 1840 the growth of the railroad system tributary to and bordering upon the Great Lakes has been as follows: In 1840 there were in this tributary country in the United States 89 miles of railroad; in 1850, 1276 miles; in 1860, 10,238 miles; in 1870, 19,703 miles; in 1880, 37,456 miles; in 1889, 63,688. In 1889 these railroads moved 208,179,478 tons of freight. In Canada there were in 1889, in its two principal railroad systems, 8087 miles, making a total more or less tributary or adjacent to the Great Lakes and the St. Lawrence River of 70,775 miles. These railroads have in connection with the transportation facilities of the lakes built up great centres of population and trade. These cities lie directly upon what may be made a continuous and adequate water-way to the seaboard. The immense commercial business which is transacted annually at one of these great commercial ports may be appreciated by an examination of the following statement of the traffic at the city of Chicago in 1889:—

Length of main lines of railroad terminating at Chicago....................................	54,411 miles.
Number of freight cars received and forwarded.	4,248,769
Tons of freight received and forwarded..........	43,013,444

While the railroads with their important facilities carried a larger part of the products westward, the record of 1889 shows that there were transported on the lake two-thirds of all the cereals that went eastward.

HARBOURS.

The United States Government has not only deepened the channels between the lakes, and vastly improved them for a large traffic and for the increasing size of vessels, but it has inaugurated a system of harbour improvement of equal capacity. Its present policy is to improve the harbours of the principal ports, so that there will be a depth of 20 feet, the depth of the entrance channels to be the same. In harbours of minor importance the depth of the entrance to depend upon the improvements of the harbour and the facility with which it may be improved. The average depth at present in the harbours of the large and important ports is 16 feet.

COMMERCE.

1st. Increase in the size of vessels.

In 1859, 36 of the largest propellers on the Great Lakes averaged about 700 tons net register. The largest was 981 tons and the smallest of this number 583. The draft when fully loaded was about 11 feet, greatest draft 11½ ft. Without tracing the growth of intermediate steps, it may be stated that in 1890, what is called the business fleet of the Great Lakes consisted of 2055 vessels of 826,360 net register tons. Its value is $58,125,500. Of these 1153 are steam vessels, 232 of these steamers are over 1000 tons register, 110 are over 1500 tons, and half of the larger class range from 1600 to over 2100 tons net register, and carry a cargo of from 2850 net tons to over 3700. The draft of these vessels is at present limited by the depths of the channels and harbours, being a maximum of about 16½ feet, but many of them could safely and profitably load to 19 or 20 feet.

The Inland Lloyd Register of 1886 shows a total valuation of Lake vessels of $30,597,450 against $58,128,500 in 1890. The type of vessels also has greatly changed. In 1886 there were only 21 steamers of over 1500 net register tons. In 1890 there were 110 such steamers. In 1886 there were six steel vessels on the lakes valued at $694,000. In 1890 there are 68 valued at $11,964,500. The Census of 1890 shows that there was carried on the Great Lakes in 1889 27,417,598 net tons of cargo. The increase of commerce upon the Great Lakes may be appreciated from the increase in and out of Lake Superior. In 1870 the entire amount passing through the St. Mary's Falls Canal was 690,826 net registered tons; in 1880, 1,734,800 tons; in 1883, 2,042,259; in 1887, 4,897,598; in 1889, 7,221,935; in 1890, 8,454,-435; and the actual weight of cargo carried in 1890 was 9,041,213 net tons. The value of this tonnage has increased as follows: in 1881 it was $28,965,612.94; in 1885, $53,413,472.13; in 1889, $82,732,527.-15; in 1890, $102,214,948.70.

An excellent summary and comparison of lake commerce made by London *Engineering* of date September 26th, 1890, is here given for the purpose of showing forcibly and reliably the vast importance of the commerce of the great lakes:—

"A recent article in Bradstreet's gives some surprising statistics of the commerce of the Great Lakes. During 234 days of navigation last year, tonnage passed through the Detroit River to the amount of 10,000,000 tons more than the entries and clearances of all the seaports in the United States, and 3,000,000 tons more than the combined foreign and coastwise shipping of Liverpool and London. This does not include traffic between Lakes Superior and Michigan or Lakes Erie and Ontario, or local traffic between ports on these lakes. Nearly three times as many boats yearly pass through the St. Mary's Falls Canal at Sault Ste. Marie as through the Suez Canal, with an aggregate tonnage of 7,221,935 in 1889, against 6,783,187 for the Suez Canal, though with only 234 days of navigation, whereas the Suez Canal is open all the year round. The figures for the lake shipbuilding are equally striking. Last year the tonnage constructed by lake builders was almost exactly equal to that of the Atlantic, Gulf and Pacific shipyards combined. The lake vessels numbered only 225 out of a total of 994 for the country (exclusive of western river boats), but this fact shows that on the average the lake builders launched a better class of vessels. On the lakes were built only four less steamers than on the Atlantic and Gulf coasts, and their tonnage was more than twice as great. Of the whole steam tonnage of the United States, about a third is on the lakes, and of steamers between 1000 and 2,500 tons they have more than half the total. Naturally the sailing tonnage is not great, but it is half as large again as that of the Pacific slope. Last year there were twenty-one sailing vessels of more than 1000 tons on the lakes and 156 between 500 and 1000 tons. The growth of ship-building on the lakes has been very marked in the last few years. In 1886 87 there were thirty-one boats built valued at $4,074,000; in 1889-90 there were fifty-six built, valued at $7,866,000. The tendency, as elsewhere, has been toward iron and steel for large ships. Ten were built of steel in Cleveland in 1888-89, aggregating 22,989 gross tons. One of steel and one of iron were built in Detroit and two of iron in Buffalo."

The immensity of the long distance lake traffic will be appreciated from the following statement:—

The traffic through the Detroit River in 1888 was about 19,000,000 net register tons, the number of vessels 31,404, exclusive of traffic between foreign parts; in 1889 it was about 22,000,000 tons; in 1890 over 23,000,000 tons. The tonnage in and out of Duluth increased in the four years previous to 1889 from 1,372,233 tons to 2,452,113 tons. At Buffalo the tonnage of lake vessels was about 6,006,000 in 1888, and nearly 7,000,000 in 1889.

The total lake arrivals and clearances at the port of Chicago in 1889 was 10,268,031 tons, in 1870 it was 6,033,207 tons, an increase of 72 per cent. in 20 years.

While this unprecedented increase of commerce upon the Great Lakes has been going on during the last few years, and is evidently destined to increase to still greater proportions, and while the railroads of the country are transporting much of this freight from what are practically the Eastern termini of the lake commerce at Buffalo, Cleveland and Erie to New York, Philadelphia and Boston, the water-ways out of the eastern end of Lake Erie and beyond to the sea have had no appreciable increase; in fact, there has been a decrease during the last 15 years. The Erie Canal is carrying no more than it did many years ago, and through the Welland and St. Lawrence River Canals there has been practically no increase. In 1883 the total tonnage on the Welland Canal was 880,957, in 1887, 787,307; on the St. Lawrence Canals in 1883, 1,847,865 tons, and in 1887 1,715,295 tons.

There is no question that one of the principal reasons for the commerce through the canals east of Lake Erie remaining practically stationary, or decreasing, is the fact that they are not adequate for the business.

The Welland Canal has 14 feet depth of water. According to the United States Bureau of Navigation Report of 1889, there were 330 United States vessels in the Great Lakes above Niagara Falls which drew too much water when loaded to go through this canal, of which 86 were sailing vessels with a registered tonnage of 74,500, and 244 steam vessels with a tonnage of 369,692, or a total tonnage of 444,192, that could not pass through the Welland Canal. Those that passed through in the season of 1889, most of which were United States vessels, were obliged to reduce their cargoes from a total tonnage of 71,502 to 63,283 tons in order to pass through.

Improved methods of transportation by rail and increase in the size of lake vessels, the rapid increase in the cargoes and tonnage of the vessels, the rapid growth of steam transportation, and the rival competition which exists between the various lines and between the railroads have compelled a continual reduction in the cost of transportation to the public. From careful records kept by the United States Government Engineer in charge of the St. Mary's Falls Canal, it was ascertained that the cost per ton per mile of carrying freight an average distance of about 800 miles was, in 1887, 2.3 mills and in 1889 1.5 mills. Rates on other lake lines favourably compare with this. It is estimated by Mr. Charles H. Keep, secretary of the Lake Carriers Association, in a paper addressed to the United States Congress, December 5th, 1890, that the value of the entire cargoes carried on the lakes this last season was $305,432,041.72. He estimated that the average distance of carriage of the entire commerce of the Great Lakes is 566 miles, which would make the total ton mileage for 1889 15,518,360,-468. The entire mile tons of railroad carriage in the United States in the year ending June 30th, 1889, was 68,727,223,146; in other words, the freight service on the Great Lakes is 22.6 per cent. of the total freight service rendered by all of the railroads of the United States. At the average railroad rate of all the freight moved in 1889, according to the statistician of the Inter-State Commerce Commission, 9.22 mills per ton per mile, the cargoes carried on the lakes in that year would have cost the shippers \$143,079,283.51. Adopting $1\frac{1}{2}$ mills per ton per mile as the average cost of lake transportation the entire cost for the season of 1890 was \$23,177,540.70. The saving to the public therefore by water transportation on the lakes in that single year was \$119,801,742.81. Much of the heavy freight has been carried for considerably less than $1\frac{1}{2}$ mills per ton per mile. Anthracite coal is carried from Buffalo to Duluth and Superior, a distance of 1000 miles, for 30 cents per ton, or $\frac{3}{10}$ mill per ton mile.

The total tonnage of freight moved in the Central Northern and Northwestern groups of States, according to Poor's Manual, was, in 1888, 195,773,526. The increase of foreign trade at the Atlantic ports was, between 1870-89, from 9,155,659 to 15,952,119 tons.

A detailed history of the reduction in rates between the Northwest and the Atlantic seaboard by river, canal and rail would be of great interest in this discussion. We cannot, however, give more than some of its salient points.

During 1852 (the first year of free competition between canals and railroads) the New York Central Railway hauled flour from Buffalo to Albany for 60 cents per barrel, which is nearly 50 cents below the average price transported by canal for nearly 20 years subsequent to the opening of the canal. The above is equivalent to about \$6.00 per ton, or a little over 2 cents per ton mile. On the railways of the State of New York in 1855 the average receipts per ton mile for freight were 2.79 cents. About this time a report signed by the superintendents of the four Trunk Lines claimed that the lowest rates at which ordinary freight could be carried and pay interest and expenses was an average of 2 cents per ton mile for heavy agricultural products, 3 cents for groceries, and 4 cents for dry goods. In 1858 the Lake Shore & Michigan Southern Railway forwarded from Chicago to New York 43,304 tons of freight at an average rate of 2.38 cents per ton mile.

The average charge per ton of wheat from Chicago to New York during 1868 to 1872 was as follows: All-water route 5.54 mills per ton mile. The average of the four years, 1868 to 1872, lake and rail route, 6.66 mills; all rail 12.79 mills. The rate per ton mile by the present shortest rail route is about 5 mills. During 1878 the wheat rate by water from Chicago to New York was something under $3.30 per ton, or 2.3 mills per ton mile.

During the season of 1879 grain was shipped from Chicago to Liverpool for 17 cents per bushel, a rate but little greater than was paid for transportation by canal from Buffalo to New York, only ten years before, that is, in 1869. In 1890 grain was shipped from Chicago to Liverpool for $9\frac{3}{4}$ cents per bushel.

The average lake rates from Chicago to Buffalo on wheat have been as follows:—

1861	11	cents	per	bushel,
1865	9.7	"	"	"
1870	6.2	"	"	"
1875	3.5	"	"	"
1878	3.1	"	"	"
1889–90	2.5	"	"	"

Large steamers with barges in tow can transport grain at 2 cents a bushel between Chicago and Buffalo with a profit.

The growth in population of some of the lake cities will give an idea of the growth of the commerce of the country tributary to the Great Lakes.

Population of Buffalo in 1850 was	42,261
" " " 1890	255,000
Cleveland in 1860	17,034
" 1890	262,000
Chicago in 1850	29,963
" 1890	1,100,000

The above general commercial statement has been compiled from a large amount of detailed information, which has been placed in the author's hands by the kindness of the officials of the United States and Canadian Governments, and by the officers of Transportation Lines and Secretaries of Boards of Trade of the lake cities, and obtained from other reliable sources. This one subject of the growth of the commerce of the Great Lakes, the reduction in freights, and the actual cost of the same, and a description of the methods of transportation both by rail and water, would of itself form a most interesting and important paper.

It is necessary now with these general facts in mind to take up the physical features of the present and projected routes, and ascertain if it is practicable to develop, within a reasonable cost, a commercial route between the Great Lakes and the Atlantic seaboard.

PHYSICAL FEATURES.

The brief historical summary of the constructed or partially constructed water-ways, with almost constant improvements and enlargements, by both the United States and Canadian Governments, to keep pace with the rapidly increasing commerce of the Great Lakes and the increase in dimensions of vessels, and particularly in their draught, leads us, in our discussion, to attempt to predict for the near future, either by lake, river, canal or by other adequate means, an enlarged commercial highway between the Great Lakes and the seaboard. Any one who traces the very interesting history of the improvement of the water-ways up to this time, and studies only casually the history of commerce on the Great Lakes, will be led quickly and inevitably to a conclusion that the opinion outlined in the beginning of this paper is correct, that a channel large enough for vessels of a draught of 20 feet, the cargoes of which will average not less than 3000 tons weight, is absolutely necessary. The various projects, with their estimates following, are based on these requirements.

The "Soo" Canal and lock, now being built by the United States Government, is fully equal to these requirements. The canal being built by the Canadian Government is not equal to them. To construct a lock costing, with its approaches, several millions of dollars for a draught of only 18 feet is, in the opinion of the author, unwise for reasons, some of which have already been given and for others which will appear as this discussion goes forward.

OTTAWA SHIP CANAL BETWEEN GEORGIAN BAY AND MONTREAL.

In 1858 a report was made on this project by Mr. Walter Shanley civil engineer to the Legislative Assembly of Canada.

The route lay from Lake Huron up the French River to Lake Nippissingue, thence across the watershed of the St. Lawrence and Ottawa into Trout Lake at the head of the River Matawan, a tributary of the Ottawa River, thence down the Matawan to the Ottawa River, and along its course to its mouth, thence by the Lachine canal to Montreal. The supply for the summit level was to be taken from Lake Nippissingue, which was to be raised by dams to the height of Trout Lake, 23 feet higher than its natural level, enlarging the area of the lake from 12 to upwards of 300 square miles. At the rapids along this route dams were to be built and locks placed to overcome the difference of level. The French River, and the tributaries of the Ottawa, and the Ottawa River, also, were to be made navigable by these dams and locks. The summit would require a canal 5 miles in length with a maximum cut of 30 feet through granite rock. The summit level was to be 83 feet above Lake Huron. The lockage from the summit level down to Montreal was 615 feet, a total of 698 feet. The total distance from Georgian Bay to Montreal is 430 miles.

An examination of the manuscript copy of this report, which was kindly furnished the author by the Minister of Public Works, shows that, while Mr. Shanley was not able to obtain all of the detailed physical data which he desired, yet his general conclusions can be relied upon as reasonable. The size of the locks of Mr. Shanley's project was as follows: length 250 feet, width 50 feet, and depth on miter sills 10 feet. His estimate for the entire work was $24,000,000. While his plan contemplated throughout dams across the streams, wherever necessary to overcome rapids, his general principle was to build canals rather than to resort to high and expensive dams across the rivers.

In 1860 a second report on this project was made by Mr. T. C. Clarke to the Commissioner of Public Works. Mr. Clarke's estimate was about one-half that of Mr. Shanley, being $12,057,680. His plan, however, was much different from Mr. Shanley's, resorting still more to making as long reaches of slack water navigation as was possible, thus avoiding to a great extent the excavation through very hard and refractory rock which would be required by Mr. Shanley's project. On the other hand, Mr. Shanly preferred to cut canals at the sides of rapids rather than to raise the levels of large rivers like the Ottawa by artificial structures. There was also a large difference in the price of rock excavation, Mr. Clarke estimating it generally at an average of about $2.00 and Mr. Shanley at $4.00 per cubic yard. Mr. Shanley also estimated the cost for enlarging the Lachine Canal, 8½ miles in length near Montreal, which Mr. Clarke did not; but on the other hand Mr. Clarke estimated for a canal with 12 feet on the miter sills. Mr. Shanley estimated that the difference in cost between a 10 foot and a 12 foot canal must not be less than $5,000,000, making his estimate for a 12 foot canal $29,000,000. It is difficult to explain the difference in the estimates. It is unnecessary to go into the details of the plans and estimates of these two projects, except so far as it is necessary to use the very complete details given in Mr. Clarke's report for making an estimate for such an enlarged water-way as this paper contemplates.

For the purposes of comparison, it should be stated that Mr. Clarke's plan contemplated locks 250 feet long, 45 feet wide, and 12 feet depth on the miter sills, with a depth of 13 feet in the canals, widths in bottom of short sections 100 feet, and in long sections 146 feet, where it was intended for boats to pass, with a depth of 15 feet in the slack water reaches. A plan for the enlarged water-way proposed by the author is as follows: Locks 600 feet long, 85 feet wide, and 20 feet deep on the miter sills. The depth of canal prism 22 feet, with a width of 150 feet in short sections and 200 feet in the long sections, and with 24 feet depth in the rivers and in slack water reaches. The general methods of Mr. Shanley and Mr. Clarke to be adopted alternatively according to the conditions existing at special points. Employing the data given in Mr. Clarke's report, which appears to be accurate and quite complete, but using prices for rock excavation about midway between his and those of Mr. Shanley, and allowing for the many new obstacles which the enlarged water-way would meet in the deepening of rivers and of locks where submarine rock excavation would be required, in either of the earlier plans, the total cost of the work would be about $83,000,000, allowing for the enlargement of the Lachine Canal to the dimensions of the enlarged water-way. A careful examination leads to the inevitable conclusion, that a free unrestricted water-way cannot be found on the line of the Ottawa route at any cost which the traffic would bear. A ship railway, as an alternative, has been suggested. The course of the river is too tortuous and the cost of removing natural obstructions too great to give this alternative project serious consideration.

GEORGIAN BAY AND TORONTO SHIP CANAL, OR ITS ALTERNATIVE, THE HURONTARIO SHIP RAILWAY.

A project for a ship canal was initiated on this route as early as 1846, and an examination made by Mr. Kivas Tully, civil engineer, of Toronto. In 1851 and in 1855 further examinations were made under the auspices of the Board of Trade of Toronto, to be used at a convention of delegates from various Western cities. The Hurontario route at that convention was favourably considered, and Mr. Tully was appointed to complete the survey. There was associated with him as consulting engineer Colonel R. B. Mason of Chicago, who, himself, examined the route in 1855. The survey was completed in 1858 and published with maps and profiles. The estimate was

$22,170,150. The length of the route, which was by way of Lake Simcoe, was 100 miles, with 50 locks 265 feet in length, 55 feet in width, 12 feet lift, with 12 feet on the miter sills. Almost insuperable difficulties in the way of excavation were found at the summit, where for 10 miles there was a continuous cutting, the greatest depth of which was 197 feet and the average cutting 90 feet. A company was, however, incorporated in 1856 for carrying out the project. Its charter was amended in 1865 under the name of the Huron and Ontario Ship Canal Company.

In 1881, when the late Mr. James B. Eads was engaged in the project of a ship railway across the American Isthmus in Mexico, he was requested by Mr. Tully, the Hon. D. Blain of Toronto, and others associated with them, to give an opinion as to the feasibility of building a ship railway between Georgian Bay and Lake Ontario. His opinion was that it was not only entirely practicable, but that the route furnished one of the most favourable locations for such a construction, as the alignment was good and the grades low. This opinion was given in 1885 after three or four years of consideration at various times by Mr. Eads.

The length of the route is 66 miles. There were to be three railway tracks of the standard gauge, 4 feet 8½ inches, with rails 110 pounds per lineal yard. It was intended to transport vessels of 1000 tons register, or say 2000 tons displacement weight and 14 feet draught. The estimated cost was $12,000,000.

The author was at that time associated with Mr. Eads and familiar with the data and the discussions of the subject. In order to present it now in connection with other projects for an enlarged water-way, he has considered it important to re-examine the subject, and to have a personal examination of the country made by one of his associates, in order to supplement data already in existence, and to reform the estimates on the basis of a ship railway of larger capacity than was contemplated by Mr. Eads; that is, for vessels of a displacement weight of 5000 tons, with a draught of 20 feet, and the railway to be capable of transporting, during the navigation season, 8,000,000 tons of traffic.

It is impracticable, except at great cost, to build the railway on a straight line between the two terminal points. There will necessarily be in the central part of the route two, and perhaps three, deflection tables for changing the direction. The grades, as ascertained from all available data, will be 33 feet per mile as a maximum, although on the larger part of the route the grades will be 11 feet and 14 feet per mile. The summit to be surmounted is 670 feet above the mean level of Lake Ontario.

The streets, public roads and railroads to be crossed can all be easily provided for. The material to be moved is entirely earth, no rock being found on the route. The harbour improvements at the termini will not be expensive. The cost of the railway fully equipped for the kind and extent of the traffic contemplated is $15, 459,318.09.

At the proper time the author will make a comparison between this route and the Ottawa route, as to distance, constructive features and other navigation features. In reference to the physical features of the two routes the advantages are altogether in favour of the ship railway. The material to be removed on the Ottawa route is almost entirely rock and of granitic quality, being syenite and gneiss, these rocks, according to Mr. Shanley's report, "thrusting themselves forward harsh, naked and repellant over the whole of the more distant portions of the line"...." On the nearer sections from the Chats Rapids to St. Ann, the formation to be dealt with, though of less impracticable character than that named above, is still rock—rock everywhere." The rock on the western part of the line is Laurentian, the very hardest that can be found. Insurmountable obstacles exist, such as the flooding of the country around Lake Nippissingue. At the time Mr. Shanley and Mr. Clarke made their reports this was an almost uninhabited country. Since then along the northern part of the lake, which would be the shore to be submerged, there is now the main line of the Canadian Pacific Railroad, and there are several towns and settlements and an improved country over nearly the entire area. It is questionable whether the plan proposed in 1860 could be carried out in 1890. Again, the fluctuation of 12 feet in the level of the Ottawa River (being 24 feet at the city of Ottawa) is a serious objection to canalizing this route. Again, the examinations show that to obtain a depth such as is proposed by the present enlarged water-way submarine excavations in hard rock must be made at various points in rivers and lakes not necessary for the depths proposed in 1860.

Another disadvantage of the Ottawa route is the difference between it and the Hurontario route in the opening and closing of the navigation seasons, a different latitude making the navigation season nearly a month shorter than by the Toronto route.

Another important difference is the difference in time of construction. The Hurontario Ship Railway could be built within three years, and no doubt, if the Government of Canada would make the necessary appropriations, the St. Lawrence canals between Lake Ontario and Montreal could be enlarged within five years, while it would probably require 10 years time to build an enlarged water-way along the Ottawa route, and it is not improbable that 15 years would be required for this work.

As propositions for ship railways at other points will be brought forward in this paper, the author reserves the general discussion of the question of feasibility of ship railways and of their physical and commercial advantages for a subsequent point in the discussion.

WELLAND CANAL.

The present size of this canal has been given in a previous part of this paper. It is now proposed to enlarge it according to the standard dimensions of an enlarged water-way already given in connection with the plans of the Ottawa navigation. It has cost to enlarge the Welland Canal, from about 10 to 14 feet, $16,000,000. The estimate for deepening it to 20 feet and greatly enlarging the locks is $25,000,-000, which is a low estimate considering the previous cost of enlarging this work.

NIAGARA FALLS SHIP CANAL.

The United States Government has taken more or less interest in this project since 1867, Congress having at that time by joint resolution instructed the Secretary of War to have an examination made. This work was performed by Col. C. E Blunt of the United States Corps of Engineers. His project was for a canal of 14 feet depth with lock chambers of 275 by 46 feet. He examined six routes, some of which present great difficulty in the ascent of what is called the Niagara Terrace. In 1888 Congress appropriated funds for an examination for a water-way around Niagara Falls, its capacity to be sufficient to float ships drawing 20 feet of water. The surveys of Col. Blunt were used for the purpose of ascertaining the feasibility and cost of building such a canal as Congress proposed. The dimensions considered were: width of canal at bottom 100 feet, depth 20½ feet, length of lock chamber 400 feet, width 80 feet, depth over miter sill 21 feet and the lift in general to be 18 feet. The route is 25 miles long, number of locks 18, estimated cost $23,617,900. A revision of this estimate on the basis of larger locks and larger canal prism, and of an increase in price of rock excavation, which the author considers advisable, makes the total cost $35,000,000.

NIAGARA FALLS SHIP RAILWAY.

The estimate is made on the Twelve Mile Creek route of Col. Blunt's surveys, beginning east of Cayuga Island, Niagara River, and ending at the mouth of Twelve Mile Creek. The length of the line is $18\frac{1}{2}$ miles. The maximum grade surmounting the Niagara Terrace is 50 feet per mile, a continuous grade of $4\frac{3}{4}$ miles. The total estimate on the same basis as the Hurontario Ship Railway, namely, for vessels of 5000 tons displacement weight, 20 feet draught, and an annual traffic of 8,000,000 tons, is $10,731,613.71, fully equipped.

MICHIGAN PENINSULA SHIP CANAL AND RAILWAY.

It is proposed to build a ship canal of the standard dimensions above given across the Michigan Peninsula, from Benton Harbour on Lake Michigan to near Monroe on Lake Erie, a distance of about 160 miles. It would require 65 locks and the crossing of 19 railroads. The estimate is $138,405,432.

A ship railway across this peninsula fully equipped will cost not over $39,000,000, and the grades will not be heavy. The height to be surmounted at the summit is 475 feet.

LAKE CHAMPLAIN ROUTE BY WAY OF THE CAUGHNAWAGA RIVER.

The estimates made at various times for a canal with locks 270 feet by 45 feet by 12 feet, from the St. Lawrence River about 8 miles above Montreal to Albany on the Hudson River, is about $20,000,000. To build this on the plan of the enlarged water-way now designed, and to deepen the Hudson from Albany to Hudson City, and to deepen Lake Champlain over long reaches, where there is now sufficient depth of water for a 12 foot navigation, but not for 20 feet, would cost at least $50,000,000, and for the purposes of an unrestricted adequate water-way for deep draught vessels from the Great Lakes to the seaboard, is apparently impracticable.

ERIE CANAL AND OSWEGO CANAL ENLARGEMENTS.

To build such a water-way as is now proposed between Buffalo and Albany would cost probably $250,000,000, and we would then have nothing but a continuous canal where the speed of vessels would be restricted. The Oswego Canal enlargement can be dismissed also with the opinion, that to enlarge it for deep draught vessels is impracticable. It has been suggested to build a ship railway instead on one or the other of these two routes. The author considers this impracticable, not only on account of its expense, but on account of the natural and artificial obstacles that at points would prevent its construction. The Mohawk Valley is entirely occupied by two railroads (six railroad tracks), the Erie Canal, the Mohawk River and an almost continuous line of cities and towns for long distances, these natural and artificial conditions being hemmed in on either side by steep and rugged bluffs of hard rock.

ST. LAWRENCE RIVER ENLARGEMENTS.

There remains the consideration, briefly, of the enlargement of the St. Lawrence River and its canals, to give an outlet to the seaboard for either the Hurontario Ship Railway or the ship canals or ship railways at Niagara Falls and across the Michigan Peninsula. The very voluminous records of the Canadian Government extending over many years, the reports of the Chief Engineer of Canals, numerous other descriptive and statistical documents, and the examinations, maps, charts and profiles kindly furnished by the Department of Public Works of Canada, have enabled the author to make an estimate for the enlargement of the canals and the deepening of the channels in the river itself between Montreal and Kingston. This estimate is based on the standard dimensions for an enlarged waterway used in making estimates of other routes. The total cost, asfuming that the present canals have already been deepened to 14 feet (this work is now being done by the Canadian Government), is $27,000,000.

COMPARISON OF COMMERCIAL CONDITION.

A statement of the commercial conditions of the proposed routes is necessary in order to make a comparison between them. These conditions have an important bearing on the general question of location and advantages, and are, therefore, stated in full in the body of this paper. "The sailing distances" are steamer distances, and are compiled from many records, a selection being made from the most reliable. The time per hour forming a basis of the total time on each route is open to amendment, being in some respects a matter of opinion, but formed from much study of the subject and from definite records of speed under practical and similar conditions.

The cost of transit is made up from the actual average cost on lines now operated on rail, lake, ocean, barge and ship canals. As to the speed, time and cost on a ship railway, while there is no actual transportation of this kind in existence, yet, the results of ten years of careful study of the subject on the two principal ship railway projects of the world—the Tehuantepec and Chignecto—are used in this statement. Though made from different conditions and by persons working independently, the results closely agree and may be considered the concensus of the best thought on the subject. The figures, however, await the actual test of practice soon to be applied at the Chignecto Isthmus.

TABLE OF SAILING DISTANCES, SPEED, TIME AND COST.

Table of Sailing Distances.

	Statute Miles.
New York to Liverpool	3440
Boston to "	3211
Philadelphia to "	3625
Baltimore to "	3891
Quebec to "	3065
Quebec to Straits of Belle Isle	826
Straits of Belle Isle to Liverpool	2239
Montreal to Quebec	160
Montreal to Liverpool	3225

ALL RAIL DISTANCES.

The all-rail distance from Chicago to New York is 913 miles via the Pennsylvania Lines, 932 miles via Nickle Plate & Lackawanna Railways, and 949 miles via Nickle Plate and West Shore Railway. The all-rail distance from Chicago to Montreal is 837 miles via Grand Trunk Railway and 859 miles via Wabash and Canadian Pacific Railways.

SAILING DISTANCES FROM CHICAGO TO MONTREAL.

1st. *Via Hurontario Ship Railway and the St. Lawrence River.*

Chicago to Northern terminus of Ship Ry			570 miles
Ship Ry. (2 lifts and three deflection and turning tables).			66 "
Toronto to Montreal	Canal and 26 locks.	43.63 miles	
	Lake Ontario	161.37 "	
	St. Lawrence River	160.00 "	365 "
Chicago to Montreal			1001 miles.

2nd. *Via Ottawa Navigation.*

Chicago to mouth of French River			548.00 miles.
Ottawa River & Canal	Canal	29.32 miles	
	Lakes and river ½ each	401.44 "	430.76 "
	64 Locks		
Chicago to Montreal			978.76 miles.

3rd. *Via Lakes, Welland Canal and St. Lawrence River.*

Chicago to St. Clair River			568.00 miles.
St. Clair River			41.00 "
Lake St. Clair			16.00 "
Detroit River			27.00 "
Lake Erie			218.25 "
Welland Canal (27 Locks)			26.75 "
Lake Ontario			161.00 "
St. Lawrence River	Canals	43.63	
	River	161.37	205.00 "
Chicago to Montreal			1263.00 miles.

4th. *Via Michigan Peninsula Ship Railway, Lakes, Welland Canal.*

Lake Michigan			61.00 miles.
Michigan Peninsula Ship Ry			158.50 "
Lake Erie (to Pt. Colburn)			230.00 "
Welland Canal			26.75 "
Lake Ontario (to Kingston)			161.00 "
St. Lawrence River	Canals	43.63 miles.	
	River (proper)	161.37 "	205.00 "
Chicago to Montreal			842.25 miles.

5th. *Via Michigan Peninsula Ship Ry., Lakes, Niagara Falls Ship Railway and St Lawrence River.*

Lake Michigan			61.00 miles.
Michigan Peninsula Ship Ry			158.50 "
Lake Erie (to terminus of Niagara Ship Ry.)			252.00 "
Niagara Falls Ship Railway			18.50 "
Lake Ontario			146.00 "
St. Lawrence River	Canals	43.63 miles.	
	River (proper)	161.37 "	205.00 "
			841.00 miles.

6th. *Via Michigan Peninsula Ship Ry., Lakes, Niagara Falls Ship Canal and St. Lawrence River.*

Lake Michigan		61.00	miles
Michigan Peninsula Ship Railway		158.50	"
Lake Erie (to terminus of Niagara Ship Canal)		252.00	"
Niagara Falls Ship Canal		25.00	"
Lake Ontario		139.50	"
St. Lawrence River { Canals	43.63 miles.		
River (proper)	161.37 "	205.00	"
Chicago to Montreal		841.00	miles.

DISTANCE BY DIFFERENT ROUTES.

1st. Hurontario Ship Railway	1001.00	miles
2nd. Ottawa Navigation	978.76	"
3rd. Lakes, Welland Canal & St. Lawrence River	1263.00	"
4th. Michigan Peninsula Ship Ry. & Welland Canal	842.25	"
5th. Michigan Peninsula Ship Ry., Niagara Falls Ship Ry., etc	841.00	"
6th. Michigan Peninsula Ship Ry., Niagara Falls Ship Canal	841.00	"

RATES OF SPEED (STEAMERS).

Rate of speed on the Ocean and Lakes, 15 miles per hour.
" " Ship railways and Rivers, 10 miles per hour.
" from Montreal to Quebec, 10 miles per hour.
" on the Canals, 7 miles per hour.
" " Welland and Niagara falls Canals, 4 miles per hour.

Lockage and Ship Railway lifts and deflection tables, 30 minutes each.

SCHEDULE OF DISTANCES AND SAILING (STEAMING) TIME FROM CHICAGO TO MONTREAL.

1st. *Lakes, Hurontario Ship Railway and St. Lawrence River.*

						hours.
By Lakes (570 and 160) =	730 miles	at 15	miles	per hour =		48.67
By River	161.37	" 10	"	"		16.14
By Ship Railway	66.00	" 10	"	"		6.60
By Canals	43.63	" 7	"	"		6.23
By detentions on Ship Ry						2.50
" in locks (26 at 30 minutes)						13.00
Sailing time Chicago to Montreal						93.14

2nd. *Ottawa Navigation.*

By Lake	548.00	miles at 15	miles per hour......	36.53	hours.
By small lakes	200.72	" 15	"	13.38	"
By Rivers	200.72	" 10	"	20.07	"
By Canals	29.32	" 7	"	4.19	"
By detentions in 64 locks			....	32.00	"
Sailing time Chicago to Montreal			....	106.17	hours.

3rd. *Lakes, Welland Canal and St. Lawrence River.*

				hours.
By Lake—Chicago to St. Clair River	568 mi. at	15 mi.	per hr.	37.87
By St. Clair River and Canal	41.00 "	10	"	4.10
By Lake St. Clair	16.00 "	15	"	1.07
By Detroit River	27.00 "	10	"	2.70
By Lake Erie	218.25 "	15	"	14.55
By Welland Canal	26.75 "	4	"	6.69
By Lake Ontario	161.00 "	15	"	10.73
St. Lawrence River	161.37 "	10	"	16.14
" " Canals	43.63 "	7	"	6.25
By detention in Welland Canal—27 locks—at ½ hour each......				13.50
" " in St. Lawrence Canals—26 locks at ½ each.......				13.00
Sailing time Chicago to Montreal....................................				126.58

4th. *Via Michigan Ship Railway, Lakes, Welland Canal, etc.*

By Lake Michigan	61 mi. at	15 mi.	per hr.	4.07	hrs.
By Mich. Peninsula Ship Ry.	158½	" 10	"	15.85	"
By Lake Erie (to Pt. Colburn)	230.00	" 15	"	15.33	"
By Welland Canal	26.75	" 4	"	6.69	"
By Lake Ontario	161.00	" 15	"	10.73	"
By St. Lawrence River	161.37	" 10	"	16.14	"
" " Canals	43.63	" 7	"	6.23	"
By detentions on Ship Ry..................				550	hrs.
" " in Welland Canal..............................				13.50	"
" " in St. Lawrence Canals......				13.00	"
Sailing time Chicago to Montreal..............................				107.04	hrs.

5th. *Via Mich. Peninsula Ship Ry., Lakes, Niagara Falls Ship Railway and St. Lawrence River.*

By Lake Michigan	61	mi. at	15	mi.	per	hour	4.07 hours.
By Mich. Pen. Ship. Ry.	158½	"	10	"	"	"	15.85 "
By Lake Erie	252.00	"	15	"	"	"	16.80 "
By Niagara Falls Ship Ry.	18½	"	10	"	"	"	1.85 "
By Lake Ontario	146.00	"	15	"	"	"	9.73 "
By St. Lawrence River	161.37	"	10	"	"	"	16.14 "
By St. Lawrence Canals	43.63	"	7	"	"	"	6.23 "
By detention on Mich. Pen. Ship Ry....................							5.50 "
" Niagara Falls Ship Ry..................							1.50 "
" in St. Lawrence Canals....................							13.00 "
Sailing time Chicago to Montreal							90.67 hours.

6th. *Via Michigan Peninsula Ship Railway, Lakes, Niagara Falls Ship Canal and St. Lawrence River.*

By Lake Michigan	61 miles	at	15	mi.	per	hour	4.07	hrs.
" Mich. Pen. Ship Ry.	158½	"	10	"	"	"	15.85	"
" Lake Erie	252	"	15	"	"	"	16.80	"
" Niagara Falls Ship Canal	25	"	10	"	"	"	2.50	"
" Lake Ontario	139½	"	15	"	"	"	9.30	"
" St. Lawrence River	161.37	"	10	"	"	"	16.14	"
" St. Lawrence Canals	43.63	"	7	"	"	"	6.23	"
By detention on Mich. Peninsula Ship Ry.							5.50	"
" " " Niagara Falls Canal							9.00	"
" " " St. Lawrence Canals							13.00	"
Sailing time Chicago to Montreal							98.39	"

RECAPITULATION.

	hours
1st. Via Lakes, Hurontario Ship Ry. and St. Lawrence River	93.14
2nd. Via Ottawa Navigation	106.17
3rd. Via Lakes, Welland Canal and St. Lawrence River	126.58
4th. Michigan Peninsula Ship Ry. Lakes, Welland and Niagara Falls Canal, etc.	107.04
5th. Michigan Ship Ry. Lakes & Niagara Falls Ship Ry.	90.67
6th. " Ship Ry. Lakes, Niagara Falls Ship Canal, etc.	98.39

It is necessary to give the following notes for the purpose of ascertaining the correct basis of the cost per ton per mile. On this basis the tables which follow have been prepared :—

ACTUAL RAIL RATES, SEASONS OF 1889 AND 1890.

The lowest summer rate from Chicago to New York was 20 cents per 100 pounds on grain, flour, etc., or \$4.00 per ton, $4\frac{4}{10}$ mills per ton per mile via shortest line.

About $\frac{9}{10}$ of the freight East and West comes under classes 4, 5 and 6.

At 25 cents per 100 pounds Chicago to New York (the regular schedule rate), or \$5.00 per ton, the rate per ton per mile is $5\frac{47}{100}$ mills. The mean of these two rates is almost exactly one half cent. per ton per mile.

The summer rate from Buffalo to New York is 11 cents per 100 pounds, or \$2.20 per ton $=5\frac{38}{100}$ mills per ton per mile.

The regular rate on grain from Buffalo to New York is 13 cents per 100 pounds, or \$2.60 per ton $=6\frac{36}{100}$ mills per ton per mile.

CHICAGO TO BOSTON.

The summer rate on grain is 25 cents per 100 pounds, or \$5.00 per ton $=$ 5 mills per ton per mile. The winter and all year rate is 30 cents per 100 pounds $=$ \$6.00 per ton, or 6 mills per ton per mile.

The average rates from Chicago to Montreal are the same as from Chicago to New York, which would make a higher rate per ton per mile than is given above from Chicago to New York.

Taking rates per ton per mile from Chicago to New York and applying on roads from Chicago to Montreal will give the following:—

Chicago to Montreal, summer rate....................	\$3.68 per ton.
Regular rate.........	\$4.58 " "

Taking same rates from Chicago to Montreal as rule to New York, we have:—

Chicago to Montreal, summer rate, about $4\frac{3}{4}$ mills per ton per mile ($4\frac{78}{100}$ mills), and regular rate equals almost 6 mills per ton per mile.

It is safe to assume that the rates from Chicago to Montreal on export freight will never be much, if any, lower than those to New York.

Inasmuch as the ocean voyage from Montreal to Liverpool is only 190 miles shorter than from New York, the difference in rates could not be more than 10 cents per ton.

From the above it is safe to assume $\frac{1}{2}$ cent per ton per mile for the railroad rate over all lines. Assuming this as the rail rate, and the following rates over different portions of the water route and over ship railways, we have the table given below. In order to fairly compare routes, the rate per ton per mile covers cost of operation of ship railways and canals and six per cent. interest on cost of construction.

TABLE.

RATE OVER HURONTARIO SHIP RY.—$3\frac{4}{10}$ MILLS PER TON MILE.

Rate over Niagara Falls Ship Ry	7 mills per ton mile.
" on Lakes..................................	$1\frac{1}{2}$ " " " "
" " Ocean..................................	$\frac{1}{2}$ " " " "
" " Michigan Peninsula Ship Ry.....	$3\frac{1}{2}$ " " " "
" " " " " Canal...	8 " " " "
" " Ottawa Route........................	5 " " " "
" " St. Lawrence Canals................	7 " " " "
" " Niagara Falls Ship Canal.........	12.5 " " " "
" " Welland Canal........................	10 " " " "

One of the conditions importantly affecting the various routes to the seaboard under consideration is the time lost during the year by the rigor of a Northern climate. The effect which this suspension of navigation, of from 126 to 150 days out of the 365, will have upon the transportation question it is difficult to estimate.

A careful examination has been made of the length of time each year that different harbours will be closed by ice. The table prepared by Mr. L. E. Cooley, late chief engineer of the Chicago Drainage District, appears to be the most reliable, although authorities differ, and it is used to determine the length of time that each of the routes will probably be open for business.

LOCALITY.	No. years Observation.	No. days closed average.	Date closing.	Date opening.	Remarks.
Erie Canal	20	153	Dec. 3	May 5	Official closing
Welland Canal	20	136	" 9	Apr. 24	Actual closing
Buffalo, N. Y.	10	126		" 16	Say 126 days
Detroit River	7	121	" 2	" 2	
Straits of Mackinaw	20	140		" 20	" 140 days
St. Mary's Canal	10	147	" 3	" 29	Actual closing
Duluth	9	132	" 26	May 7	
Montreal	10	131	" 15	Apr. 24	
Hudson River	19	107	" 12	Mch. 29	Albany, N. Y.
Ill. & Mich. Canal	41	126	Nov. 26	Apr. 1	Official closing
Illinois River	11 & 34	70	Dec. 25	Mch. 4	Morris, Ill.
Mississippi River	25	$30\frac{1}{2}$	" 23	Jan. 23	St. Louis, Mo.

Using the above mentioned table, and 30 days for one month, we find the various routes will be opened for business, as follows:—

DESCRIPTION OF ROUTE.

No. of Routes.	Days open.
1. Hurontario Route..................................	225 days.
2. Ottawa Navigation..................................	205 "
3. Lakes, Welland Canal & St. Lawrence River......	225 "
4. Peninsular Routes, Lakes, Welland Canal, etc...	229 "
5. Peninsular Route, Lakes, Niagara Falls Ship Ry. and St. Lawrence River..	234 "
6. Peninsular Route, Lakes, Niagara Falls Ship Canal and St. Lawrence River.....................	229 "

The following table gives the results of all of the preceding tables, relating to length of route, time of transit, cost per ton, and length of time that each route will be open.

CHICAGO TO LIVERPOOL.

Description of route.

No. of Routes:	Length miles	Time in hrs.	Cost per ton	No. of days route is open.
1. Hurontario Ship Ry., Lakes and St. Lawrence River	4226	313.47	$3.48	225
2. Lakes and Ottawa Navigation	4203.76	326.50	4.59	205
3. Lakes, Welland Canal and St. Lawrence River	4488	346.91	3.97	225
4. Mich. Peninsula Ship Ry., Lakes, Welland Canal, etc.	4067.25	327.37	3.66	229
5. Mich. Pen. Ship Ry., Lakes, Niag. Falls Ship. Ry. & St. Lawrence	4066	311.00	3.53	234
6. Mich. Pen. Ship Ry., Niag. Falls Ship Canal and St. Lawrence	4066	318.72	3.70	229
7. All rail to Montreal	4062	328.33	6.25	234
8. All rail to New York	4353	337.33	6.74	365

NOTE.—Should the Canadian Government enlarge the St. Lawrence Canals at its own expense, deepen the river where required, and remove the tolls to commerce from Lake Ontario to Montreal, as it has done seaward of Montreal, there can be deducted from total cost of transportation from the Great Lakes to Liverpool by this route 20 to 22 cents per ton. The Hurontario route to Liverpool will then compare with the all-rail route via New York as $3.26 per ton is to $6.74, that is, less than one-half the cost by rail, or a saving to commerce in one year on 8,000,000 tons of traffic, of more than the entire estimated cost of preparing the enlarged water-way from the foot of Lake Ontario to the sea.

The competition in English and other importing markets of Europe between the wheat of our Northwest, the Pacific Coast, India, Russia and the Argentine is so close, that a substantial advantage in cost of transportation like the above to both Canadian and United States cereal producers will at once work a revolution in trade, and lead to an important development of agricultural products and to a material prosperity over the 450,000 square miles, comprising the basin of the Great Lakes, and extending to the lands outside and remote from it, but capable of reaching, by rail or water routes, its seaports, as the great cities of the lake will then be.

SHIP RAILWAY DISCUSSION.

The author has, without any hesitation, placed on an equality, as transportation methods, the ship railway and the ship canal. The former he considers superior in many respects.

1st. The cost of construction at each special location is more than 50 per cent. less than the cost of a ship canal to handle the same class of vessels and an equal amount of traffic.

2nd. The cost of operation and maintenance will be less.

3rd. The rate of speed will be greater, and there will be much less detention *en route*.

These features have been brought out fully in the plans of the Tehuantepec and Chignecto Ship Railways, and in the discussions which for ten years have been before the world, comparing the methods by railroad and barge canal and by ship railway and ship canal. The most extended, minute and careful examinations and investigations have been made. The results in the case of the Tehuantepec Ship Railway were:—

1st. The Mexican Government became so well assured of the practicability of the method, that it agreed to guarantee the interest on the cost of the railway up to $1,200,000 per annum.

2nd. The leading and most experienced naval architects of this country and England gave their full approval to the method and the plan.

3rd. Many vessel owners and navigators of England and this country expressed an entire willingness to entrust their vessels to the ship railway.

As to the Chignecto Ship Railway, the Dominion Government wisely adopted the plan of the ship railway instead of the ship canal, and guaranteed the interest on the cost of the work. English capital is constructing it, and the leading engineers of Great Britain, if not of the world, have charge of its construction.

The United States Government, after an exhaustive examination in this country and Europe, by a Board composed of three Government engineers of high rank and ability, adopted a ship, or a boat, railway to avoid the rapids of the Columbia River in Oregon.

The well-considered detailed plans of the Tehuantepec Ship Railway, worked out carefully by the late Mr. James B. Eads, and which contemplated a railway for the transit of vessels of a displacement weight of 5000 tons, have formed the basis of the plans for the Hurontario, Michigan Peninsula and Niagara Falls Ship Railways proposed in this paper, and the cost of transportation, carefully ascertained by Mr. Eads and his associates, has been applied to these railways, taking into due account the difference in conditions.

The author had the good fortune last summer to examine personally the route, the constructions and the detailed plans of the substructure, superstructure and the mechanical appliances of the lifting docks, and the equipment as well, including the motive power of the Chignecto Ship Railway. There is no doubt in his mind of entire success in the construction, operation and economy of this railway.

There is nothing novel in the methods, only in the combination of methods. Vessels are at present raised out of the water continually, whether loaded or unloaded, on hydraulic lifts, by marine railways and by floating docks.

The views and the advanced thought of ship builders on the Lakes may be seen from the following extract from a letter of date December 19th, 1890, by Mr. W. I. Babcock, manager of the Chicago Ship Building Company, which is now engaged in building large steel vessels at Chicago, on Lake Michigan, and to whose Company the author had written to ascertain if it was prepared to build vessels of 5000 tons displacement weight, when laden, with a draft of 20 feet, to navigate the route between Chicago and Liverpool, 66 miles of which would be over a ship railway between Georgian Bay and Toronto. Mr. Babcock, on behalf of his Company, replies as follows:—

"The question of the size of vessels that can be built here seems to be the only one on which Mr. Corthell desires information, and I would, therefore, say, that at this yard we can build anything from 400 feet over all, 50 feet beam, and any depth, provided that a channel such as he specifies can be used to salt water. There would be, of course, no reason why we could not build vessels for any service there if we get money enough for them. As for transporting such vessels on a ship railway between Georgian Bay and Toronto, I believe such a carriage is entirely feasible, and that no special arrangement would be required on the vessel herself at all. It would, therefore, be entirely immaterial to us as ship builders what was done with the vessel after she left the yard."

The increasing size of rolling stock, both motive power and freight cars, on ordinary railroads, has proven the great advantage in carrying greater and greater loads at one time. A few years ago 10 ton cars were the rule in this country. Now, 30 tons are becoming more and more numerous. Cars for still larger loads for special purposes are becoming more and more common, and the locomotives have increased in weight and power from 30 and 40 tons to 90 and 100 tons, and the cost of transportation has been reduced from $2\frac{1}{2}$ cents to $\frac{1}{2}$ cent per ton mile.

A ship railway is the logical result of the continual improvements in railroad methods from the time of the first railroad to the present. If it is possible to raise vessels and transport them over land with safety and economy, why should they be compelled to make great detours costing time and money?

If the immense business between the St. Lawrence and the coast of New Brunswick and New England can save 500 to 700 miles by operating a railway 17 miles long across the Chignecto Isthmus, why should it continue to take this long and dangerous voyage around Nova Scotia? If engineering skill can provide lifts and a railway and motive power that can haul vessels weighing 2000 to 2,500 tons, as already arranged for at Chignecto, who will say that it cannot design, construct and successfully operate a railway that will handle vessels weighing 5000 tons? Necessity knows no law, and this applies to commerce as well as to other things; and the demands of this commerce and of a great people, seeking the markets of the world by the least expensive route, will be satisfied with nothing less than the most approved and economical methods which it is in the power of man to provide.

The question now arises, how can the desired and best route be provided? Will the mutual interests of two great countries between which the St. Lawrence River is a dividing line, in part, and through one of which, having passed an artificial and arbitrary line, it finds its way to the sea, bearing the commerce with it, be willing to unite to construct the ship canals and ship railways necessary to remove the obstructions to navigation? Will the Great Northwest, both of the United States and Canada, with its millions of people, its rapidly growing cities, centers already of finance and commerce, with the constantly increasing business of the Great Lakes—a common heritage of both nations and free to both, and God-given—will these two nations, with so much in common, permit longer arbitrary national boundary lines to remain a barrier—a Chinese wall—to the commerce of both? Shall cities like Chicago, Milwaukee, Duluth, Buffalo, Cleveland and Toronto be longer compelled to send their exports to Europe and receive their imports by expensive channels, when they can load them for Liverpool or Havre at their own wharves, and receive their imports directly at those wharves from the ports of the Old World?

If these two Governments, so closely united in commercial relations, cannot, on account of grave political reasons, unite in the construction of the desired route, then why should not Canada herself undertake the task and assume the burden of its cost? The reasonable plan appears to be for that Government to enlarge the St. Lawrence Canals and the intermediate river reaches, where necessary, for the navigation recommended by the author, and to encourage the construction of the Hurontario Ship Railway by guaranteeing the interest on its cost, as it has already done on that of the Chignecto Ship Railway. That Government must now provide these new and enlarged channels of commerce, or see the vast amounts already expended practically lost through its inability, or its unwillingness, to meet the demands of commerce. It will inevitably see the greatest commerce of the world diverted from its natural channel, and taken out of its domains into the artificial channels of its neighbour's territory, to enrich and develop a country lying along these artificial routes. The commerce and financial importance in every way to Montreal and to other cities, both Canadian and United States, situated on this enlarged natural water-way, can scarcely be over-estimated. To be in the pathway of such a commerce, as will move from the great Northwest to the Old World and back again, will insure to any city situated upon it a prosperity—commercial, industrial and financial—surpassing the most sanguine anticipations.

The argument may be brought forward that, on account of the close competition between the present routes by way of the several ports along the Atlantic seaboard to Liverpool, there is such slight difference in rates, that no advantage would accrue from an enlarged water-way commensurate with the great expenditures required to obtain it. Granted that the case may even be similar to that of the Mississippi River, upon which the United States Government is spending already vast amounts in removing the obstructions from its mouth nearly to its source, but which does not have upon it the amount of business anticipated—the railroads being able on shorter lines to move the freight to the seaboard—nevertheless it stands there as a great regulator and minimizer of freights. When for any reason the slightest increase in rates occurs over the rail routes, the freight is given to the barges and boats, and the products then reach New York and other Atlantic ports via the mouth of the Mississippi, and the rates again come down to a water rate.

If an enlarged water-way shall compel the slightest reduction in through rates to the Atlantic seaboard and Europe, the producers will reap the advantage, whether the new route obtains the larger part of the business or not. If this route can carry freights to Liverpool cheaper than the present rates, and shall do so to any extent whatever, then all the other routes must come down in rates to meet it.

There is, however, no question about this enlarged channel from Chicago, Duluth and Port Arthur to Liverpool obtaining a large part of the European business. The enlarged facilities proposed will vastly increase the volume of the carrying trade between the Northwest and the Old World. The advantage to the country bordering on the Great Lakes and the St. Lawrence can scarcely be over-estimated. The increase in commerce everywhere, and the material prosperity sure to quickly follow the opening of such a route outlined in this paper, is beyond conception.

It is estimated by statisticians that the Mississippi River gives a direct advantage to the producers of the Mississippi Valley, amounting to from 50,000,000 to 100,000,000 dollars per annum. The St. Lawrence route will give a direct advantage not only to agricultural producers but to manufacturers, importers and merchants, and through them to all the people. "DIRECT TRADE WITH EUROPE" should be the demand of the Northwest and of all the country tributary to it. The direct pecuniary advantage to the people should not be estimated at less than $200,000,000 per annum.

As civil engineers we should promote in all possible ways the development of these commercial routes, and lend our good offices to the patriotic effort to improve the commercial conditions of what is after all a common country.

The author is greatly indebted to the officials of the Dominion and United States Government, and to other persons, for the information necessary to compile and to write this paper. He is particularly indebted to Sir Hector Langevin, Minister of Public Works of the Dominion of Canada; and Mr. Baillairgé, Deputy Minister; Mr. H. F. Perley, chief engineer Public Works Department; Mr. John Kennedy, chief engineer of the Montreal Harbour Commission; Mr. G. P. Brophy and Mr. Thomas C. Keefer of Ottawa, Mr. Walter Shanley of Montreal, M. P., Superintendent U. S. Census; United States Commissioner of Navigation; Chief of the Bureau of Statistics U. S.; Colonel O. M. Poe, U. S. engineer; Capt. W. L. Marshall, U. S. engineer; Hon. D. Blain, Mr. Kivas Tully and Mr. Joseph Blakeley of Toronto, also to Mr. Chas. H. Keep, secretary Lake Carriers' Association; secretaries of the Boards of Trade of Buffalo, Cleveland, Chicago and Duluth; Mr. L. E. Cooley, president Western Society of Engineers; and to the author's associate, Mr. A. F. Robinson, civil engineer.

From the drawing accompanying this Paper Plate II has been prepared.

DISCUSSION ON MR. CORTHELL'S PAPER ON "ENLARGED WATERWAY," ETC.

TORONTO BRANCH DISCUSSION.

Mr. Blain.

Mr. David Blain said he fully endorsed Mr. Corthell's views, and considered the Ottawa River and Trout Lake route as now impracticable, and that the Georgian Bay and Lake Ontario route offers greater advantages.

Prof. Galbraith

Professor Galbraith said the fact of there being at present no ship railway in operation, and hence that no practical knowledge exists of its working, must not be lost sight of. The speaker would introduce Captain Crangle, who would give his views.

Capt. Crangle.

Captain Crangle said he was a practical sailor, having had 35 years experience. That there is being now introduced a new type of vessel called the "Whaleback," the object being large tonnage capacity at minimum amount of material used in building; and he was of opinion that a vessel of this kind would suffer serious injury by being carried on a ship railway. He would not like to say a steamship railway is not feasible, but it is as yet unproven. He considered the Chignecto *Ship Railway may be feasible for small coasting craft, but he had grave doubts whether a vessel 250 ft. in length could be transported by a ship railway without occasioning damage to the vessel, the weight of the vessel and cargo being 3,000 tons. He considered that the vessel should be in a cradle on a pivot, so as to keep it always level; that one of the greatest objections he sees to a ship railway is that it is similar to dry docking a loaded vessel, and in his experience he could always see places where unequal straining had occurred by such a process.

Mr. Redway.

Mr. Redway observed that the question of carrying a loaded vessel by railway had been discussed in England 10 years ago, when Captain Eads presented his projected Isthmus of Tehuantepec Ship Railway, and it was then generally admitted to be feasible. That at the Edinburgh Exhibition, held a short time ago, there was a model shown of the method of transporting a loaded vessel in water over a ship railway, and that the Commission appointed to report considered that a ship and cargo weighing 5,000 tons could be safely carried any distance on a properly constructed ship railway.

Professor Galbraith said it is the carrying out of the principle on a large scale where the difficulty arises, the tank would have to be transported with the same care as the ship. Prof. Galbraith

Mr. Redway replied, it is not a tank. Mr. Redway.

Professor Galbraith observed it is a vessel floating in a tank, whether there is $\frac{1}{16}$ of an inch of water or 16 feet of water. The experiment on a small scale may be successful, but carried out practically the trouble increases in geometric ratio. Prof. Galbraith

Mr. Kivas Tully said he felt obliged for the invitation to be present. He considered that raising loaded vessels out of water and carrying by railway had been pronounced upon as feasible by eminent experts; that personally he had no doubt it could be done; that a ship railway is not subject to a difference of grade; that no curves are less than 20 miles radius; that deflections are done by turn-tables. The platform will be rigid, the cars supported by a large number of wheels, none of which will carry more than five or six tons; that if any one doubted the feasibility of lifting a vessel out of water and carrying by a ship railway, he would refer him to the model in New York, made under the directions of the late Captain Eads. Mr. Tully.

Mr. Alan Macdougall considered it difficult to discuss the engineering question involved in the carriage of loaded vessels up to 5,000 tons gross by ship railway without experience, and that the operation of the Chignecto Ship Railway would be awaited with interest. Mr. Macdougall

CORRESPONDENCE.

Hon. E. Murphy

The Hon. Edward Murphy of Montreal considered the undertaking too great, and that it would involve a serious loss of time to vessels in transit.

Mr. Clarke.

Mr. Thos. C. Clarke endorses Mr. Corthell's views as to the superior advantages of a ship railway over any other means for connecting Lakes Huron and Ontario.

Mr. Budden.

Mr. Henry A. Budden of Montreal considers the operation of the Chignecto Ship Railway necessary to establish the feasibility of the project aimed at by Mr. Corthell. Mr. Budden considers transportation of grain by barges from Port Colborne on Lake Erie to Montreal, and thence by ocean steamer, as the best means of transit.

Mr. Tate.

Mr. R. F. Tate is satisfied that a ship canal as proposed can be constructed and successfully operated, and considers that Mr. Corthell is right in his dimensions for securing ample water-way—both breadth and depth.

Mr. Gisborne.

Mr. F. N. Gisborne considers the economic capacity for grain-carrying vessels must be considered independently of their mode of transit by canal or ship railway, and he considers the route via the Peace and Saskatchewan Rivers, via St. James Bay and St. Johns Lake to Seven Islands Harbour in the Gulf of St. Lawrence, as offering in the future an effective route to England for the North West.

Mr. Ruttan.

Mr. H. N. Ruttan of Winnipeg points out a practicable water route to Liverpool from Fargo and Winnipeg, via Lake Winnipeg, the Nelson or Hayes Rivers and Hudson Bay.

That both the Nelson and Hayes Rivers offer practical routes to the sea from Lake Winnipeg, and that by improving the Nelson River and the construction of ship canals or ship railways, ocean steamers may be brought into Lake Winnipeg, and possibly to the mouth of the Red River, offers an alternative route between Lake Winnipeg and Hudson Bay.

That the Hayes River is open from about the 20th May to the 20th November, and that Hudson Straits are navigable for at least 4½ months in the year. That the distance in miles from Winnipeg via Hudson Bay to Liverpool is 3,262.

Thursday, 26th February.

J. KENNEDY, Vice-President, in the Chair.

The discussion of Mr. E. L. Corthell's paper on an "An Enlarged Water-Way Between the Great Lakes and the Atlantic Seaboard" occupied the evening.

Thursday, 26th March.

J. KENNEDY, Vice-President, in the Chair.

Paper No. 49.

THE CONSTRUCTION OF THE COTEAU BRIDGE.

By G. A. Mountain, M. Can. Soc. C.E.

In the autumn of 1888 the Canada Atlantic Railway Company decided to replace the ferry used for the transportation of cars across the River St. Lawrence, between Coteau Landing and Valleyfield, by a bridge, the ferry being found inadequate for the Company's constantly increasing business.

After numerous careful surveys extending over a period of three seasons, the site finally selected for the bridge was at the head of the Coteau Rapids, 37 miles west of the city of Montreal. This site, while it possessed many advantages of importance to the Company on the score of economy, on account of the islands situated on the line of the proposed bridge, also possessed many difficulties from an engineering point of view, principally the depth and velocity of the water.

The width of the river, which at the bridge site is narrower than at any other point in the vicinity, is divided by two islands into three distinct channels. The north or steamboat channel from the north shore to Giroux Island is 885 feet in width. The centre channel from Giroux Island to Round Island is 2210 feet in width, and the south channel from Round Island to the south shore is 930 feet in width. The length across Giroux Island is 905 feet, and across Round Island 1220 feet, making a total length of 6150 feet from north to south shore, with 4025 feet of bridging.

The banks of the river on either side of the bridge site and the intervening islands are low, and sloping toward the water, and it was on this account that a low level bridge, with a swing over a portion of the north or steamboat channel, was decided upon.

The elevation of the rail level of the bridge, which is a through truss from end to end, is 25 feet above the ordinary summer water level. The alignment of the bridge is a tangent from shore to shore, and is divided into spans, as follows: The north or steamboat channel is composed of two fixed spans of 175 feet each centre to centre, one of 139 feet centre to centre, and one swing span of 355 feet centre to centre of toe-seats, giving an opening on either side of the pivot pier of 160 feet in the clear. The centre channel is composed of ten fixed spans of 217 feet each centre to centre, and the south channel of four fixed spans of 223 feet each centre to centre. The islands are at present crossed by trestle work, which it is the intention of the Company to fill and form a solid embankment.

In the north or steamboat channel adjoining the Coteau shore, the velocity of the current is seven miles per hour, and on account of navigation the course of steamboats and rafts passing down had to be kept clear, and the dredges, barges, and plant used in the construction were in constant danger of being run into and sunk. The velocity of the current in the centre channel is between five and six miles per hour, and the shoal water 1000 feet above the bridge line rendered the navigation of the tugs and barges very difficult. In the south channel the velocity of the current being six miles per hour, and the bed of the river above the bridge line bare rock, great difficulty was experienced in the anchorage.

The maximum depth of the water in the north channel, in which were placed four piers, including the pivot pier and two abutments, is 30 feet, the minimum being 24 feet, and the borings showed a covering of from 4 to 6 feet of cemented gravel and boulders above the bed rock.

The maximum depth of the water in the centre channel, in which were placed nine piers and two abutments, was 26 feet, the minimum depth being 20 feet, and the borings here showing a covering of from 3 to 8 feet of cemented gravel and boulders above the bed rock.

The maximum depth of the water in the south channel, in which were placed three piers and two abutments, was 24 feet, the minimum depth being 20 feet, with a covering of from 3 to 6 feet over bed rock of a similar material to that found in the other channels.

No trouble whatever was experienced from the variation of water level, the rise and fall not exceeding 2′ 6″.

It might be in place here to mention the manner in which the triangulations were performed to obtain the widths of the different channels, and in which the positions for the piers were arrived at.

The instruments used were an eight inch transit, a 300 foot steel tape, and pickets.

Owing to the marshy ground on the north shore on either side of the bridge site it was no easy matter to obtain a base line, and advantage was taken of the winter when these marshes were a solid level field of ice; on them a base line was measured at right angles to the line of bridge, and from this base the width of the north or steamboat channel was calculated. The hypothenuse of this right angle triangle was then used as a calculated base line to establish a point on Maple Island, situated mid-way in the centre channel, and about 1200 feet below the line of bridge. By connecting this point with a point on line of bridge on the south shore of Giroux Island, gave a calculated base from which the width of the centre channel was obtained; these operations were carried on in a similar manner from the south shore, and the point on Maple Island was again established from this side, giving the adjoining side of the centre triangle. Taking this side as a calculated base, the distance across the centre channel was again obtained, checking with the distance calculated from the north side to within .06 of a foot. The point thus established on Maple Island was used in laying off the angles for the position of each of the nine piers in the centre channel. A point was similarly established on Swan Island, situated in the south channel about 1000 feet below the line of bridge, and from which the angles were laid off for the position of the three piers in the south channel. A point was also established on McIntyre's Island, situated in the north channel about 1200 feet above the bridge line, and from which angles were laid off for the position of the four piers in the north channel. The angles were taken by two engineers, and by the method known as repeating the angles and the mean of this repetition taken, any little variation found in the three angles of a triangle from 180° was divided proportionately among the three angles. Two months were spent in this manner during the winter, until the engineers were fully satisfied that the widths of the channels and the position of the piers were accurately obtained. A plan was then made on a scale of 50 feet to the inch, and with all distances and angles marked on it, little trouble was necessary to fix the position of a pier at a few moments' notice.

The specifications for the substructure required a bottomless caisson 20′ in width and 67′ in length over all, and pointed at both ends, the bow being a right angle and the stern somewhat more acute; this was done for the purpose of steadying the caisson in the rapid current, and also to prevent the formation of an eddy. The walls of these caissons were built of 12″ x 12″ pine timber, and were stiffened by means of 30 uprights fastened to the wall on the inner side, and tied across by 45 cross ties placed about 4 foot centres, all of the same material and dimensions, they being heavily spiked and bolted together.

The caisson used for the pivot pier was designed in the shape of an octagon 36′ in width with sides of 15′ in length, and was built of similar material and dimensions as used in the caissons for the other piers.

The specifications for the masonry in the bridge abutments and piers required to be first class in every respect, and of the best and largest stone that the quarries afforded. They required to be sound and durable, free from all drys, shakes, or flaws of any kind whatever, and must be of such a character as to withstand the action of the weather. No course less than 15″ in thickness was allowed. The beds of all stone for face work, and the backing, where required to receive headers, were dressed parallel throughout, so as to form quarter inch joints, and the vertical joints of the face stone were dressed back square for 9″, so as to form quarter inch joints.

Headers were built in every course not more than 6′ apart, and so arranged with the adjoining courses as to leave them equally distributed over the faces of the structure; they have a length in the face of work of not less than 24″ and a depth of at least two and one half times their height.

Stretchers required to be not less than 30″, and their breadth must be at least one and one half times their height. The vertical joints must be so arranged as to overlap those in the course below at least 1 foot.

The copings and bridge seats of all piers and abutments required to be 24″ in thickness, and dressed square throughout to quarter inch joints.

The vertical joints of the cutwater stones were dressed back square to the full depth of the stone. Iron clamps of 10″ in length were used in clamping the cutwaters. Dowells of an inch and one half round iron were let through one course and one half of masonry. Over the cutwaters nose pieces of $\frac{3}{4}$ inch steel were placed 12′ in length and running back 2′ on either side, bolted by means of fox wedges to the masonry.

All masonry was laid in fresh ground Portland cement, thoroughly mixed with good, clean, sharp, coarse river sand, in the proportion of one part of cement to two parts of sand. The cutwaters and bridge seats were laid with mortar in the proportion of one part of cement to one part of sand. The cement was tested from time to time by a Fairbanks cement testing machine, and after setting from 10 to 20 days stood a breaking strain of from 275 to 410 pounds to the square inch.

The dimensions of the piers which are shown in the accompanying sketch are 48′ x 11′ 6″ at the base and 24′ x 8′ at the bridge seat, the pivot pier differing from the others in being a cylindrical column of 27′ in diameter, with a footing course of 29′ 6″.

Towards the end of the autumn of 1888 the contract for the substructure was awarded to Messrs. Neelon, McMahon & Shea, of St. Catharines, and during the following winter quarries were opened, stone was cut, barges built, dredges overhauled, and all necessary plant put in readiness for the undertaking.

On the 1st of April, 1889, ground was broken in excavating the foundation for the abutment on the north shore, and this was carried on while waiting the breaking up of the ice on the lake above. The ice having passed down on the 21st and 22nd of April, a dipper dredge was brought down to the bridge site on the morning of the 24th, and ranged up into position to prepare the foundation for the pier adjoining the north shore, dredging down stream. This operation occupied 15 days, and the dredge was then moved over to the position of the next or pivot pier. It was while working at the foundation of this pier that an accident befell the dredge. A raft, composed of nine drams, passing down in the early morning, struck the dredge, smashing a hole in the stern of about 15″ in diameter, and notwithstanding that every effort was made to save her she sank, half an hour later, in 28′ of water. The bow being pinned up on her spuds held her partly above water at that point, greatly facilitating the operation of raising her, which was successfully done in a very short period. A similar dredge was placed in position on the pier adjoining the south shore, and worked towards the centre. It was not permitted to make the excavations for the caissons more than a week ahead of placing them, in order to avoid any danger of the excavation filling up.

To do this dredging successfully in from 20′ to 30′ of water, and a current of from 5 to 7 miles per hour, required very careful management and extraordinary precaution. Frequently during the progress of this work oak spuds of 18″ × 20″ were snapped off.

The next operation was the placing of the caissons. These when completed were placed between two barges, on each of which was erected a frame to a height of 20′ above the deck; across these frames two 24″ square pieces of oak were placed, and from these 4 tackles of large quadruple blocks reeved with 6″ manilla rope, guided by lead blocks, to winches on board the barges, were used to lift the caissons.

The first caisson was lowered with hydraulic jacks from cobhouse cribs on the deck of the barges; but this method was found to be extremely slow, and was abandoned for the block and tackle system above described.

The caissons were provided with 3 anchors, varying in weight from $1\frac{1}{2}$ to 3 tons, and the barges with 1 each, all hove with $1\frac{1}{2}$ inch steel wire cables.

When the excavation was ready the caisson and barges were towed out into the current from where they were built, about 1 mile above the bridge site, by from two to five tugs, and were allowed to drift down to their position, the tugs steaming slowly up stream; 800 feet above the line of bridge the main anchor was let go, the others following in quick succession. On the anchors taking hold the tugs were let go, and by paying out the cables the caisson was allowed to drift down to within 25 feet of its position; it was here heavily weighted with railway iron, and lowered to within a few feet of the bottom. The caisson was then eased back until it was brought to the exact position previously fixed by triangulation; all that was then necessary to sink it was to ease away on the tackles simultaneously until it reached its bearings on the bed rock.

Should it not set in true position the first time some of the weight was removed, and the strain taken upon the tackles when it could be raised without difficulty; but it only occurred once or twice that a caisson had to be lifted after once having been placed upon the bottom. When it was finally settled in position it was additionally weighted with railway iron, and the footing course of masonry was also placed upon the wall of the caisson. In taking the caissons down it was sometimes found necessary, owing to shoal water, to raise them to a 6 foot draft, and for this purpose the block and tackle system was found exceedingly successful.

In placing the caisson adjoining the pivot pier on the south side, considerable difficulty was experienced, owing to the great depth of water, 30′, and the velocity of the current, which at this point is the swiftest in the vicinity of the bridge, and being in close proximity to the steamboat channel, the swell made by the steamboats passing down was severely felt. After two unsuccessful attempts to place the caisson it finally capsized, damaging one of the barges used in transporting it, and throwing its load of railway iron into the excavation. The top of the caisson was so badly damaged as to necessitate cutting it down, and using it for a pier of less depth of water, and building a new one to replace it. A dredge was again brought down to redredge the excavation, which was partly filled up by the load capsized from the caisson. The next attempt to place it was successful, and no further trouble was experienced at this point. This caisson was considered, next to the octagonal caisson for the pivot pier, the most difficult one of the bridge to set.

The pivot caisson on account of its construction presented a tremendous resistance to the current, 5 tugs and a large sidewheel steamer being unable to hold it in the swift water. 8 anchors, each hove with a $1\frac{1}{2}$ inch steel wire cable, were let go 1000 feet above the bridge line, and the cables slacked away and the caisson dropped back into position. Two of the $1\frac{1}{2}$ inch steel wire cables to anchors were led to blocks made fast near the bottom of the caisson, and taken to timber heads on deck, in order to hold the caisson in an upright position, and prevent its being carried out of plumb by the stiff current.

It was at this pier that the only fatal accident during the construction of the work was sustained, resulting in the loss of the lives of two men, both by drowning,—one during the construction of the substructure and the other during the erection of the superstructure.

Owing to the current striking the bridge line nearly at right angles, the caissons for the piers in the centres of the channels were subject to little or no side current; but those adjacent to the shores and islands received the full force of the current on one side of the bow, and great precaution had to be taken to prevent them from being swept out of position; this was done by means of anchors placed on the inshore side, and from which the cables were brought to the capstans fixed at both bow and stern of the barges, and in this manner held in position till sunk.

It was not found necessary to scribe the bottoms of the caissons, as they invariably fitted close to the bed rock, which was remarkably level and dredged thoroughly clean.

At the early stages of the undertaking it took three days to place and sink a caisson, but as the work progressed they were placed and sunk in a day.

On the caisson finally being settled and weighted in its position, the barges upon which it was transported were then removed. Divers were then sent down, and a canvas curtain, 6 feet wide, which had been previously nailed on the inside of the caisson 2 feet from the bottom, was unrolled, and upon this were piled bags of concrete to prevent any wash to the concrete afterwards to be deposited. Once commenced, the concreting was carried on continuously day and night until completed. A floating electric light plant furnished the light for the night work. A derrick scow was placed alongside the caisson, and as the concrete was mixed it was deposited in iron boxes with false bottoms holding from one to two cubic yards, and lowered slowly into the caisson, and the bottom tripped, thus preventing the separation of the materials which would ensue from allowing the concrete to fall unprotected through the water.

The composition of the concrete was: one part of English Portland cement, three different brands being used,—White's, Johnson's and Union,—one part of sand, and between three and four parts of broken stone of 2″ cube.

A bed of concrete was thus obtained, varying in depth from 8′ to 12′, and all brought to the uniform height of 12′, below water level, at which point the masonry in all cases was started from.

After allowing the concrete 48 hours for setting, the caisson was pumped out with an 8″ horizontal centrifugal pump driven by a 30 horse power engine, both on a scow alongside and connected with the caisson by a rubber suction hose. The pumping of a caisson usually took from 20 to 40 minutes, and little or no trouble was experienced in keeping them dry, they being thoroughly caulked from top to bottom. When this was accomplished the masonry was commenced and carried on to completion.

The concrete was found in all cases to have so thoroughly set as to make it as difficult to dress it to receive the masonry as an ordinary footing course.

The caissons were riprapped on the outside to the level of the top of the concrete.

The stone used for the piers and abutments is lime stone, and was taken from the quarries at Apple Hill and Caughnawaga, the last stone being laid on December the sixth, thus occupying the space of eight months and six days in the construction of the substructure.

The quantities were 8000 cubic yards of masonry, and 7000 cubic yards of concrete, in which were used 25,000 barrels of Portland cement.

In the winter of 1888, the contract for the construction and erection of the superstructure was awarded to the Dominion Bridge Company of Lachine, and preparations were at once commenced for the undertaking.

Specifications prepared by the railway company for the superstructure required that it be of the rivetted lattice type, and the general design finally adopted had a double system of triangular or inclined web members, inclined batter or end posts extending over one panel and girders of the swing span, and the longer fixed spans of varying depth, only the central upper chord panel of the fixed spans being horizontal, the chords sloping each way from the central panel to a junction with the batter posts, the depth of the girders at ends being made just sufficient to give the required clearance between track and portal bracing.

The use of inclined chords results in small economy of material, reduces wind surface, and gives good depth at centre of span with corresponding small deflections when loaded, and hence small secondary strains at and near the connections of web members on chords.

The depth of water, force of current, and nature of the bottom were such, that the setting of false work and the assembling of the metal work in place in the usual way would have been difficult, and attended with great risk of displacement by the heavy waves often running down from the lake just above the bridge.

The contractors for the superstructure decided to erect the spans in a sheltered bay, about three miles distant from the bridge, and when fully completed to take them on barges, float into place, and lower on to the masonry.

This was done in the following manner: Two scows built for this purpose, 90′ long by 30′ in width, were provided with 2 large trestle bents on each; these scows were lashed together with a space of 70′ between them. By means of valves, water could be admitted into the hulls, so as to sink them about 2′. When these scows were immediately underneath the span, the water was siphoned out, and the scows rising lifted the span off its false works, allowing the two panels on either end of the span to project over them.

They were then towed to the bridge site, placed in position between the piers, and by sinking the scows again the span was lowered to its permanent seat on the piers. The details of the scows and trestles used, and the method of placing the span in position between the piers, are fully shown in the accompanying sketch.

Notwithstanding the velocity of the current, the work was very successfully carried out. The 14 spans for the south and middle channel having been floated and placed on piers in 42 days, from October 12th to November 23rd.

Provision was made for storing a number of spans in the bay, where erected, by building the false work or staging, on which to erect them along the shore of the bay, and at right angles to this staging building out into the water two pile piers, or trestles, spaced the length of the spans apart. On these trestles a number of lines of railway iron were laid, and as the erection of each span was completed it was moved sideways out on to the trestles sliding on the railway iron.

Before the work of floating the spans into place began, seven spans had been assembled and rivetted complete, and moved sideways on the trestles into position, to be taken off in turn by the barges, thus enabling the work of assembling and rivetting to progress without interruption.

Spans have before been floated on barges into position, but it is thought this is the first instance in which a large number of spans have been made ready and stored until it was desired to place them on the masonry, and also the first time false work has been so built that the spans when assembled could be moved off it and loaded on barges, without tearing down any portion of the false work or interrupting the work of erection, the usual course having been to erect the span on staging built over the water, and to take down enough of the trestles to admit of the barges being placed beneath the span.

The erection of the superstructure was commenced on the 1st September, 1889, and the last span was floated into position on the 19th February, 1890. Trains going over the entire structure on the following morning. The entire bridge thus occupying ten months and twenty days in construction.

DISCUSSION ON "COTEAU BRIDGE."

Mr. Hannaford Mr. Hannaford said he had read Mr. Mountain's paper with a great deal of interest, because some twenty years ago the speaker was employed as the engineer in the erection of the International Bridge across the Niagara river at Buffalo, the only bridge to this day that has masonry piers, or piers of any kind, founded in that river. The Coteau Bridge comes twenty years afterwards, and is, so far as the speaker knows, the most rapidly constructed of the kind that has ever been erected. The River St. Lawrence is not a small river. There is only one River St. Lawrence, and it is with us here. When it is considered that the bridge was built inside of one year, it must be admitted that great credit is due the promoters and the engineers of the bridge.

It occurred to the speaker when he read the paper (and it brought him here this evening) to ask Mr. Mountain to be kind enough to supplement not only the quantities which he has given here, but also to give us the prices and the cost of construction, so that our paper in the Transactions may be of value to readers far from this Canada of ours, and show what it takes to build a bridge of this magnitude, including the masonry. The details as to the whole of the contracts that were let, and, in fact, everything connected with the bridge, so that it may be seen that this long bridge was probably the quickest built and the cheapest for its length, spanning as it does one of the largest rivers of the world.

Mr. Mountain. Mr. Mountain in reply said that he had followed the precedent shown him by the other papers, which, with one exception, gave no prices. He considered it a breach of faith with the contractors to do so. He had already given the quantity of masonry and length of superstructure, and he would now say that the total cost of the bridge, as given him by the Secretary-Treasurer of the Road, was $1,264,000. He did not feel at liberty to give any further details as to prices without the permission of both the company and the contractors.

Mr. Peterson. Mr. Peterson said that being the chief engineer of the St. Lawrence

Bridge he could not allow the claim made by Mr. Hannaford, viz., that the Coteau Bridge was the longest, quickest built and cheapest bridge that had been erected across the River St. Lawrence, to pass unchallenged.

What is called the Coteau Bridge is practically three separate bridges connecting islands in the River St. Lawrence, and the entire length of the three bridges is 4,025 feet. The longest bridge is 2,210 feet, whereas the St. Lawrence Bridge is, from abutment to abutment, 3,652 feet long.

As regards the quickness of construction, he stated that he was informed that the Coteau Bridge was commenced at least as early as June, 1888, and possibly earlier, and that the masonry was not finished till 7th December, 1889, so that instead of the construction of the superstructure of this bridge only occupying eight months and six days, it occupied at least from June, 1888, to December, 1889, or about 18 months. The work was let in two contracts. The contractor for the South Channel Bridge in June, 1888, had one caisson built and one well advanced, and during the summer and autumn of 1888 nearly if not quite completed the two abutments for this bridge. The contractor for the work on the North Channel and Centre Channel Bridges began dredging for the foundation of the piers in the summer of 1888. He finished the foundation for at least one pier, and was working at the foundation of another, when his dredge was struck by a raft, and was sunk. He also built the caisson for the pivot pier of the draw span, and commenced the caisson for at least another pier.

The speaker said he had no details as to the quantity of masonry built in piers, which every engineer knows requires yard per yard much more time than that in abutments, but certainly the amount must have been very considerably less than the amount put in the piers of the St. Lawrence Bridge. The quantity of masonry and concrete in the six abutments and 16 piers of the three Coteau bridges is 15,000 cubic yards, whereas the quantity of masonry and concrete in the two abutments and 15 piers of the St. Lawrence Bridge is 12,336 cubic yds.

Work was commenced on the shore abutment of the St. Lawrence Bridge on the 18th March, 1886, and upon the first river pier on the 14th May, 1886. The masonry in the last pier was finished on 12th November, 1886, less than eight months from the commencement of the abutment and less than six months from the commencement of the first river pier, work upon the piers having to be delayed until the spring ice had passed down the river.

In comparing the rapidity of construction of the two bridges, it must be remembered that the St. Lawrence Bridge is a high level bridge, the bottom chords of the channel spans having an elevation of 60 feet above the ordinary level of the River St. Lawrence ; and that the builders of the Coteau Bridge (which, as far as regards the caissons, foundations and masonry, is an exact copy of the St. Lawrence Bridge) had the advantage of seeing how the work was done on the St. Lawrence Bridge, and that what had to be experimented upon and worked out on the St. Lawrence Bridge had simply to be copied on the Coteau Bridge.

To show how closely the work on the substructure of the St. Lawrence Bridge followed the plans of working laid down on the 21st January, 1886, by the chief engineer, and Mr. R. G. Reid, the contractor, for the substructure, for completing this bridge by the first of December of that year, the following schedule is appended, showing the date when it was proposed to commence work on the land abutments, piers 1, 2 and 15, and when it was proposed to have the masonry finished, also when it was proposed to commence work on the remaining piers, and when it was proposed to have the concrete in, ready to commence masonry. Another column has been added to this, showing when the concrete was actually finished in the last 12 piers :–

TABLE SHOWING DATE FIXED TO COMMENCE AND FINISH MASONRY, ETC., PREPARED 26TH JANUARY, 1886.

	DATE FIXED TO COMMENCE.	DATE FIXED TO FINISH.	ACTUALLY FINISHED.
Abutment (Land)	1st March	1st May	2nd April
Pier No. 1 (do)	do	do	15th April
Pier No. 2 (do)	do	do	13th May
Pier No.15,(water 2 ft.)	do	do	17th August

DATE FIXED TO COMMENCE AND FINISH PUTTING CONCRETE IN CAISSONS.

Pier No. 3 (water)	1st May	15th June	13th July
Pier No. 4 (water)	7th May	do	18th May
Pier No. 5 (water)	do	do	29th May
Pier No. 6 (water)	do	do	21st June
Pier No. 14 (water)	do	21st July	8th Sept.
Pier No. 7 (water)	16th June	31st July	29th June
Pier No. 8 (water)	do	do	11th August
Pier No. 9 (water)	do	do	18th August
Pier No. 10 (water)	1st August	15th Sept.	6th Sept.
Pier No. 11 (water)	do	do	15th Sept.
Pier No. 12 (water)	do	15th Oct.	23rd Sept.
Pier No. 13 (water)	22nd August	22nd Oct.	22nd Oct.

It will be noticed that the date fixed on the 21st Jan., 1886, for finishing the concrete in the last pier No. 13 was the 22nd Oct., 1886, and that it was actually finished on that date. It will be hard to find any work of such magnitude and importance and in such a difficult position that was finished exactly to the day which was fixed for its completion, 11 months beforehand.

The contractors for the superstructure were not so fortunate; but had it not been for a slight accident, their work would have been finished during the year in which it was commenced, and trains could have crossed the bridge before the end of December, 1886. The accident referred to was caused by the thin ice coming down the river early in November, and cutting off the piles which supported the south flanking span. This span was partly erected at the time, and was the cause of considerable embarrassment to the contractors. Had they been aware of the fact that thin floating ice in a rapid current would cut off piles of more than a foot in diameter in a single night, steps could easily have been taken to protect them, and the bridge would then have been completed within the year; as it was, the delay caused by the cutting of these piles threw the work so far into the winter that it was impossible to complete it that season at such an elevation and in such an exposed position. The cost of the bridge was $943,387.00; and from grade to grade, as per contract plans $998,412.22, whereas we are told that the Coteau Bridge cost $1,264,000. So it will appear that the claims made for the Coteau Bridge belong to the St. Lawrence Bridge.

Mr. Dodwell said in spite of the difficulties due to the fact that there had been several papers on very similar subjects read before the Society, the author was to be congratulated on having contributed an interesting account of an important work. Mr. Dodwell

Mr. Hannaford had forcibly drawn attention to the great want of the paper, viz., particulars of cost, and it was to be hoped that the author would do himself the justice to supplement his paper, before it was embodied in the Transactions, by giving this information. The statement that the author has volunteered in opening the discussion, that the total cost of the bridge was $1,264,000, is interesting as far as it goes, but it does not go far enough. The author would add at least one hundred per cent. to the value of his paper if he would give the details of quantities and cost that went to make up this total.

It is much to be regretted that in giving the Society the record of their experience in the construction of public works, members are so chary of information regarding cost. It was quite unnecessary to point out that papers deficient in these particulars lose half their value.

As regards the superstructure, the only point that appears unusual or novel is the length of rivetted spans—217 and 223 feet. This is interesting as being either an unexplained variation from American practice, which limits rivetted spans to about 120 feet, or a tendency to revert to English practice, which abjures pin-connections. There are two or three members of the Society connected with the Dominion Bridge Works, and perhaps this hint will be sufficient to draw from one of them a brief monograph on the Coteau superstructure, to form a valuable supplement to the paper now before them.

The method of erection employed was obviously the proper one under the circumstances. Perhaps the author would be good enough to say whether the swing span was erected in the same manner.

Mr. Mountain.

Mr. Mountain replied that the swing span was erected in place in its "open" position.

In reference to Mr. Peterson's remarks on the Coteau Bridge, the author begs leave to make the following reply:—

1st. Mr. Peterson states that abutments 1 and 2 were nearly, if not quite, completed during the summer of 1888. The author replies that the excavation for foundations for abutments 1 and 2 were made during the summer of 1888, for the purpose of ascertaining the nature of the material to be moved throughout the work, and while the excavations were opened, the foundations were filled in, and the masonry carried clear of the water. This was the total amount of work done during 1888 on the bridge, amounting in money to some $4,000; an amount hardly worth mentioning in an undertaking of $1,264,000.

2nd. Mr. Peterson also states that the dredging for the foundation of one pier was completed and another one commenced during the season of 1888. The author begs to state that such was not the case; the contractors' dredge was taken to Coteau in the autumn of 1888, months before the contract was signed, for the purpose of dredging the slip for the Canada Atlantic Transfer Ferry, and was then taken down to the bridge site by the contractors, to satisfy themselves that it could do the work. After dredging for a few days, they found that, owing to the shortness of the dipper-arms, the necessary depth could not be reached. Instructions were accordingly given to have the dredge brought back and the dipper-arms lengthened during the winter, for work the following spring. It was on the 24th April, 1889, that the first dipper full of dredging was done at Coteau Bridge.

3rd. Mr. Peterson further remarks that the quantity of masonry and concrete built in piers, required yard for yard much more time than in abutments. Granted.

He then states the quantities of masonry and concrete in the 6 abutments and 16 piers of the Coteau Bridge amounted to 15,000 c. yds., and the quantities in the 2 abutments and 15 piers of Lachine Bridge to 12,336 c. yds., Mr. Peterson omitting to state that piers 1, 2, 3 and 15 in Lachine Bridge were built on dry land above water line, and piers 4, 5, 6 and 7 in water varying in depth from 5 to 9 feet, with a current not exceeding $3\frac{1}{2}$ miles per hour, and so little dredging required as to be able to clear the rock for foundations with a rake worked by horse power, leaving only 7 piers in a greater depth of water with a swifter current, where a dredge had to be used to clear the foundations. Against this, the 16 piers of the Coteau Bridge were placed in from 20 to 30 feet of water, in a current varying from 5 to 7 miles per hour, and all foundations had to be dredged through hard-pan from 3 to 8 ft.

4th. Mr. Peterson also claims that the foundations, caissons and masonry is an exact copy of the St. Lawrence bridge. In reply to that the author would say that concrete placed in bottomless caissons have been used for foundations for bridges for years past (authority Trautwine), so that Mr. Peterson's statement, that we copied Lachine Bridge, is not well founded. Also the manner of placing the caissons of Coteau Bridge, as described in the paper, is much superior to the method used at Lachine, and the auther ventures to predict that the block and tackle system used at Coteau will be utilized or improved upon in any undertaking of a similar nature, in preference to the older method used at Lachine. We have also added to the Coteau Bridge piers, steel cut-waters which are not on the Lachine Bridge. The manner of placing the superstructure in position is also an improvement on that used at Lachine.

In conclusion, the author would say that he thinks he has clearly shown to the engineering profession that the method used in the construction of the Coteau Bridge is a step in advance of any previous undertaking of a similar nature in this country; and while not wishing to say anything but praise in connection with the manner in which the Lachine Bridge was built, he thinks that Mr. Hannaford's claim that the Coteau Bridge was the quickest built, and, considering its length, the cheapest bridge ever put across the River St. Lawrence, has been sustained.

NOTES ON SUPERSTRUCTURE OF COTEAU BRIDGE.

BY G. H. DUGGAN, M. CAN. SOC. C. E.

The specifications prepared by the Railway Company to govern the design of the superstructure were almost identical with those of the Canadian Pacific Railway and Dominion Government, as regards capacity, but modified slightly to suit the rivetted construction which it had been decided to adopt.

The fixed spans are of moderate length and capacity, and possess little interest beyond the fact that the outline of the skeleton presents some novel features for a bridge with rivetted connections, the panels being unusually long, with but two systems of triangulation in the web, and the top chord being inclined towards the end.

Without entering into the old controversy of pin *versus* rivetted connections, some of the weak points of the rivetted truss, as ordinarily built, are acknowledged to be the difficulty of getting good connections between web and chord, the secondary strains arising not only from the stiffness of the joints, but in a greater degree from the usual eccentricity of the intersection of the axes of the members meeting at a panel point. It was in the endeavor to overcome some of these defects that the form of the Coteau spans was adopted. The use of the long panels of course set aside the common argument in favor of rivetted spans, *i.e.*, that in the event of anything striking the web, it is not likely that the web members of all the systems will be destroyed, and hence that a rivetted span has a better chance than a pin span against being knocked down.

To carry this argument to its logical conclusion, however, would lead us back to the old practice of plate webs, and it was felt that there were advantages to be gained by the use of long panels that far outweighed this objection.

A better floor system was obtained, necessarily much less subject to impact.

The secondary strains arising from deflection and stiffness of the joints were reduced by the long panels directly and indirectly, also by the fact that they permitted the use of inclined top chords, thus giving great centre height for the truss and consequent small deflection. But the most important gain was in the reduction of the web stresses by the use of the inclined chord. These stresses are very small for a span of this length and capacity. This, of course, gave greater facility in getting efficient connections between chord and web and small secondary strains should there unavoidably be any small eccentricities of intersection.

The swing is unusually long for a rivetted structure, and some difficulty was experienced here in obtaining good connections for the web members, the web stresses towards the centre being very heavy, despite the considerable inclination of the chords. It was found necessary to put in large plates to connect the diagonals to the chord, the plates on either side of the chord being connected by a diaphragm, and the floor-beam rivetted to the plates.

The table of the swing was made entirely rim bearing, consisting of a deep circular girder 24 feet in diameter and cast iron treads rolling on cast iron wheels 18 inches diameter. Great care was exercised in the manufacture and setting of the table, and as a result the swing is easily turned by two men.

The swing has to be opened only for the few steamers that run the rapids. It was therefore decided to operate by hand power, and keep but two men in attendance.

The matter of an end lift, by which two men could at any time get a full end reaction for both dead and live load on so large a structure, was rather a serious problem under these circumstances. Toggle lifts for hand power have the objection that, unless the lift is completed, all the parts are subjected to very severe strains under live load; wedges were dismissed as having not sufficient power for the conditions. The lift finally decided on, consists of a large screw, 5 inches in diameter at each corner. These screws have buttress threads, and are turned by a worm and wheel, which is operated by shafting and gears from the centre of the span. It was felt that these screws completely filled the requirements, being self-locking in any position and capable of any lift, the amount depending only on the power. Thus one man can turn the screws until there is a considerable positive reaction at the abutments, which is all that is necessary to ensure the safety of the span, as it is proportioned for the live load continuous over three supports combined with the dead load either cantilevered or resting on three supports. The screws work very easily, two men readily lifting the ends to the extent desired.

The details of the work are those of the ordinary rivetted truss. The floorbeams are generally supported on top of the chord by stiffener angles rivetted to the chord, the four lines of stringers being rivetted between the floor-beams. The top chord joints are all faced and butted, and have in addition splice plates and rivets sufficient to take up the stress at double the ordinary working strain. All tension splices have at least 10 per cent. more section than the member spliced. Chords have reinforce plates at the panel points to take up the local strains produced by the connections of diagonals and floor-beams.

Field rivets were all $\frac{7}{8}$ in. in diameter, and were valued at from 3,000 lbs. to 3,500 lbs. each in shingle shear.

Paper No. 50.

THE IRON ORES OF NOVA SCOTIA.

By Edwin Gilpin, Jr., M.Can.Soc.C.E.

The presence of iron ore in Nova Scotia was reported as early as 1604 by DeMonts, who found in the trap of Digby County veins of iron ore, and in the beaches of St. Mary's Bay layers of magnetic iron ore sand. It does not, however, appear that any attention was paid by the early settlers to the deposits, as was the case in Canada, where reference is found as early as 1672 to the iron mines and foundries of St. Maurice. This may have been due, however, to the incessant wars and changes of government which filled the early pages of Acadian history. It was not until the early part of the present century that any attempt was made to utilise these ores. During its first decade a few tons of bar iron were made in a Catalan forge at Nictaux. Haliburton, in his History of Nova Scotia, gives an account of the next attempt, which was made at Moose River. It was under the auspices of a company incorporated by the Local Legislature in 1825, and one of the earliest of those now entitled as of "limited liability." The works produced an excellent charcoal iron which was largely cast into kettles and stoves, and some bar iron, but ran only for a short time.

After an interval of thirty years the furnaces were started again for a short time and are now in ruins.

In 1828, the General Mining Association of London, the owners of the Albion Collieries of Pictou, collected a large lot of the limonite boulders, and mined some of the red hematites of the East River of Pictou, and experimented with them at the Albion Mines in a small furnace with unsatisfactory results.

In 1856, two small blast furnaces were built at Nictaux, Annapolis Co., and run on the fossil ores of the vicinity and some bog ore with charcoal, but were soon abandoned, and allowed to fall out of repair.

In 1850, a Catalan forge was put up at Londonderry, Colchester Co., and ran for three years. It was succeeded by a charcoal furnace in 1853, which ran until 1874, and produced about 45,000 tons of pig iron. The iron made from the excellent limonite ore of that locality was of the best grade. Sir William Fairbairn spoke of it in the highest terms, as possessing in an unusual degree the qualities adapting it for the manufacture of ordnance.

Steel was made from this iron to a limited extent, and proved equally satisfactory, the drills being largely used in the construction of the Intercolonial R.R. The remoteness of the works, however, from facilities for transportation retarded their development. The construction of the Intercolonial Railway, which was diverted from its course so as to pass near them, gave a chance for enlargement which was taken advantage of.

In 1873, the Steel Company of Canada acquired these works, and their great freehold property of over 55 square miles of land. Dr. Siemens, the distinguished metallurgist, was at the head of the Company, and great anticipations were entertained of a large and remunerative manufacture of steel. About two and a half millions of dollars were expended in building two large blast furnaces, and the plant necessary for an output by a direct process designed by Dr. Siemens. Rolling mills, forges, tramways, etc., were built, and the East and West Mines systematically opened, and a colliery developed at Maccan in Cumberland County. The enterprise, however, although producing an excellent grade of product, was not successful, the writer is informed, owing to the steel producers not proving satisfactory, and the attention of the Company was directed to car wheels, axles, nail plate, castings and pig iron.

The Company finally was reorganised under the title of The Londonderry Iron Company, Ltd., and is at present being successfully conducted under the management of Mr. R. G. Leckie. Further details of the operations of the Company will be given.

During the past few months the New Glasgow Iron, Coal and Railway Company, operating at New Glasgow in Pictou County, have started to develop the ores of that locality, and their enterprise is being watched with much interest, as, in the event of the production of a cheap steel and iron, there is no doubt that New Glasgow will become an important centre of ship building, bridge and locomotive works, etc.

It is stated that this Company proposes uniting with the Nova Scotia Steel Co., who have a large plant at Trenton, Pictou Co.

During the past year its output was 13,000 tons of finished iron and steel. About 30,000 tons of coal were used and 420 men employed. Their plant ontains :

2 Open-hearth Siemens-Martin steel melting furnaces.
2 Regenerative gas re-heating furnaces.
8 Reverberatory heating furnaces.
5 Steam hammers.
5 Rolling mills.
9 Pairs shears.
Lathes, planers, drills, etc., etc.
Boilers, dynamos, etc.

NOTE.—Fuller details about the history of iron smelting in Nova Scotia can be found in Dawson's Acadian Geology, Haliburton's History of Nova Scotia, and Bartlett's Manufacture of Iron in Canada (American Institute of Mining Engineers, 1885).

The different geological horizons met in the province present iron ores under varied conditions of deposition, size, and composition. The following table shows the ores characterising the horizons, and is based on the reports of Sir William Dawson and the Canadian Geological Survey.

Geological Age.		*Variety of Ore found.*
Modern.		Bog Ore.—Iron Sand.
Triassic	Sandstone. Trap.	Magnetic, Specular.
Carboniferous.	Permo Carboniferous.	Clay Ironstone.
	Upper Coal Measures.	Clay Ironstone.
	True Coal Measures.	Black Band, Clay Ironstone.
	Marine Limestone.	Clay Ironstone, Spathic. Limonite, Red Hematite.
	Lower Carboniferous.	Red Hematite.
Devonian, Oriskany Sandstone, etc.		Red Hematite, Magnetite, Spathic Ore, Specular.
Upper Silurian	Clinton. Lower Helderburg.	Red Hematite.
Lower Silurian.		Red Hematite, Magnetite.
Cambro Silurian.		Specular, Limonite.
Laurentian.		Red Hematite, Specular.

It may be remarked that the limonites and red hematites of the Marine Limestone and Lower Carboniferous are frequently found as contact deposits, or filling junction veins. The Lower Carboniferous horizon is represented in this province chiefly as black shales or conglomerates, and the Marine Limestone as alternations of shale, sandstone, limestone, marls, and gypsum. At numerous points these measures are found to carry contact deposits of iron ore where they rest on pre-Carboniferous strata. These deposits therefore occur between Carboniferous measures and Silurian, Laurentian and Devonian measures, the iron depositing agency being apparently inherent in the former.

In the table it will be noticed that all the divisions of the Carboniferous carry clay ironstones. These deposits, except in one instance to be noticed, do not as yet appear to be of economic value, but have not hitherto received any special attention. The Society will observe that the writer has not included the gold-bearing strata of Nova Scotia referred to, the Lower Cambrian or Longmynd series of Europe among the ferriferous measures.* These measures, consisting almost entirely of slates and quartzites with an occasional calcareous sandstone, do not appear to have had the organic or seismological conditions permitting of the accumulations of iron ores. Discoveries of ores have been reported in these measures, but the writer is not aware that any are of economic or mineralogical interest. As the Atlantic front of the province is occupied by these rocks and their associated granites, the iron ores are confined to the more northerly part of Nova Scotia, and form a broad band extending from Digby in the west to Guysboro in the Straits of Canso, and through the Island of Cape Breton.

For the sake of conciseness the writer will take the ores in order as they are met in passing from east to west. In the Island of Cape Breton the two predominating series are Carboniferous and Laurentian. In the former there are met at numerous points layers of clay ironstone up to six inches in thickness. Samples from Schooner Pond and Bara sois are said to yield from 25.84 to 27.89 per cent. of metallic iron. Near the top of the Lower Carboniferous at Sydney is a bed of marl, calcareous at several points, and carrying a sandstone in places containing 30 per cent. of metallic iron as a peroxide of iron.

At Big Pond, Ben Eoin, Red Island, Loran and several other places on the Bras d'Or Lake, where these measures rest on the Laurentian felsites, etc., are found contact deposits of red hematite. Some of these have been tested, and at several points a few tons of ore extracted, and they are believed to be of considerable extent, but have not yet been systematically mined. The ore occurs in veins and in pockets, frequently apparently replacing limestones or marly shales, and is often observed for considerable distances. On Boulardarie Island spathic

* Note. See the Nova Scotia Gold Mines, by E. Gilpin, Am. Inst. M. E., 1886.

iron ore occurs in a bed about three feet thick, carrying 32.58 per cent. of metallic iron. Bog ores are met at Boisdale, Schooner Pond and at several other points. Samples submitted to the writer appear to be of fair quality.

At George's River there is a narrow band of Lower Silurian measures extending across to Eskasoni in East Bay. The slates and sandstones of this series are in places literally "soaked" with peroxide of iron. The mineral in places is segregated into beds or veins. Openings made by Mr. I. Greener at George's River show two deposits from five to ten feet wide, and apparently continuous for several hundred yards. A bed of red hematite which measured twelve feet in width has been exposed at Smith's Brook, East Bay.

It is, however, in the next horizon, that of the Laurentian, that the most important iron ore deposits of this Island will probably be found. These strata are divisible into two groups, the felsitic and the calcareous; the latter also having felsites, gneisses, etc. This division appears to be markedly ferriferous, and at two localities important red hematite and magnetite deposits are known. At Whycocomagh these two varieties occur in close proximity. Nine distinct beds are said to have been discovered and partly tested. They vary in thickness from three to nine feet. A five-foot vein of unusual purity has recently been opened here by Judge Tremaine. Near Gillies Lake, East Bay, the Moseley iron ore bed has been traced for about 2½ miles, and varies in thickness from four to thirteen feet. It is closely connected with crystalline limestones, and it is believed that there are other similar beds in the vicinity. Near the Indian Reserve and at Peter's Mountain near St. Peter's, in rocks of Devonian age, are found several veins of specular ore. These deposits have not yet been systematically examined, but are promising and close to shipping. They resemble in quality and manner of occurrence the Guysboro ores, to be noticed. Their iron contents appear to run from 50 to 60 per cent. At points considerable quantities of sulphur are visible, but large portions of the veins are composed of very fine ore. Iron ores are also known near Lake Ainslie, Mabou, Cheticamp, Hunter's Mountain, Craignish, Grand Anse, Loch Lomond, etc., but no attention has yet been paid to them.

The following table will serve to show the composition of some of these ores. It may be remarked that, judging from their quality as tested by superficial openings and samples, they should furnish some very good ores for steel making, and, as they are nearly all near deep water, they should be available for exportation. Other deposits again are lower in iron and higher in posphorus, but would be rich enough for consumption in local furnaces.

	Loch Lomond.	East Bay.	East Bay.	Whycocomagh.	Whycocomagh.	Loran.	Big Pond.	Georges R.
Metallic Iron............	64.49	59.52	57.92	48.25	60.90	63.09	61.39	62.50
Silica....................	7.76	5.13	12.80	24.78	10.80	5.45	9.04	7.82
Phosphorus.	.03	—	—	trace	trace	—	trace	.09
Sulphur..................	.07	.07	trace	trace	trace	.10	trace	trace
Phosphoric Acid........	—	.03	.16	—		.11	—	
Alumina	—	—	1.55	2.72	1.40	—	—	
Magnesia	—	—	.60	1.08	1.64	4.20	1.22	.88
Lime	—	—	1.20	1.18	1.85	—	—	.67
Water.....................	—	—	1.30	1.30	—	—	1.53	1.10
Manganese..............	2.85	—	.26	—	—	—	—	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)

(1) Geo. Sur. Can.
(2) Geo. Sur. Can.
(3) Steel Co. of Canada.
(4) Dr. Howe.
(5) Dr. Hayes.
(6) G. F. Dowing.
(7) Geo. Sur. Can.
(8) E. Gilpin.

} Analysts.

Passing to Nova Scotia proper, the first ores met are those of the Devonian of Guysboro County. In strata of this age in Annapolis County are known the valuable bedded hematites, sometimes altered into magnetites, of Clementsport and the Nictaux district. In Guysboro County, however, important deposits have been opened, and their mode of occurrence has a direct bearing upon the probable ore-yielding localities on the opposite side of the Strait of Canso. At Erinville is a large and important deposit of specular ore. Some years ago a test was made of the extent of this deposit. A shaft was sunk in the ore fifty feet, and a tunnel driven, exposing a body of ore sixty-five feet wide; another bed in the vicinity was twelve feet wide. The ore is fairly compact, running from 55 to 62 per cent. of metallic iron, and very low in phosphorus, and not holding above the amount of sulphur usually found in ore of this character. The walls of the veins are composed of greenish, dioritic, feldspathic, trappean, brecciated rock. About a mile further west,promising indications of ore have been found in altered slates, and shales with quartz. In the vicinity are large masses of dark gray trap, in contact with conglomerate.

At Boylston, on the east side of Milford Haven, are a series of veins of specular ore from two to four and a-half feet wide, in shale, with calcite. These deposits are connected with dioritic rocks as at Salmon River Lakes. A few tons were mined and found of good quality, but the expense of transport to the Londonderry furnaces, their only market, proved too great.

At Polson's Lake, Antigonish Co., are found lenticular masses of spathic ore, in some cases associated with copper sulphides, and beds of limestone carrying considerable amounts of carbonate of iron. A limonite from this locality yielded on analysis:—

Iron	48.00.
Water	11.12.
Manganese oxides	4.73.
Silicious matter	3.86
Phosphorus	trace.
Sulphur	trace.
Magnesia	trace.

Passing to the northern part of the County, among the Lower Silurian metamorphic rocks, which form a broad band extending from the head waters of the East River of Pictou to Cape St. George, there are found abundant traces of specular, limonite, hematite and magnetite.

At Arisaig, on Doctor's Brook, are important deposits of hematite

One bed is six feet thick, overlaid by another said to be twelve feet thick, and underlaid by thinner beds. On the road from Doctor's Brook to Pleasant Valley is a six feet and a twenty-four feet bed, and other deposits occur in this locality. The ore is oolitic, and in many places of good quality. Little work has yet been done to determine the extent and nature of these ores. They occur in connection with reddish and mottled fragmentary rocks, diorite with veins of epodite, red concretionary and hematitic slate and similar rocks, and perhaps owe their origin to the proximity of syenite, diorite and other igneous rocks. At Arisaig Brook is a bed of red hematite one to three feet thick, oolitic and fossiliferous. This ore is referred to by Mr. H. Fletcher as apparently belonging to the Niagara. The only analysis of an ore from this district that has come under the writer's notice gave 52.34 per cent. of metallic iron, but was high in silica and phosphorus. These ores could be shipped at Arisaig, if further researches prove them to be available for export. They could doubtless be smelted at present with charcoal as there are large tracts of woodland in the vicinity.

PICTOU COUNTY.

The accompanying map (Plate VI) shows the position of Pictou Harbour in relation to the coal, limestone, and iron ores of the County. Geologically speaking, the district may be described as made up of Carboniferous resting on Silurian and Cambro Silurian. The two horizons of the Carboniferous most interesting in this connection are the middle coal measures at New Glasgow forming the "Pictou" coal fields, and the Carboniferous foundation carrying numerous beds of limestone. As the basal conglomerate or shales of the Carboniferous is sparingly met in this district, the limestones may be compared to a fringe around the pre-Carboniferous, and lying between the coal and iron ore deposits. The iron ore district may be roughly described as a triangle formed by the ore outcrops and the Intercolonial and Cape Breton Railways, the former marking the base and the latter the sides of the triangle, having its apex in the coal field at New Glasgow. The construction of a railway has been begun to bisect the base, following the course of the East River.

From Arisaig to Sunny Brae on the East River of Pictou there extends a band of Silurian measures which have been extensively studied by Sir W. Dawson and the late Dr. Honeyman, and are shortly to be illustrated by the map of the Geological Survey under Mr. Fletcher. In this connection the most important horizons are perhaps the

Lower Helderberg, Niagara, and Clinton. Although veinlets and indications of iron ore abound in this range west of the deposits just referred to, it is not until French River is reached that evidences are presented of any attempt to ascertain the value of the iron contents of these horizons, which are in Nova Scotia proper classed as the principal homes of the ores of this important metal. There is no doubt that when the demand arises there will be found at numerous points, in this apparently barren interval, deposits of iron ore at least equal to those characterising it at Arisaig and on the head waters of Sutherland's and the East River.

The chief ore of this formation is a bedded red hematite found in four principal deposits. The most northerly of these, distant about two miles from the Pictou Coal field, is known as the Fall Brook, or Watson ore. It has been opened by a few trial pits, and found in Fall Brook to be about fifteen feet wide, and to maintain this size for about a mile to the eastward.

The next bed, known as the Webster ore, has been carefully trenched and tested at several points. Its thickness varies from fifteen to thirty feet, its dip being generally north at angles varying from 25 to 60 degrees.

At two points it presents the following sections:—

	ft.	in.
Ore	4	4
Smooth parting	0	0
Ore	3	0
Slate	2	11
Ore	3	3
Total	13	6

	ft.	in.
Ore (in four layers)	5	0
Smooth parting	0	0
Ore	2	6
Smooth parting	0	0
Ore	3	0
Slaty ore	3	10
Ore	6	10
Total	20	4

This ore follows the crest of a high hill, cut transversely by the valley of Sutherland's River, and admits of adit drainage to a depth of 300 feet. The ore is compact, non-fossiliferous, and brick red when weathered.

The third exposure is known as the Blanchard Great Bed. No attempts have yet been made to trace it beyond the natural exposures, which extend about half a mile. It varies in width from 30 to 100 feet measured across a dip nearly vertical. It is also situated on elevated ground, and would yield a large amount of ore.

At a geological horizon about 700 feet higher than the last mentioned bed is a conformable range of red hematites forming the fourth series. This ore appears, as shown on the map, to form a synclinal trough. On the west side the ore is twelve feet thick, and at the apex there appear the outcrops of two other beds, eight and three feet in thickness, the larger possibly representing the great bed. On the east side of the synclinal only one bed has been opened, varying in width from three to five feet. Underlying this bed, and on the line where the great bed would show its eastern outcrop, are large boulders precisely similar in appearance to the one on its western outcrop, and it is expected that it will shortly be found there.

It is considered by some geologists that the three large single beds were originally one, and owe their present disjointed condition to faults and erosion. No detailed survey, however, has been made to prove the correctness of this opinion, and at present it can only be said that they are apparently contained in a limited vertical range of strata.

The outcrops of other red hematites have been marked on the map, but no work has been done to allow of details being given.

These red hematites are all of the same class, being of a red color, with earthy to steely lustre, compact or laminated, sometimes oolitic owing to the peroxide forming minute concretions around grains of sand. In places these ores contain fossils, but the larger proportions are quite free from them.

Similar ores, called fossil red hematites, are found in Pennsylvania in strata of the Clinton age, and extensively worked near Tyrone for mixture with rich hematites and magnetites. For comparison an analysis of one is given, made at the University of Pennsylvania :—

Sesquioxide of iron	38.48
Peroxide of iron	4.37
Silica	37.99
Alumina	9.56
Lime	1.08
Alkalies	2.89
Phosphoric acid	1.48
Sulphur	trace
Volatile	4.50
Metallic iron	30.34

These ores are in firm and compact strata, and should be mined very cheaply as little timbering would be needed, and the measures will be found dry below water level. Although their contents of metallic iron are not equal to those of the other deposits, their cheapness, proximity to coal and immense extent will make them important items in iron-making in this county.

Passing to the west side of the East River there extends from Sunny Brae to a point about six miles west of Glengarry Station a belt of strata comprised principally of black and grey slates and quartzites. They have been considered to be the Eastward Extension of the Axial measures of the Cobequid Mountains (carrying the Londonderry iron ores), and are termed provisionally Cambro Silurian. In the district lying west of Glengarry Station there are numerous exposures of specular ore up to three feet in thickness. The ore occurs as veins, usually conformable but sometimes traversing the strata. At one point about two miles west of Glengarry there is a large vein of ankerite with calc-spar carrying several bodies of specular ore. The quality of the ore as exposed by trenches is frequently excellent, at other points it is mixed with vein matter.

So little, however, has yet been done to test their size and economic values that no definite information can be given. From Glengarry westward to Drug Brook, a tributary of the west branch of the East River, traces of specular ore are found, but no deposit has been exposed in site. At this point there are natural exposures showing three beds of limonite, the thickest thirty inches in width. Some distance south of this in the West Branch Lake is a vein of limonite about two feet thick. It is not yet settled if the ore at Drug Brook represents that met near Glengarry, and possibly it belongs to a second ore range lying to the south of the specular. This vein is strengthened by the fact that limonite occurs further east to the south of the specular.

From the Drug Brook westward for about three miles traces of specular ore are met. At this point, in an area owned by Mr. S. H. Holmes, an opening has been made on a specular vein seven feet wide. Thence eastward to the East River the passage of the specular ore vein has been traced and several openings made. The vein is, strictly speaking, a stratum vein, and has a course agreeing closely with that of the slates, and a nearly vertical dip. Its width is from 50 to 150 feet, and the ore bodies run in width from one to twenty feet. The principal openings have been made on areas held by Messrs. Holmes and Bartlett. At the point where the vein approaches the river, there are indications that it carries limonite as well as specular, and, as already mentioned, there is a body of limonite lying about a quarter of a mile to the south, and said to be about six feet wide. These ores are found along the crests of the hills bordering the river valley, and admit of considerable adit mining, and should be easily drained. They are compact and foliated, and of good quality. The principal impurities observed in the ore is sulphur, but it appears to be confined in a small compass at a few points, and is presumably due to some agency of faults later in date than the formation of the ore vein, and the remaining portions of the veins are free from it.

Along the valley of the East River above Springville the Lower Carboniferous marine formation rests upon the Silurian, the actual unconformable contact being visible at several points. So far as explorations have been carried, there appears to be a junction fracture or series of faults.

These seem to have become receptacles for numerous deposits of an excellent limonite ore. The ore occurs in the Carboniferous and in the older slates as either horizon was faulted, and along the junction. For a distance of about eight miles extending down the river from Sunny Brae, there are numerous exposures of ore. At several points the bodies are over twenty feet wide. The mining operations initiated by the New Glasgow Iron, Coal and Railway Co. during the past few months have shown that the deposits maintain their size in depth. At several places the ores are highly manganiferous, and from one opening about 100 tons of manganese ore of excellent quality was extracted. The limestones which are found in close connection with the limonite are frequently highly ferruginous and manganiferous, and specimens have been found showing that spathic ore also occurs in this valley of the East River. At the point where the West Branch of the East River crosses the junction of the Carboniferous and Cambro Silurian, drift, limonite has been observed, but no search has been made for it.

The ore of this valley is compact, concretionary and fibrous, with considerable quantities of gravel ore. At two points the ore has been noticed to rest on the Silurian clay slates, and has limestone on the hanging walls, with a gore of red clay, frequently holding concretions of manganite and pyrolusite intervening. These ores are very pure and free from phosphorus, the average of five analyses giving .118 phosphoric acid, or .083 of phosphorus in 100 parts of iron.

The belt holding ore is 800 yards wide at several places as shown by surface indications, and it appears probable that there is a large amount of it in the valley.

The limonite may have been derived, like the limonite of Cumberland Co. and other localities in Pennsylvania, as a residual precipitate from the disseminated iron sand grains of the Upper Silurian strata, as well as a deposit from the gradual dissolution of the marine limestone. In view of this it may be stated that in this district the rocks of both ages contain considerable quantities of iron as carbonate and peroxide, and that the erosion has been on an enormous scale.

Passing to the Sutherland's River district, an opening has been made on a bed of spathic ore which occurs in red marl, associated with limestone and gypsum. Its width varies from six to ten feet, and from surface indications it appears to extend over a considerable tract of country. The bed in places is highly manganiferous, and is a typical spathic iron, granular and crystalline in texture, and of a light grey colour. The following analyses will show its character :—

	I.	II.
Sesquioxide of iron	20.52	——
Carbonate of iron	57.40	82.11
Carbonate of manganese	8.29	4.70
Carbonate of lime	4.02	2.37
Carbonate of magnesia	5.66	9.06
Silica	2.38	1.69
Moisture	1.43	——
Sulphur	none	.10
Phosphorus	none	none
Metallic iron	42.07	39.64

I. Dr. T. S. Hunt. II. J. H. Huxley.

Indications of spathic ore have been found on Sutherland's River, McLellan's Brook, etc., under similar conditions, and this ore may prove a widespread and important addition to the ores of the county. Still further east on French River, at a horizon apparently several hundred feet higher, and considered to represent the upper part of the Marine Limestone formation, there are several beds of a nodular red hematite, varying in thickness up to four feet. These beds have been recognised as extending for several miles. They appear to be the weathered outcrops of carbonate ores, but they have only been examined superficially. Samples taken from the outcrop of a four foot on French River yielded 35 per cent. of metallic iron.

In the productive coal measures, clay, ironstone and black band ores have been noticed at several horizons. It may be questioned if any of the ores hitherto casually exposed in shafts and stone tunnels are present in quantities large enough to warrant the expectation of independent workings, although in some cases they could be worked in connection with the coal beds. The following analyses by the writer will serve to show the quality of some of these ores :—

	I. Clay Ironstone.	II. Black Band
Moisture	2.132	——
Sulphur	.612	.214
Phosphoric acid	trace	.586
Manganese oxide	——	4.450
Lime	trace	3.780
Magnesia	1.655	.783
Alumina	16.962	3.180
Silica	.780	16.546
Carbonic acid	——	27.589
Iron protoxide	45.361	36.000
Metallic iron	35.000	28.000

Although no attempts have yet been made to find iron ore in the coal districts, the indications observed up to the present date may fairly be considered to show the probable presence of a large and cheap supply of ore.

In the Upper Carboniferous measures lying to the north of New Glasgow there are several thin layers of clay ironstone not apparently of economic value.

In the surface drift there have been beds of bog iron ore observed at numerous points. These deposits have nowhere been observed of large dimensions, but would probably be utilised for furnace purposes in the vicinity of the iron ore districts more particularly alluded to above.

ANALYSES OF PICTOU IRON ORES.

	Specular.			Limonite.		Red Hematite.	
	1	2	3	4	5	6	7
Oxides of iron	92.01	64.03	97.52	93.09	81.19	70.00	65.26
" manganese	2.16	2.74	—	1.10	.20	—	trace
Alumina	.21	2.95	—	—	—	—	5.59
Carbonate of lime	1.27	.041	—	.01	.63	3.03	1.88
" magnesia	.43	.046	—	—	—	—	1.05
Phosphoric acid	.08	.031	—	—	.15	.20	——
Sulphur	.16	trace	.06	.04	trace	—	——
Silica	3.68	17.89	3.20	4.80	4.26	25.82	25.68
Metallic iron	64.41	44.82	68.33	65.20	56 83	45.47	43.40

1. Dr. Macadam.

3, 4, 7, Dr. T. E. Thorpe. 5, 6, S. H. Huxley.

River John, French and East Rivers may be mentioned as localities yielding this ore; and the following analysis by the writer is of ore from a small bed exposed in a cutting of the Glasgow and Cape Breton Railway in Merigomish near French River:—

Moisture	5.500
Water of composition	6.100
Sulphur	.208
Phosphoric acid	.384
Manganese oxide	5.886
Lime	trace
Magnesia	trace
Alumina	3.106
Silica	12.325
Iron peroxide	66.510
Metallic iron	46.557

At Newton Mills, Upper Stewiacke, the New Glasgow Coal, Iron and Railway Co. have opened an important deposit of red hematite, occurring in connection with measures provisionally referred to the Upper Silurian. The slates connected with the deposit are in places rich enough to work as ore. It is believed that further search will show a valuable deposit here.

A working sample gave:—

Peroxide of iron	60.380
Phosphorus	.018
Sulphur	.164
Lime	.340
Alumina	6.640
Silica	27.970
Manganese and magnesia	trace
Alkali	2.690
Water	1.310
Iron	42.27

In Hants County, on the west and east sides of Grand Lake, where the Lower Carboniferous measures rest on the Lower Cambrian (Auriferous measures), there are pockets of red hematite of excellent quality. Little attention has yet been paid to this locality, which may prove important, as the ores, if present in quantity, are rich enough to ship via Halifax for export to the United States, and would be about 80 miles from New Glasgow and Londonderry.

These ores are similar in quality and mode of occurrence to those found at the contact of the Carboniferous and Laurentian at numerous points in Cape Breton, already referred to. At Brookfield, about 8 miles south of Truro, a mine has been opened on a large vein of limonite, in places over twenty feet wide. Shipments have been made by rail to Londonderry, and it is probable that it will be largely drawn upon for the proposed furnaces in Pictou County. The ore is of good quality, some of it being almost chemically pure. It is about thirty-five miles by rail from Londonderry and fifty miles from New Glasgow. At Goshen, between Windsor and Truro, a vein of ankerite containing limonite has been opened in strata of the Marine Limestone age, and proved to be forty feet wide. The following analysis of the ore is interesting from the amount of manganese present. In connection with this ingredient it may be stated that considerable quantities of manganite and pyrolusite have been mined and exported from this district.

Metallic iron	35.10	
Oxide of manganese	24.74	
Alumina	3.68	
Lime	.35	
Magnesia	4.76	
Silica	4.81	
Iron pyrites	.20	
Phosphoric acid	.21	
Water	11.10	
100 of iron contain	.26	phosphorus.

At the mouth of the Shubenacadie River the lowest visible Carboniferous bed is a dark laminated limestone which, with the overlying sandstones and marl, contains small veins holding limonite and specular ore, with ankerite, barite, calcite, goethite, manganite and siderite. In the same formation, a few miles to the eastward of Clifton, similar ores are found. At this point they are of more importance, one of the limonite veins being six feet wide.

At Selma, to the west of the Shubenacadie River, a compact red hematite occurs. A partial test made by the New Glasgow Coal, Iron and Railway Co. shows eight feet of ore. Further work will, it is expected, show an important deposit.

The ore resembles very closely, and can hardly be distinguished from, choice Lake Superior red hematite. The deposit is in measures of Lower Carboniferous age, but does not appear, so far as work has been carried, to be a contact deposit. The following analysis of averages will show its quality :—

Silicious matter....................	12.610
Phosphorus..........................	.037
Sulphur.............................	.020
Iron................................	46.02

At Mount Thom, in Colchester County, drift boulders of specular ore were found last summer by the New Glasgow Coal and Iron Co., and openings made on what appears to be the parent vein; and at Kemptown, on the easterly prolongation of the Londonderry vein, an important deposit of limonite was found, and is now being proved. Working samples yielded :—

Iron................................	53.040
Phosphorus..........................	.112
Sulphur.............................	.022
Silica..............................	7.490

On the upper waters of the North River of Truro magnetite occurs in a vein three feet thick, and is of good quality.

LONDONDERRY. The mineralogical and geological relations of the ferriferous strata here have been fully described by Sir Wm. Dawson and Dr. Selwyn. It may be remarked that running along the southern flank of the Cobequid Mountains there is a band of strata, referred by some writers to the Cambro Silurian period, carrying for a distance of many miles a stratum vein composed of carbonates and oxides of iron, with carbonate of lime and magnesia. Situated on elevated ground, cut transversely by deep ravines, this vein has as yet been inappreciably worked. Its width varies up to two hundred feet, and ore bodies of limonite have been found in it over fifty feet wide. There are also immense masses of spathic ore, and at some points the vein carries ankerite. At present, mining operations are confined principally to the limonite, but from this date more attention will be paid to the spathose ores, which will yield on calcining a valuable furnace material. There are two mines, known as the East and West mines, connected by railway with the furnaces standing between them, about three miles from Londonderry Station, on the Intercolonial Railway. These mines give employment to about 100 miners, who are housed by the Company. There are two furnaces, the one now being put in blast having a height of 75 feet, 19 feet bosh, and a nine feet hearth, and will, it is expected, yield 100 tons of pig a day. The other furnace is 62 feet high, with 19 feet bosh, and 7 feet hearth, and will probably be altered to correspond with the more productive dimensions of its mate. Two gas calcining kilns, of a capacity of one hundred tons each day, are being built to calcine the spathic ore which has the following composition:—

Iron	40.60
Silica	1.60
Volatile	32.8

and would yield upon calcination about 60 per cent of iron. Some of this ore enriched by veinlets of specular runs as high as 59 per cent. of iron. The following analysis from the reports of the Canadian Geological Survey will serve to show the quality of the other ores:—

	Limonite.	Hematite.
Peroxide of iron	82.65	96.930
Oxide of manganese	.25	—
Alumina	.56	.330
Lime	.15	.040
Magnesia	.10	.110
Phosphoric acid	.18	.007
Sulphuric acid	.12	.030
Water	10.71	.820
Insoluble	4.79	1.260
Metallic iron	57.85	67.850

A small quantity of ankerite has been used as a flux and yields:—

Carbonate of lime	51.61
Carbonate of magnesia	28.69
Carbonate of iron	19.57
Insoluble	.13
	100.00

The Brookfield limestone which is used for flux, and resembles a compacted heap of recently opened and cleaned shells, is remarkably free from sulphur and phosphorus, as shown by the following analysis:—

Lime carbonate	97.39
Magnesia carbonate	.94
Oxide of iron	2.70
Phosphoric acid	none
Insoluble residue	trace

About 35,000 tons of charcoal pig were made here during the early history of the establishment, the following analysis of which is by Tookey:—

Carbon	3.50
Silica	.84
Sulphur	.02
Phosphorus	.19
Manganese	.44
Iron	94.85

The indications are that this vein will continue for many years to come to yield a supply of excellent ore equal to the demands of an establishment much larger than the present one.

The coke used here is made from coal from the Intercolonial and Albion mines, Pictou county, and from the Spring Hill mines, and varies somewhat in ash percentages from 15 to 20 per cent. The coke in other respects is hard, and free from deleterious substances. An attempt is now being made to work the lower portion of the Albion Main Seam, Pictou county, which yields an excellent furnace coke. The coal gives on analysis:—

Ash	9.00
Volatile matter	27.65
Fixed carbon	63.35

And the coke shows:—

Ash	13.1
Volatile matter	3.0
Fixed carbon	83.9

The furnaces are fitted with blowing engines, hot blast stoves, lifts, ore sheds, etc., substantially built and of modern pattern. In addition there are:—

Rolling mill:—

8 double puddling furnaces.
1 single " "
Horizontal squeezer and rolls.
18 inch train of rolls.
16 " do do
9 " do do
2 steam hammers.
5 heating furnaces.

Capacity of mill, 8,000 tons a year.
do blast furnace, 20,000 tons a year.
do do do under construction, 35,000 tons a year.
Pipe foundry, 6,000 tons a year.

At Canfield Creek, Cumberland Co., Mr. R. G. Leckie has opened a large bed of limonite conveniently situated for mining and for transportation by land or sea. The following analysis shows its quality:—

Sesquioxide of iron	68.01
Insoluble matter	5.40
Oxide of manganese	5.67
Lime	2.50
Volatile	16.30

The Nova Scotian, or southern side of the Bay of Fundy is girt by a wall of dioritic trap, with ash, lying upon and connected with sandstones referred to the Triassic period. At numerous points this trap holds veins of magnetite and specular, and not unfrequently the soil derived from it holds limonite as the outcome of a secondary process. Usually the veins are irregular and small, the largest deposit which has come under the writer's notice being near Digby, and from eighteen inches to two feet in width. The magnetite is frequently massive, sometimes crystallised in partly filled veins, and associated with quartz, colourless and amethystine. It is usually pure, the principal foreign substance being silica. The ore also occurs disseminated in the trap at numerous points in small grains, sometimes only recognisable when separated by the magnet from the pulverized rock. At a point near Digby Neck it is associated with specular ore, and a few tons were shipped some years ago.

The following analyses will show the characters of these ores:—

	I.	II.	III.
Iron	60.430	49.291	68.33
Silica	14.320	26.872	5.46
Phosphorus	.036	.031	——
Sulphur	.046	.021	——
Titannic acid	trace	trace	——
Magnesia	——	——	1.27

Digby Neck, Granville, Margaretville, Malvern are among the localities where surface indications appear to warrant a belief that workable deposits exist.

Red hematite occurs in a similar manner associated with quartz, agate, and calcite. It is sometimes presented in the form of small crystalline plates, in a granular quartz matrix, and sometimes as crystals, apparently showing its derivation from the magnetite. Specimens are met, especially the more highly crystalline ones, having decidedly magnetic properties. These ores are frequently met throughout the trap range, which is 120 miles in length.

Titaniferous iron ore is found at St. Mary's Bay, west of Digby, as sand forming irregular layers in the beach. The indications are said to be extensive, but no attempts have been made to test its value for working.

A sample yielded :—

Magnetic iron sand or iserine	30
Non-magnetic or ilmenite	56
Silicious sand	14
	100

Both varieties containing a large amount of titanium and a little magnesia. This ore is reported from Shelburne and other points on the Atlantic Coast, and from Musquodoboit, near Halifax; that from the latter place being a dark micaceous schist, holding crystals of magnetite with titanium in considerable quantity. The writer has also observed a similar ore near Sutherland's River, in Pictou County, holding titanium. So far these ores have not been much prized by the metallurgist. Attempts were made a number of years ago to smelt similar ores at Bay St. Paul, on the north shore of the Gulf of St. Lawrence, but were abandoned chiefly, it is said, owing to the cost of fuel. The pig made was white and of fair quality. There are, however, on the northern shores of the Gulf and in Newfoundland deposits of magnetites apparently free from this ingredient, and they may prove an important aid to the iron smelting operations in Pictou County. South of the long range of trap referred to, is a narrow fertile valley traversed by the Annapolis and Cornwallis valleys, and underlaid by Triassic sandstones. On the south side of the valley a band of strata, referred by Sir William Dawson to the Devonian, succeeds the sandstones. This band varies in width from three to six miles, and is known to extend from Digby to a point a few miles west of Windsor, and is divided into two nearly equal parts by a mass of granite. In the western part are the Clementsport ores, in the eastern those of the Nictaux district.

At Clementsport there are two beds of ore running nearly east and west, and underlying to the south at nearly vertical angles. The highest of these beds is known as the Milner deposit, and varies in thickness from two to four feet. It is a specular ore, metamorphosed with magnetic properties, and retains casts of virelibite, spirifers and associated mollusks. The ore, which is of fair quality, yields about 33 per cent. of metallic iron, and has been mined by open cast work. The underlying or Potter bed may perhaps be classed as a magnetite, and the former workings presented the following section :—

	ft.	in.
Ore	3	0
Slate	2	6
Ore	3	6
	9	0

It is compact and dark gray in colour. The writer has seen no analysis of it, but it has been reported as running low in phosphorus and yielding 48 per cent. of iron.

At Bloomfield and several other points in this vicinity are beds of bog ore, yielding about 25 per cent. of iron. It is found a few inches under the surface, in layers from six inches to two feet in thickness. Reference has already been made to the furnace built here, and details of its size, etc., are without interest in this connection. The fuel was charcoal, and the daily yield from a mixture of ore from the various openings was five tons.

At Nictaux, 37 miles east of Clementsport, an attempt was made a number of years ago to work similar ores. The ore was taken from a bed of highly fossiliferous peroxide of iron associated with dark gray slates, which has been traced about four miles, and varies in thickness from three to four and a-half feet.

The fossils of the red hematite and associated beds are spirifer, arenosus, strophemena, magnifica, and depressa, Atrypa unguiformis, and species of Avicula, Bellerophon, Favosites and Zaphrentis,etc., compared by Professor Hall with the fauna of the Oriskany sandstones, and proving the beds to be of Lower Devonian age. There is also found in these measures a bed of gray magnetic ore about eight feet wide. Several other deposits of ore have been found at Torbrook, and considerable amounts have been shipped by Mr. Leckie to his furnaces at Londonderry. These newer openings yield a good ore, and the beds vary in thickness from five feet up to eight feet. The following analysis will show their quality :—

		Magnetite.	Red Hematite.
	I.	II.	III.
Metallic iron	59.11	57.93	59.86
Sulphur	.09	.036	.11

Phosphorus	.17	.16	none
Alumina	5.53	—	3.14
Lime	2.70	—	2.16
Magnesia	.41	—	—
Silica	14.97	17.21	5.93

The ores of this district appear to have been originally red hematites or peroxides, but they have lost more or less of their oxygen and become magnetic. Specimens can be got showing the gradual change from normal red hematites with cherry red powder, to magnetic ores with brown or black streaks. This is probably a local metamorphism due to the presence of organic matter and the granitic dykes which traverse the works in the vicinity.

A bed four feet wide of manganiferous ore from this locality owned by Mr. R. G. Leckie yielded :—

Metallic iron	18.47
Metallic Manganese	9.80
Insoluble	33.50
Lime	3.00

The writer has received specimens of limonite, red hematite, and bog ore from the district lying to the south of the Devonian band, and extending east nearly to Windsor, a distance of fifty miles. As yet these ores are not known in amounts of economic value, but no search has yet been made for them ; and as the Silurian, Arisaig, horizons probably exist here, important discoveries may be anticipated.

CONDITIONS UPON WHICH IRON ORE LANDS ARE GRANTED.

The following is a brief outline of the conditions under which minerals other than gold and silver, owned by the Provincial Government, are granted.

A license to search for eighteen months can be secured for $30.00, covering five square miles. Before the expiration of the license to search a lease of one square mile can be selected on the payment of $50.00. This runs for twenty years, an annual rental of $30 00 being paid unless work is performed, and is renewable. A royalty of five cents a ton is levied on all coal sold or smelted. The law also provides that any land required for mining purposes may be secured by arbitration.

There are many localities in the Province where the land grants made previously to 1809 conveyed the iron ore also. These mineral properties in this respect belong to the owner of the soil, and are not liable to the Government royalty.

CORRESPONDENCE.

Mr. R. E. Chambers.

Mr. Chambers of the New Glasgow Iron, Coal and Railway Co. remarked that be had recived a copy of Mr. Gilpin's valuable paper on "The Iron Ores of Nova Scotia," with a request to make some remarks on it. The paper covers the ground so completely as to require nothing in addition.

As in most other countries, there are many places showing ore in Nova Scotia which are not of economic importance, but there are also many deposits of large size and very great value. After 18 months of exploring and prospecting the Company represented by the writer have secured and developed sufficient high class ore to warrant the erection of furnaces of large capacity. A personal examination of the iron resources of the Southern States and the Lake Superior region makes it evident that there is no place in the United States or Canada where iron can be made to better advantage than in Pictou County, Nova Scotia.

Thursday, 9th April.

P. A. PETERSON, Member of Council, in the Chair.

The folowing candidates, having been balloted for, were declared duly elected as :—

ASSOCIATE MEMBERS.

ANDREW LAKE McCULLOCH.
CAMILO ENRIQUE PANI.
BRYCE JOHNSON SAUNDERS.
WILLIAM HILL TOUT.
WILLIAM FRASER VAN BUSKIRK.
PERCY WEBB.

ASSOCIATES.

JOHN BELL.
ROSWELL FISHER.
OVID M. GOULD.

STUDENTS.

JAMES WILLIAM DOMVILLE.
ARTHUR MILES GRANTHAM.

The following has been transferred from the class of Associate Members to that of Members :—

WILLIAM MAHON DAVIS.

The following have been transferred from the class of Students to that of Associate Members :—

JOHN PLAW BALL.
MARSHALL WILLARD HOPKINS.

Paper No. 51.

SEWERAGE AND WATER-WORKS OF ST. JOHN'S, NEWFOUNDLAND.

By Alan Macdougall, M. Can. Soc. C.E.

Devastated by a fire which left hardly a single building standing in 1846, hampered by the peculiar policy of the Imperial Government towards the colony, which only received Responsible Government in 1854, governed by the Provincial Government as a part of the general property in the island, and only now permitted to enjoy a partial self government, and sadly hindered by a most curious system of land tenure, the city of St. John's certainly did not rise like the Phœnix out of its ashes. The city has had a great deal to contend with during the past 45 years, and more so in the period more immediately passing away. Absent landlordism and absent capitalists draw all the profits from the city, and leave the money makers to battle with all the expenses attendant upon the building up of the city. The whole of the city is built on leasehold, nearly all of the earlier leases are non-renewable, and contain provisions that all improvements belong to the owners of the land at the termination of the leases. The system of land tenure savours more of the feudal and vassal system than of nineteenth century advancement.

The city of St. John's is built on a steep hill-side. It is surrounded by high steep hills rising 300 to 600 feet above sea level, with a land-locked harbour of 345 acres in extent.

The entrance to the harbour is through a narrow gorge bearing evidence of having been scoured out by glacial actions. The rocks in the neighbourhood are Huronian.

The present population is estimated at 30,000. Nearly all the buildings are of wood; the only stone and brick buildings being on the two principal business streets—Water and Duckworth. Public buildings, such as Government house and buildings, the principal churches and so forth, are of stone imported from Ireland. After the fire no re-survey was made, or any regulations passed governing the erection of buildings; consequently a town has grown up full of curious irregular streets, full of encroachments and narrow spaces such as one meets with in European Continental cities, where people can almost shake hands out of their windows. The streets are all closely built upon, there are no spaces between the houses; the blocks are solid masses, in many cases without any means of access to the rear of the houses, and in many cases the backs almost touch each other.

The streets rising from the harbour are very steep, the ruling gradient is about 1 in 9. The rear parts of houses in many streets are so much below the street level, the lowest portions cannot be connected to the sewers. The city is practically built upon rock, it crops out everywhere in the streets; huge masses overhang the backs of houses, shewing it has been quarried out to allow the houses to be built. The problems relating to sewerage are complex and interesting from a variety of circumstances, the discussion of which will occupy more space than the limits of this paper will allow.

The population consists largely of working people, who are poor; nearly everyone of them is engaged in the fishing trade, either seal or bank fishing. The houses are of poor construction, of small rental, and incapable of bearing the expense of such sewerage and plumbing as the experience of the present day teaches to be necessary. Under one roof can be ordinarily found six to eight different families, occupying one or two rooms each, and in many cases being the proprietors of these small apartments, thus illustrating the "tenement" house of the Eastern States, or the "flat" of Scottish cities. These people are not able to put in "the latest modern improvements," nor have they the space to devote to them. The buildings and occupants are far from squalid; the occupants are cleanly and tidy people, with a very marked taste for flowers; the houses, generally, being in good condition.

Under the present régime, which was inaugurated two years ago, when the city received its present form of government, great and marvellous changes have been effected. The present municipal control is vested in a "municipal council;" it is expected that at the next meeting of the Legislature, a proper form of civic government will be granted to the city. When this is effected its influence on the good of the city will be rapidly felt.

That portion of the town site which slopes towards the harbour was in the early days intersected by a number of natural water courses, twelve or fourteen in all, which were used for a long time for culinary and dietetic purposes. With the gradual growth of the population, these water courses were turned into drains or storm-water courses, and in the ordinary course of events they became sewers, discharging into the harbour.

WATER-SUPPLY.

The first effort to obtain water supply was made about 1850, when water was brought from a small lake situated at the hill commanding the entrance to the harbour, called "Signal Hill." The lake is 300 feet above the sea level. A small distribution was made along Water street, on which the pipes still remain, supplying water from the present system under a pressure of 100 lbs.

In 1858, the present system was laid out by Messrs. Robson, Foreman and McCall of Glasgow. The water is brought from Windsor Lake, 4½ miles northwest of the city. The surface of the lake is 500 feet above the tide water; it has a surface area of 1370 acres. The grade for the first mile is very flat, compared to the rest, particularly to the last 2½ miles, where the fall is 273 feet. The grades are 1 in 520 for 903 yds., 1 in 185 for 1496 yds., 1 in 95 for 1190 yds., and 1 in 47 for 4287 yds., which brings the main delivery pipe to the city at an elevation of 156 above tide water. The supply of water was not satisfactory, and the Company who originally constructed the work consulted Messrs. Kinipple and Morris in 1873, when Mr. Morris came to Newfoundland and made exhaustive researches, which were presented in a full and carefully detailed report. The pipe as originally laid was 16 ins. diameter for its entire length. Mr. Morris found, as would be expected, that the portion nearest the lake was incapable of supplying to its full capacity the pipe nearest the town. He also found a remarkable and unnecessary waste of water going on. In some houses in the lowest lying parts, where pressure was greatest, there were no fixtures on the pipes, only a bent end, with the water flowing at the full bore.

After making many practical suggestions as to prevention of water waste, he advised certain alterations in the sizes of the pipes, which were carried out. A 24 inch supplanted the 16 in. for 903 yards from the lake, two double 16 inch stretched for 1496 yards further, and the single 16 inch remained for the balance of the distance.

This arrangement worked well for some time, though it did not give entire satisfaction. In 1883, the superintendent, Mr. John Martin, M. Am. W. W. Assoc., added a 12 inch pipe to the end of the double 16, for a distance of 1188 yards, bringing it to the head of the heavy grade next the city. This addition now balances the relative discharging capacities of the grades, and keeps the single 16 inch full. The daily flow is now close on 5,000,000 gallons (Imperial) per day.

In spite of these gradual approaches to the full capacity of the pipe, the supply was unsatisfactory, as the upper part of the city had very poor supply and low pressure, and during winter was without water.

The writer has just finished an examination into the causes of the dearth of water in the higher levels. He finds that an undue amount of water is run to waste in winter through constant flowing taps in the lowest levels; that economy in the use of water is not practised in winter; and that the main supplying "Water street" robs the other streets, the water having to rise to the upper levels chiefly from this low level of Water street. Observations taken with a pressure gauge have agreed closely with calculated pressures. The alterations recommended by the writer will probably be carried out next year, when all the trouble, it is hoped, will pass away.

The pipes are of cast iron, with turned and bored joints; they have been imported from Scotland till lately, when they were cast in the city. Those made in city were cast on their sides. A short distance of the supply main was laid with leaded joints. The superintendent informed the writer he found the change of temperature in the water affected the leaded joints, and that they began to leak after two years, and had to be attended to every second year, the turned and bored joints had never given him any trouble. This seems to be an unusual experience.

House services are of lead, stop cock boxes are of cast iron, placed over the valve, close to the main, and not in the service on the sidewalk.

Fire hydrants are of the Leadbetter pattern, which was the first one used here; it has been adopted ever since.

Public fountains are scattered over the city; they are constant flowing, discharging from two to four and in a few cases more gallons per minute. Self-acting and closing valves are now being attached to the fountains.

There are about:

9½ miles of mains.

2000 house services.

165 fire hydrants.

70 public fountains.

The quality of the water is good, soft, pure, potable, and well adapted to culinary and dietetic purposes. It is rather hard on steam boilers, pitting the shells and tubes severely. The latter have to be renewed frequently, in periods ranging from six to twelve months.

The supply main from the lake was cleaned out in 1885, by Mr. H. C. Burchell, M. Can. Soc. C. E., during Mr. Martin's absence on sick leave. The writer is very pleased to state that Mr. Burchell will shortly give to the Society a paper on this very interesting piece of work. The pipes have been cleaned out every two years since that date (1885), about an eighth of an inch of rust or incrustation forms in that time. A descriptión of the present method of cleaning the pipes will be given by the writer as an addendum to Mr. Burchell's paper.

The position of many of the lakes is remarkable, being on the highest points of the water shed. Windsor Lake has a water shed to its south of perhaps eight square miles, otherwise it is at the highest point of land. The level was raised 9 feet when the works were constructed; the top of the intake pipe is 6 ft. 6 ins. below high water, and 2 feet 9 ins. below low water. The water is drawn from the shallowest end. Had the pipe line been carried up the valley immediately to the north of its present line, a much more uniform hydraulic grade could have been established, and water drawn where the lake is 40 feet deep. The lands immediately surrounding the lake are nearly all controlled by the city, which now owns the water-works.

A small dam of rip-rap encloses an area of about half an acre, and forms a settling basin in which the intake pipe is placed. A good deal of trouble was experienced from anchor ice; but this has been cleverly overcome, by forming a number of telegraph poles into an open raft. They are fastened together by wire, about 10 feet apart, and anchored over the mouth of the pipe; the ice forms quickly between them, and prevents the formation of anchor ice.

The annual rainfall for the past six years is about 49.15 ins. per annum. A careful record of water level since the commencement has been kept by the superintendent, who kindly permits its publication in this paper. The gradual fall in the lake level is due to the equalization of the discharging capacities of the supply main.

There are good reasons for believing the lake is supplied by springs: it is the last sheet of water in the neighbourhood to freeze, and the last to thaw out in spring.

The works were constructed by a joint stock company with a capital of $400,000, the interest of which was guaranteed by the Government, who afterwards purchased the works, and handed them over to the City, bonding the cost of them at $423,800.

The estimated revenue is $30,000 per annum.

SEWERAGE.

The natural water courses which intersected the city became in course of time more or less polluted by sewage. Large stone drains or culverts, rectangular in section, were built from time to time on the lines of the water courses, consequently they are crooked, and in too many instances situated on private property. In later years the Government, through its Board of Works, constructed a number of sewers, varying from 12 to 24 ins. in diameter, without regard to any systematic plan. The pollution of the water front of the harbour and necessities of life demanded a better arrangement. Messrs. Kinipple and Morris, MM. Inst. C. E. of London, were again consulted, and prepared plans for a system of sewerage on the combined system. They proposed to collect the sewerage at a point in the eastern end of the harbour, and either discharge it there at the level of half tide, or raise it by pumping to a higher level and discharge it into the open sea. They strongly recommended the latter course, in which they were undoubtedly correct. Two outlets were proposed: one directly into the open ocean, by which plan the works would have cost £80,116 stg. ($390,165); the other at the entrance to the harbour at a rock locally known as the "chain" rock. By this system the works would have cost £74,886 stg., ($364,595). Their scheme proposed 19 miles of sewers. No action appears to have been taken on this report.

Some years after, in 1886, Mr. H. C. Burchell, M. Can. Soc. C. E., the Government engineer, was instructed to report on the sanitary condition of the city, which was followed up by another report from him in February, 1887, "on the subject of improved sewerage for the town of St. John's." Mr. Burchell went over the ground very carefully, and prepared an exhaustive and valuable report, in which he differed materially from Messrs. Kinipple and Morris, and recommended the separate system, leaving the existing sewers for storm water and surface water sewers. He selected his point of outfall at the chain rock. Under his proposal there were about 14½ miles of sewers, which he estimated to cost $205,875.

In March of 1889, the City consulted Mr. Rudolf Hering, M. Can. Soc. C. E., who prepared the scheme which is now being carried out. He recommended the Rawlinson system of small sewers, the principles of which are well known to the members of the Society. He adopted the chain rock as the permanent outfall. Under his directions, the City Engineer, the late Mr. C. F. Harvey, has worked out the details of the system. There are 15½ miles of sewers contemplated, at a cost of $272,183. Mr. Harvey added $75,000 for improvement of old sewers, culverts, superintendence, storage, etc., otherwise his estimate would not differ materially from Mr. Burchell's.

Copies of these three reports can be found in the library.

The intercepting sewer was calculated to receive as much roof water as the maximum quantity of sewage, which was assumed at 12.5 cubic feet per second, for 60,000 persons, on a basis of 75 gallons per head per day.

The grades are steep everywhere, except for the intercepting sewer on Water street, which is 1 in 1000. A portion of this sewer (and the most difficult portion), the outfall and the portion next to it, are now being constructed. About 2,000 feet are in tunnel work. The Huronian rocks are generally very hard, and form a good roof for the tunnel, which will dispense with the need of arching the culvert, except in a few places where the rock is much shattered, and pockets of loose earth are encountered.

A good many lateral sewers have been laid, which are temporarily connected to the existing surface water sewers. As the construction of the Water street intercepting sewer is completed, the several lines of branch sewers will be connected to it, leaving only storm water to escape into the harbour. The western portion of the city lies rather low, the intercepting sewer for it is also on Water street, with a temporary outfall into the harbour. It is intended eventually to raise this by pumps for a short lift, and discharge the sewage at the permanent outfall.

A temporary outfall has been selected at the eastern end of the harbour. The permanent outfall will be at the mouth of the harbour, at the "chain rock"; at which point the discharge will take place into a strong current and ensure perfect security. The outfall sewer will be in rock tunnelling for its entire length, and discharge 6 inches above low water mark: the cost is estimated at $35,000.

The ordinary range of tides is 3 feet 6 inches, extremes tides rise to 5 feet 3 inches.

TUNNEL.

The tunnel under Water street is 2000 feet long; six feet high by 4 feet wide, and 6 inches below the sole plate of invert block, to allow for a French drain. Being the first work of its kind, a good deal of experimental work had to be carried out regarding prices and mode of construction. The work was all hand drifted, and was let in short contracts to working miners, who each worked from a shaft. There are six shafts, the greatest distance between any two being 400 ft. and the average 320 ft. A great deal of difficulty was experienced from want of proper ventilation, which was eventually effected by placing a stove at the head of the shaft, and leading air pipes from the workings to it. Dynamite was used, the gases from which polluted the air in the drifts, acting injuriously on the workmen. This added to the dripping water and damp atmosphere caused several deaths among the workmen.

In addition to the hard and irregular formation of the rock, much trouble was met with from shattered roof rock, wet seams and loose earth.

Two surface water sewers caved in and one water pipe burst, flooding the workings. After battling for a considerable time with the water and pumping it, the eastern portion was abandoned and filled rapidly. This work was attended with great difficulties during construction, and is a satisfactory record to the energy, perseverance and engineering skill of the late Mr. C. Harvey.

TRENCHING.

In digging the trenches, benching is not used. The earth is thrown up at once from the bottom of the trench, when it does not exceed 9 or 10 feet deep, by long handled shovels—the blade is smaller and sharper in shape than the ordinary navvy shovel. The men acquire great skill in handling this shovel; its use could be profitably extended westward.

MATERIALS.

The City supplies all the materials required, as recommended by Mr. Harvey in his report; the contractors are called on to cut and fill in trenches, build brick work, etc. The City employs its own pipe layers.

The bricks were purchased in Boston, as there were no home-made obtainable. This year two firms have manufactured on an experimental scale; there is good clay within reasonable shipping distance. Some of the home-made bricks were first-rate, well shaped, hard-burned clinker brick, quite as good as the American article.

The sewer pipe is chiefly Doulton's make, and ranges from 9 to 24 inches. There are two qualities, the "London" and "Liverpool" Doulton. The first is a hard stoneware substance, with light yellow glaze, which so far has proved very satisfactory, cutting more easily and regularly than the other qualities. The other qualities are similar to the best grade of Ohio pipe. Scotch pipe has been used to some extent, they have not much of it in stock. All necessary fittings, such as channels, bends for manholes, half pipes, gulleys, junction blocks, are Doulton's make. The invert blocks of the same make have a large radius; the chord is 10 to $10\frac{1}{2}$ inches, ver. sin. 2 to $2\frac{1}{4}$ inches, which makes a large invert. The breakage on the pipes during shipment is very great, often 50 per cent., which adds greatly to their cost.

The cement is of two brands, English and Alsen. The latter, a German brand and a slow setting cement, gives great satisfaction and makes excellent work.

Under the Board of Works a good many sewers were laid, Scotch pipe being largely used. In one 12 inch sewer which had been laid for about 15 years, on a very steep grade, (1 in 8), it was found that no wear had taken place, the pipe being sound and hard, and almost as good as when laid. The large sized pipes, 18, 21 and 24 inches, break in the same manner as those described in Mr. Rust's paper,* on the axis of the pipe, at the crown and at the haunches.

MANHOLES.

The manholes are circular, 4 feet diameter at the bottom, tapering to 2 feet at the top, with junctions of sewers arranged according to "Rawlinson's suggestions." They are built in 8 inch brick work.

There are a few lampholes and inspection tubes.

Dirt baskets are suspended under each cover, which catch a large quantity of dirt.

SEWER INSPECTION.

Mr. Ryan, the sewer inspector, has succeeded in constructing an effective light, or lamp, for inspecting and locating junctions, with which he has located a junction at 68 feet from a manhole, in a 9 inch sewer. A float or boat of the radius of the sewer, and nearly half its diameter, carries a looking-glass reflector with a hood over it. The reflector is placed at 45° to the axis of the sewer, at a convenient distance from it the light is placed. By fastening it on a pivot, he is able to read right and left hand as desired. The boat is pushed up the sewer by means of jointed rods.

Manholes are examined weekly, dirt baskets cleaned, and in many cases sewers flushed from the hydrants. Automatic flushing cannot be introduced, as there is scarcity of water in many streets newly sewered.

During construction a careful record is kept of the depths of rock and earth, and the position of every manhole and junction for private drain connections is noted. After each sewer is completed a plan is prepared shewing the positions of the manholes and junctions, and on the same sheet a profile is plotted, giving the depths of cutting and depths of rock and earth passed through.

Whenever it is necessary to take up a pipe, either from its being defective or to put in a junction in its place, instead of stripping several pipes and trying to spring them, Mr. Ryan adopts the plan of cutting off one half of the flange. By cutting off the upper part of one flange or socket in the sewer, he can raise the pipe easily, and by cutting the lower portion of the socket of the pipe to be put in, he is able to replace a pipe without disturbing more than one pipe. The pipe is turned round and the broken part placed upwards; the defective sockets are

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* Construction of Toronto Sewers, by C. H. Rust, Vol. II, page 302.

made good with cement. He uses fire clay instead of cement in such places, and under water has found it to set and become effective when cement washed out. This is a novelty the writer has not met with in his practice, but the experience in St. John's has proved most satisfactory.

SEWER VENTILATION.

Although this forms a part of the general Rawlinson system, a word of explanation will be advantageous at this point: All sewers are laid in right lines, junctions are made in the manholes by curved channels formed of half pipes laid in cement. At all changes of alignment and grade, manholes in most cases and lamp holes in a few are placed. The writer tested this work in a great many sewers, and takes pleasure in bearing testimony to the excellent way the sewers have been laid. The lamp can be seen clearly from manhole to manhole. A special feature of this work is the avoidance of "dead ends" in the sewers. Allowances are made in every manhole for connections from side sewers to cause a circulation of air. This is the first sewerage system in which the writer has seen this excellent idea brought into practical use.

COST OF WORK.

The engineer's department has not had the advantage of experience gained by many years of work; it had also to deal with a hard and troublesome rock to blast. Prices of work done compare favourably with Ontario. Laborers get $1.00 per day; bricks cost $13.00 per M. and $6.00 per M. to lay them; bricklayers' and masons' wages are $2.30 per day; cement costs $2.70 to $3.00 per bbl. as imported by the Council. Pipe is much the same as Ohio pipe prices. Contract work: earth trenching 50 to 60 cts. per cubic yard; rock, from $2.50 to $2.60 per cubic yard. Day time: earth trenching 30 to 35 cts. and rock $1.90 to $2.00 per cubic yard. Tunnelling costs from $7.50 to $12.00 per cubic yard, including timber framing.

ROADWAYS.

The roadways are all macadamized, the surface is in good order, well kept up, and in their general condition the streets compare favourably with Canadian streets. Like all macadamized surfaces, they are muddy; still, the writer knows many western cities which are notorious for muddy streets.

Water channels are pitched with cobble stone. Kerbs are of a local slatey rock, 2½ to 3 ins. thick, and not very well dressed. The pitching of the water channels is well done, the stones are uniform, oval and well shapen.

Gulleys are of the old Board of Works pattern. As they are replaced, either the Doulton gulley or proper brick ones are used. It is necessary to have a good depth under the trap, to catch the mud and débris. They are constantly cleaned out. The city owns a ten ton Aveling & Porter steam road roller.

SCAVENGING AND STREET CLEANING.

No systematic arrangements exist for sweeping and scraping the surface of the streets, as in the present financial condition the revenue will not permit this to be carried out on a large scale. The scavenging is more directly carried out in the narrow steep streets and lanes which form the "poor" part of the city. The night soil is collected under the "pail system;" the pails are put out after 10 o'clock at night (22 o'clock). At midnight, the carts leave the stables to collect night soil, which they do in about 3½ hours; the horses are fed, start out at 4.30 to collect ashes, which takes the same time; then about 9 o'clock the carts again go out to collect garbage and sweep the streets, and finish about 12 o'clock. There are only 14 carts for night soil and 14 for garbage and 14 horses, which are hard worked under existing arrangements. The carts for night soil are of iron, semicircular, hung on trunnions, and self-tipping. The lid is held down by clamps, and in it is a manhole for emptying the pail. The carts are washed out at the stables every day.

The system of scavenging is well and ably managed and handled by Mr. Hughes, the inspector. The writer devoutly hopes that no steps may ever be taken to impair the efficiency and usefulness of this department. It is worked with the least offence to the citizens, and the very best results.

The night soil is carted to the adjoining farm lands, where it is covered during the day with garbage and street sweepings, the farmers frequently adding earth and peat bog to the mixture. There is a good demand for this material, and it is readily disposed of. During summer it is put on lands some distance from the main roads, and so far the work has been carried on without creating a nuisance. The work costs about $17,000 per annum, the city owning the whole outfit.

FLUSHING OF SEWERS.

It is a part of the sewerage plan to have flushing tanks introduced at proper points on all the sewers. This is not yet practicable, owing to the want of pressure and scarcity of water in the higher parts of the city, where much sewerage has been put in. All sewers are examined weekly, and flushed from the fire hydrants, and soon a system will be at work flushing them by automatic discharges filled from the waste water of the public fountains, as well as by direct supply in the way recommended by Sir Robert Rawlinson and Mr. Hering in his report.

SANITARY WORK.

The writer desires to record his appreciation of the excellent sanitary arrangements which exist. The nature of the subsoil has fortunately prevented the formation and use of privy pits, and compelled some form of removal of night soil. The record of the past is not flattering to the manners of the citizens, but since the present régime has been inaugurated a great change for the better has taken place. The sanitary department has had to deal with the poorer classes who have not the means to introduce water and sewerage into their houses. The apartments which serve as a domicile are from one to three rooms, there is not therefore accommodation for a closet. The custom of the country differs from Canada in the matter of house heating, the principles and practice being much more British than Canadian; and as a general rule, houses are not heated. In the very coldest weather, a small hall stove or "heater" tempers the atmosphere of the house, but so far as the writer can learn, can hardly be said to heat it. If this condition exists in the houses of the upper classes, it is useless to expect those of the lower to be warmed; therefore, even if water were introduced into their houses, it would certainly freeze.

The writer has had sufficient experience of sanitary work in Western cities to know what the condition of drainage in cheap houses leads to, the troubles caused by it, and the dangers to which inmates are subjected. In St. John's he finds a system of water supply from public fountains in full working order, the people accustomed to draw from them, and suffering no inconvenience from the arrangement; the slops emptied into well-formed and graded side channels, which are carefully swept every day, and in numerous streets flushed by the waste water of the fountains; a daily collection of garbage, and a nightly one of night soil. Here everything tends to internal cleanliness of the household, and no danger of dissemination of disease from sewage gas can exist from defective plumbing arrangements. On the other hand there is a certainty that if sewers were led into these houses, and any plumbing fixtures, especially water closets, introduced, there would be bad joints, stoppages, breakages in pipes, and resultant outbreaks of zymotic diseases. He therefore advised the Municipal Council to give frequent connections to the sewers by means of gullies, placed so as not to intercept surface water, for carrying away household water, to flush the sewers, and to continue the use and daily collection of night soil though the "pail" system.

The Board of Health, a body similar to the Provincial Board of Ontario or Quebec, is endowed with extraordinary power, which it does not hesitate to use. With such a mentor over it, the Municipal Council has small chance to relax its rules and regulations regarding the proper preservation of the public health.

The city has plumbing by-laws, based on the practice of large American and Canadian cities, which are perhaps too exacting for its present requirements. It will not be practicable to put fixtures into small houses renting under $40 per annum, when the plumbing by-law calls for self-flushing cisterns and water-saving appliances, and expensive cast iron soil pipes extending through the roof of the house. One certain result of these cold houses will be frozen pipes, traps, and other fixtures. To put in deep hoppers with the trap below the frost line, and flush them with the ordinary rim flush, will not answer, as the writer knows by experience. He favours and has suggested making a trial of a trough closet in a proper building under Municipal control, in which a self-acting flushing tank would discharge at short intervals—these closets to be common to a range of two or three houses, having compartments for males and females, and close by them he would place yard slop hoppers for the use of every two houses. By careful attention to these under the special exigencies of the city, he believes a successful solution of the problem will be arrived at.

APPENDIX No. I.

Average Rainfall for Eight Years.

	1873	1875	1876	1879	1880	1884	1887	1888
	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.
January	4.51	....	3.46	4.74	3.58	5.03	4.35	7.72
February	4.60	....	2.34	2.42	6.14	5.23	1.90	5.01
March	2.86	....	4.29	3.84	4.40	5.84	6.77	3.78
April	2.57	....	1.67	6.87	3.20	4.77	4.96	3.41
May	3.06	4.67	4.13	4.33	1.98	7.71	4.05	3.70
June	2.05	2.56	1.19	3.44	6.65	1.40	1.01	3.90
July	3.79	3.05	4.09	3.96	2.88	6.87	2.10	2.13
August	2.16	3.08	7.47	3.21	1.97	2.64	3.75	4.43
September	2.51	3.56	8.75	2.70	2.84	2.19	5.78	1.63
October	2.92	6.14	4.19	4.17	....	5.03	4.42	10.00
November	8.14	3.48	3.68	4.22	3.23	5.44	5.19	4.19
December	8.75	1.70	2.99	2.17	5.20	4.65	4.81	2.73
	47.92	28.24	48.25	46.97	42.07	56.80	49.09	52.63

GREATEST DAILY RAINFALL.

	1872		1875		1884		1885		1887		1888	
	Ins.	Hrs.	Ins.	Hrs.	Ins.	Hrs.	Ins.	Hrs.	Ins.	Hrs.	Ins.	Hrs.
January.......	....	....	....	....	1.17	13	0.82	7	0.66	9	....	....
February......	....	....	....	....	0.61	4	....	....	2.40	24	....	....
March.........	....	....	....	....	0.86	10	1.37	9	1.04	6	....	....
April..........	1.48	12	....	....	....	....	....	....	....	....	....	....
May...........	3.47	22	1.03	7	1.64	17	1.76	12	....	....	....	....
June..........	1.63	13	1.80	10	0.63	6	1.93	22	....	....	....	....
July..........	1.77	10	1.30	2	2.26 0.88	24 5	1.49	24	0.76	3	0.57	1.30
August........	1.22	....	....	....	0.88	4	0.91	....	....	....	....	....
September.....	2.16	14	....	....	....	....	....	....	....	....	....	....
October.......	3.71	8	....	....	1.14	12	1.48	12	....	....	1.20	3
November......	1.27	....	....	....	1.56 3.52	9 26	1.27	15	....	....	2.78	12
December......	2.07	15	....	....	....	....	...	..	....	....	....	....

APPENDIX No. II.

WINDSOR LAKE. DEPTH OF WATER OVER INLET PIPE.

Date.	Month.	Thickness of ice.	Low water levels.				
			Date.	Depth on inlet pipe		Depth on waste weir	
1862	Febr'y. 2	29 ins.	Sept. 1	6 ft.	6 ins.	4 ins.	Water turned on to town 16 June, 1862
1863	1	30		6	6	4	
1864	3	33		6	6	5	
1865	2	28		6	6	6	
1866	4	34		6	6	4	
1867	1	29		6	6	5	
1868	2	32		6	6	6	
1869	3	29		6	6	6	
1870	1	33		6	6	5	
1871	4	29		6	6	6	
1872	1	30		6	6	5	
1873	2	32		6	6	5	
1874	1	33		6	6	6	Water supplied thro' 24 inch pipe, Mr. Morris' plan.
1875	3	30		5	1		
1876	1	29		5	6		
1877	2	32		5	0		
1878	1	33		5	2		
1879	4	33		5	0		
1880	1	32		5	4		
1881	3	31		5	0		
1882	1	34		5	3		
1883	2	29		5	6		12 in. pipe added, Mr. Martin's plan
1884	1	30		4	0		
1885	4	29		4	4		
1886	1	30		4	2		
1887	2	32		4	0		
1888	1	34		4	3		
1889	5	29		3	10		
1890	3	34		3	9		

APPENDIX No. III.

CEMENT TESTS BY THE LATE MR. C. J. HARVEY.

Name of brand.	Neat cement.		Cement, 1 part. Sand, 3 parts.	
	Age in days.	Tensile strength.	Age in days.	Tensile strength.
		lbs.		lbs.
Alsen's Portland.				
Average of 4 samples.	7	416.5		
10 "			7	138
10 "	28	460.3		
13 "			28	188.9
English Portland. (brand not known)				
Average of 4 samples.	7	364.75		
6 "			28	123.66
TESTS BY MR. MACDOUGALL, OCTOBER, 1890.				
Alsen, in stock abt. 12 months. Average of 5 briquettes	8	300		
Whites, in stock 12 months. Average of 4 briquettes	8	188		
Whites, this year stock Average of 4 briquettes	8	198		

APPENDIX No. IV.

COST OF SEWERS.

Name of Street.	Diameter inches.	Depth feet.	Length feet.	Cost.		Cost per foot	Nature of soil.
Feavers Lane.. ...	9	5	186	76	90	$0.41.1	Hard gravel and rock.
Chapel Street......	6	5 to 7	200	133	63	0.66.8	" "
Darling Street.....	9	8 to 10	638	736	68	1.15.4	" "
Bacon's Lane......	6	4 to 7	108	51	12	0.47.3	" "
Knight& Carew Sts.	9	5 to 9	902	704	22	0.78	Gravel
Water Street West..	15 & 18	6 to 11	260	416	77	1.60	Hard gravel and rock.
Lazybank Road....	9	5 to 10	1425	1596	40	1.12	
Gower Street East..	9	7 to 9	134	228	63	1.70	
Dogstown.........	12	5 to 7	491	550	86	1.12	
Balsam Street.....	9 & 6	7 to 9	420	464	39	1.10.5	Hard gravel.
Brine Street.......	9	5 to 10	788	633	69	0.80.4	" " and rock.
Plymouth Road....	9	6 to 9	303	244	60	0.80.4	" " and boulder.
White Cat Hill....	9	5 to 6	135	82	90	0.61.4	Hard gravel.
Sanitary Stables...	6	6	117	46	65	0.39.8	Gravel.
Clancy's Lane......	9	6	20	11	20	0.56	Gravel and rock.
Haward Ave......	9	8 to 9	882	1319	27	1.49.6	Hard gravel and rock.
James Street.......	9	8 to 9	719	900	55	1.25	" "
Monkstown Road..	12	5 to 9	1290½	1440	97	1.11.7	" "
Fleming Street	9	7 to 9	421	467	36	1.11	" "
Maxse Street......	9	7 to 9	486	411	75	1.05.5	" "
William Street.....	9	7½ to 10	793	942	78	1.18.8	" "
Monkstown on Hall.	12	4 to 11	1176	996	20	84.2	Gravel.

DISCUSSION.

Mr. Walbank said, being a native of St. John's, Newfoundland, he had felt no little interest in learning that Mr. Macdougall proposed reading a paper on the sewerage and waterworks of that city. W. McLea Walbank.

The speaker said he would pass over the historical and geographical portion of the paper, and proceed at once to the technical portion. It was to be regretted that Mr. Macdougall did not furnish a plan of the town of St. John's, as without that it is almost impossible for others than those personally acquainted with its physical features to follow the paper.

In reference to the water supply, Mr. Macdougall unfortunately has only treated the subject in a cursory manner, referring more to existing defects than showing us any novelties, if any there be, in the system as laid down. It must strike even the unsophisticated that there is something radically wrong in a system of water-works showing a daily consumption of five million gallons for a population of thirty thousand people, equivalent to about 3,470 gallons per minute, which has to be carried through a 16 inch pipe, which means a velocity of about 153 feet per minute, entailing an immense loss by friction.

The author tells us that there is a dearth of water in the higher levels, and that he has made an examination of the cause thereof, and finds in 1890 practically the same cause as was found by Kinipple and Morris in 1873. The author has recommended certain ameliorations which he hopes will remedy the defects; but, unfortunately, he has not given us what his recommendations were. The speaker does not agree with Mr. Macdougall regarding the introduction of the latest modern improvements. He can see no reason why they can not be as well introduced into the houses, even of the poorer classes, with perfect safety. It certainly is not necessary that the poor of Newfoundland should be deprived of modern sanitary conveniences because they cannot afford to have their houses heated by furnaces. The speaker knows of houses in St. John's, N. F., that are heated only from hall stoves, and yet possess all modern sanitary improvements; besides this it must be remembered, that although a foreigner may feel the cold more in Newfoundland than in Canada, yet the thermometer never falls so low there as here, and even if the argument of house heating held good, few houses in Canada possess the modern improvements referred to.

SEWERAGE.

The want of a plan is much felt in order to follow intelligently Mr. Macdougall's paper. The speaker said he must admit that he was disappointed that the paper appears more in the form of a health officer's report than that of a paper on the sewerage of St. John's. This is to be regretted, as he knew of no town offering better advantages for a discussion on any system of sewerage. It is not of much interest to the readers whether the navvies threw up the earth with long-handled shovels with a smaller blade or used the ordinary type, or whether the town had much pipe in stock or not; but it would be decidedly interesting to have had a complete report with working plans of the system of sewers at present under construction, with the arguments in favor thereof. The contour of the town is rather peculiar, and presents many difficulties in the way of sewerage. The general fall is to the west, while the outfall lies to the east. If the question of utilization of sewerage for agricultural purposes be set aside, rapid disposal should be the next consideration; and taking it for granted that it is not the wish of the inhabitants to have their harbour converted into an elongated cesspool, an outlet into the Atlantic naturally presents itself as the most desirable method of disposing of the sewerage. Many schemes have at various times been proposed to effect this object, the two principal ones having their outlet at "Chain Rock" and "Quidividi." The speaker thought that a combination of the two might serve the best interest of the town. He took it, however, from Mr. Macdougall's paper that the "Chain Rock" outlet has been chosen. He disagrees with Mr. Macdougall when he says at this point the discharge will take place in a strong current, and ensure perfect safety. Pilots differ as to the strength of the tidal stream, but all agree that it is greatly influenced by the wind, and undoubtedly the larger portion of sewerage thus discharged will move in and out as the surface of the water takes it, except that portion the specific gravity of which would cause it to sink to the bottom. With an east wind, the floating sewerage would be carried up the harbour, and in certain seasons of the year, especially the spring, this is the prevailing wind from six to eight weeks at a time. The "Quidividi" outlet, while possessing some objections, has very many advantages. It would discharge the sewage straight to sea. It would provide for the drainage of the future growth of the town, possesses few engineering difficulties, and the outlet is more sheltered from the effects of ice and sea.

SCAVENGING AND STREET CLEANING.

In one portion of his paper, the author states that no systematic arrangement exists for sweeping and scraping the streets, and in another place, he states that at 9 o'clock the carts go out to collect the garbage and sweep the streets, and finish at 12 o'clock, proving a systematic if not a perfect arrangement. The speaker cannot see wherein St. John's possesses any excellent sanitary arrangements, as, judging from Mr. Macdougall's paper, it would not be pleasant, to say the least of it, to walk through the streets of St. John's after 10 o'clock, when the pails are out. Mr. Macdougall says the record of the past is not flattering to the manners of the citizens, but at the same time he devoutly hopes that no steps may ever be taken to impair the efficiency of this department. It is worked with the least offence to the citizens, and with the very best results. The speaker said he trusted for his part that the usefulness of the pails would soon be over.

CORRESPONDENCE.

Mr. J. Butler. Mr. Butler referring to the author's statement that "the quality of the water is good, soft, pure, potable water, well adapted to culinary and dietetic purposes. It is rather hard on steam boilers, pitting the shells and tubes severely."

Said that it would seem a contradiction of terms to include soft water and the corrosion of boilers in the same description. What is the chemical composition of the water ?

Ponds and small lakes on summits are found in various parts of Ontario. There is one at Glenora in Prince Edward county, 175 feet above Lake Ontario, and being 1,000 feet from the shore, the water being very deep. Another on the Oak Hills near Stirling. Another in the Thunder Bay district, in the vicinity of Fort William. As the watershed in the three instances is small, the source of supply is undoubtedly subterranean.

It seems to the writer that the city of St. John's in semi-arctic Newfoundland has shown a spirit of energy and enterprise that will bear favourable comparison with more favoured localities.

The table of cement tests shows for the Alsen's Portland an average of a good well-balanced cement.

The tests of White's Portland seem to indicate that a poor lot had been received.

Portland cement is now being manufactured in Canada.

The Rathbun Co.'s "Star" Portland cement is of the following composition :—

Calcium oxide	58.06
Silica	25.72
Alumina	7.09
Ferric oxide	3.73
	94.10

When taken freshly from the stones, still warm, and made into briquettes, and broken on a Fairbanks' standard testing machine, show, at the end of 40 days, 570 pounds tensile strength. An English company is also erecting a cement factory for the manufacture of Portland cement near Marlbank. Another company is erecting works in the vicinity of Kingston.

Mr. Macdougall, in reply, said that it was not possible, without entailing a larger expenditure than he could afford, to present a plan of the sewerage system. Mr. W. McLea Walbank's remarks show he did not read the paper carefully. For purposes of his discussion he could have found Mr. Hering's and other reports in the library. Without a large map any discussion of outlet would have been useless. Mr Macdougall

As to the quality of the water, it is undoubtedly soft, as soft as the Ottawa River water, yet it has corrosive action on boilers. This can be found in several streams in the North West Territory, where water coming from the glaciers is contaminated by alkali from the plains, being brought in by the coulées and small streams, and makes a perfectly soft water with alkali action on boilers.

Thursday, 24th April.

J. KENNEDY, Vice-President, in the chair.

Paper No. 52.

MINING IN BRITISH COLUMBIA.

By Thos. Drummond, B.A.Sc.,

A.M.Can.Soc.C.E.

Before the discovery of gold in British Columbia, or what afterwards became known as that province, it was a comparatively unknown country, under the control and government of the Hudson's Bay Company, whose interests were bound up in the fur trade, and in that alone. In 1849, the Company's headquarters were removed from Fort Vancouver, on the Columbia River, to Fort Victoria, on Vancouver Island, which had been established in 1843. In 1851, James Douglas was made Governor of the Colony, vesting in his person the authority both of the Hudson's Bay Company and the Colonial Government. In 1856, Vancouver Island was divided into four electoral districts, and seven members were elected. At this time the united white population of the island was about 300. After the discovery of gold on the mainland in 1857, and the consequent rush to the new country, Douglas was forced, by the increased responsibility of government caused by the conflicting interests of the fur traders and gold miners, to resign his position as head of the Hudson's Bay Company, which he did in 1859. In the same year the Imperial Government re-purchased the exclusive right of the Hudson's Bay Company to trade, and the Company, as a monopoly, ceased to exist on the Pacific Coast. In 1858, the Colony of British Columbia was created, and Douglas became its first governor.

The discovery of gold then marks a new era in the history of the country, and though the stirring events of that time are now things of the past, still they are not without interest, for with them began the real history of the province, which, from being a country comparatively unknown, was raised to the dignity of being one of the great gold-producing centres of the world.

People by the thousands and tens of thousands rushed to its shore, and in their search for the precious metal also discovered the capabilities of the country; so that, after the gold excitement, many settled down, and formed, so to speak, the nucleus of the future growth and prosperity of the province.

In the first part of this paper, then, the author proposes to give a history of the more important discoveries of gold, and the dates at which they occurred, and also a short description of the methods adopted in separating the gold from the alluvial washings in which it is found.

Before going on with the paper, it is right to state that, in the absence of actual statistics, the subject matter of this paper has been obtained from the most reliable sources available. In many cases from personal observations, and, where this was impossible, from miners and others who actually worked at the places to be mentioned later on—men to whom the author is greatly indebted for information, and whom he knew personally to be little given to exaggeration. Statements were verified by comparisons when possible, and different authorities who had written upon the subject were also consulted, such as Dr. Selwyn, Dr. Geo. Dawson, and other members of the Geological Survey of Canada, Bancroft's History of British Columbia, Sessional Papers and Reports of the Provincial Government, J. W. McKay, and many others; so that, though the information and figures given are not in the nature of actual statistics, still they are near approximations of these taken from the most reliable sources. This is mentioned because reliable information upon this subject is difficult to obtain, and were all statements accepted this would read more like fairy land than what the author wishes it to be: a sober history of events which have occurred in the history of British Columbia, and which there is every reason to suppose will be repeated in the near future in a more permanent form when the discoveries in quartz, even those already made, have been sufficiently developed to shew their value.

For convenience, the subject has been divided into

(1) Placer Mining.

(2) Vein Mining.

The first authentic discovery of gold in British Columbia, or what afterwards became part of that province, was at Gold, or Mitchell's Harbour, on Queen Charlotte's Island, in 1851. The discovery was in the form of a nugget weighing about five ounces, found on the seashore by an Indian, who sold it to the Hudson's Bay Company. A vessel was shortly afterwards sent out by the latter to examine the locality, resulting in the discovery of a small vein of quartz containing gold, from which it is estimated that ore to the value of $20,000 was obtained by the Hudson's Bay Company and other adventurers. The deposit then proving limited, it was abandoned. About the same time, or a little earlier, Mr. McKay also found colours of gold at various places on Vancouver Island, between Victoria and Nanaimo, when exploring for land.

Hudson's Bay Company's Journals also state that in 1852, Indians brought samples of gold from the Skeena River. G. B. McClellan's party also discovered gold on the Similkameen River in 1853, when engaged on exploratory surveys for the Northern Pacific Railway.

Gold was also discovered at Pend d'Oreille by Colville men in 1854 or 1855, and worked with success, and the finding of gold in British Columbia was a direct result of this discovery, for Indians from the Thompson River, visiting their friends near Walla Walla, stated that gold like that was found in their country. Accordingly, some French Canadians and Indians crossed over and discovered paying placers in the vicinity of Nicoamen, on the Thompson River, in the fall of 1857. The news spread and caused the Fraser River excitement of 1858. California was at this time filled with a mining population, attracted there by the gold excitement of 1848 and 1849, and when the authentic discovery of gold on the Fraser River became known, a perfect rush was made for the new El Dorado. From thirty to thirty-five thousand people are said to have come into the province early in 1858.

Many of these became discouraged and turned back, but those, however, who did reach the Fraser River, pushed their way onward and found gold in paying quantities on the bars and tributaries, from the mouth of Harrison River up both the Thompson and Fraser Rivers as far as the season of 1858 would allow them to go. Some of the more important of these bars were as follows:—Maria, Hudson, Cornish, American, Union, Cameron, Emory, Texas, Hills, Sailor, Wellington, Spuzzum, Chapman, Nicaragua, Boston, Yankee, Mariner's, Lytton, Mormon, Foster, Lillooet, French, Robinson, Upper Mormon, British, Ferguson, and Long Bars.

Of these, Hills Bar, just below the town of Yale, may be taken as an example of the richest. It is reported to have produced $1,000,000 worth of gold during the excitement, from an area of less than half a square mile, and from a report of the Minister of Mines in 1875, it is credited with having produced up to that time $2,000,000. On this bar four men washed $4,000 in six days. Ned McGowan, of historical fame, took out $33,000 in three months. It is also said that the present site of the town of Yale with the flat opposite would yield a large amount of gold if worked by hydraulic power, and I understand that a company is now being formed with that object in view. The gold in the bars especially below Yale was fine, and in shallow ground, and at first they were only mined a little below the surface of the river, and in the most primitive manner with pick, shovel, rocker and pan, and yielded, when worked even in this way, large returns of gold. Between Yale and Hope one rocker yielded $830 in eight days, another $800 in twelve days, and a third $248 in five days, and at Yale 150 rockers gave in one day 723 ounces. Sailor Bar is said to have averaged one ounce a day per man, and two to five ounces was quite common. As the surface of the bars was washed out, wing damming was resorted to, where possible, to reach deeper ground. Many flumes and ditches were also built to carry water to the benches along the river; they varied in length from one to fourteen miles, and cost many thousands of dollars. Water wheels were also built, one below Cornish Bar being 30 feet in diameter.

These pioneers and prospectors had many difficulties to overcome in making their way up to the new diggings. At first there were no steamers to the mouth of the Fraser, and afterwards when there were, a great many were unable to pay their way, so they went from Victoria to the mainland in canoes and small craft built by themselves, and many were lost in the dangerous tide rips and currents of the coast. Early in 1858, it was found that the Fraser River was navigable as far as Yale, which became the distributing point for the upper country. Beyond this, the country was rough, mountainous and comparatively unknown, and travelling by land and water was hard and laborious work. Supplies were scarce and difficult to transport, and the Indians for a time were hostile. Is it strange then that many became discouraged and turned back? The wonderful thing is, that so many succeeded in forcing their way onward through so many difficulties and dangers.

In the fall of 1859, rich diggings were discovered on Quesnelle River, and this stopped the onward march for a time.

In 1860, Keithley Creek was discovered, and this marks a renewed era of prosperity in mining, for with it was discovered the famous Cariboo District, one of the richest placer mining centres ever found.

In the winter of 1860 and 1861, miners discovered Antler Creek. They tried to get a grant of this stream from Governor Douglas in Victoria, but it was refused. The news became known and caused a second influx of miners, this time to the Cariboo District. During the same year (1861) William's, Grouse, Lightning, Jack of Clubs, Lowhee and other creeks which have since become famous, were discovered. Of these, William's, Grouse, and Lightning were the richest. These creeks with their tributaries yielded, up to the end of 1861, some $2,000,000.

William's Creek was discovered by William Dietz, better known as Dutch Bill. He located in the cañon, and his claim, though the Discovery, turned out to be one of the poorest on the creek. Other owners located ground along the creek about the same time. The ground was supposed to be shallow, the yield of gold was poor, and the creek was known for a time as Humbug Creek. The first run of gold was found in shallow ground over a stratum of blue clay. To test below this, Abbott & Co. sunk a hole 4 x 7 feet and took out 57 ounces of gold, and the other companies soon followed their example. Deep ground was located in an old channel behind the cañon and also below it by Black Jake, Barker, Cameron, and others, and Barkersville, Cameron Town, and Richfield were started. Starting at the head of the stream and going downwards, some of the claims were as follows:—

Steele & Co.,	Lillooet Co.,
Point Claim,	Forest Rose,
Abbott & Co.,	Cameron & Co.,
12 Foot Davis,	Tinker Co.,
Adams & Wilson,	Raby & Co.,
Casto & Co.,	Caledonia Co.,
Dutch Bill,	Grizzlie Co.,
Diller & Co.,	Never Sweat Co.,
Canadian Co.,	Ballarat Co.,
Welsh Co.,	Prince of Wales,
Wake Up Jake Co.,	Sheepshead,
Cariboo Co.,	Coonskin,
Aurora,	—and others.

As may be seen from the following examples, William's Creek was immensely rich. Diller is said to have taken out 202 lbs. of gold in one day, with only two men drifting: this represents about $38,784. Steele & Co.'s claim yielded on two consecutive days 387 and 409 ounces of gold, and in two months, $105,000. The Cunningham claim averaged 125 ounces of gold for the season of 1862, and on several occasions gave 600 ounces, or 50 lbs. a day. The Adams claim yielded each of its three owners, $40,000. The Caledonia gave for a time $5,000 to $6,000 a day, and the Cameron and Tinker were not far behind.

The Raby, in one day, yielded 310 ounces of gold as witnessed by Milton & Cheadle. The Point Claim yielded $90,000 in dividends.

The Wattie claim, $85,000. The 12 foot Davis, a gore between two other claims, $25,000. Diller took out $100,000. Cariboo Cameron, $160,000. In 1863, three claims below the cañon produced $300,000, and 20 claims were steadily producing from 70 to 400 ounces per day. In the Aurora one pan of picked dirt is said to have yielded 387 ounces, and $600 to $900 to the pan was obtained on several occasions. The Erricson claim, according to Victoria *Colonist*, produced for seven consecutive weeks, between June 17th and July 29th, 1864, as follows:—900, 640, 1,400, 1,926, 1,256, 1,300, and 2,600 ounces. Two miles of creek is said to have averaged $1,000 to the running foot, and that this is within possibilities may be seen from the following statement:—

Adams' Claim	100 feet	$	120,000
Steele "	80 "		120,000
Diller "	50 "		240,000
Cunningham "	500 "		270,000
Burns "	80 "		140,000
Canadian "	120 "		180,000
Never Sweat "	120 "		100,000
Moffat "	50 "		90,000
Tinker "	140 "		120,000
Watty "	100 "		130,000
	1,340		$1,510,000

—or say $1,127 per running foot of creek.

Next in importance and richness was Lightning Creek, also discovered in 1861. For a time the annual yield is said to have been larger than on William's Creek, but it was not so lasting.

In 1861 the Campbell & Whitehall adjacent claims yielded $200,000, and Campbell is said to have taken out 1700 ounces of gold in 3 days as follows:—1st, 900 ounces; 2nd, 500 ounces; 3rd, 300 ounces. In 1870 the deep channel was bottomed, leading to the subsequent discoveries. At one time the Butcher, Aurora and Caledonia claims yielded respectively as follows:—Butcher, 350 ounces per day; Aurora, 300–600 ounces per day; Caledonia, 300 ounces per day. The old channel was worked for a distance of 16,000 feet, and is said to have yielded $300.00 to the running foot. The following statement, taken from the report of the Minister of Mines for 1875, showing the yield of some of the more important claims, will give some idea of the amount produced by this Creek:—

Campbell & Whitehall	$200,000.00
Dutch & Seegel	130,000.00
Dunbar	30,000.00
Lightning	153,962.00
Discovery & Butcher	120,000.00
South Wales	141,531.00
Spruce	99,908.00
Point	136,625.00
Van Winkle	363,983.00
Victoria	451,642.00
Vancouver	274,190.00
Vulcan	56,955.00
Costello	20,476.00

A statement obtained by the author from miners, and supposed to give the total yield, is also given. The figures are much larger, and are perhaps exaggerated, though given for a later period than the above:—

Van Winkle	$600,000.00
Victoria	600,000.00
Vancouver	300,000.00
Point Claim	180,000.00
South Wales	200,000.00
Lightning	220,000.00
Butcher Bench	250,000.00
Dunbar Flat	150,000.00
	$2,500,000.00

Grouse Creek was also very rich. Mr. Heron, the discoverer of the famous Heron lead, says that his company took out from 100 to 400 ounces per day, and made $300,000.00. The old channel was followed for about a mile, giving immense yields, and was then lost.

Antler Creek also yielded a large amount of gold, both from the benches and gulches, and also from the bed of the stream. The gold was taken from shallow ground, as the stream was never bottomed. One company made $83,000.00 in 3 weeks. The creek yielded $10,000.00 a day for some time in 1861, and some spots are said to have yielded as much as $1,000.00 to the square foot. Besides these, there were Jack of Clubs and Lowhee Creeks, and all the tributaries, gulches and ravines of the above streams, which, though not so rich, yielded in the aggregate a large amount of money and many independent fortunes.

Some of these were as follows:—Van Winkle, Chisholm, Last Chance, Davis, Anderson, Harvey, Cunningham, Cedar & McArthur's Creeks, and numerous gulches, ravines and valleys.

These deep placers, however, were expensive to open before any return was obtained, and the actual working expenses were also heavy. The Van Winkle mine cost $40,000.00 to open before the channel was reached; it yielded a large amount of gold afterwards, however, 3 consecutive weekly clean-ups being as follows: $15,700.00, $14,000.00 and $12,000.00. Cunningham Claim cost $100,000.00 to open work, and yielded $500,000.00. The California Claim, about the same cost and yield, also the Tontine. The Black Jack cost about $50,000.00 to open and work, and yielded $200,000.00. In Raby & Co.'s claim the pay roll for 2 weeks is said to have amounted to $12,000.00. Mr. Heron, the discoverer of the famous Heron Lead on Grouse Creek, says that their weekly pay roll amounted to from $1,200.00 to $2,300.00. The great expense of working can easily be accounted for. The pay dirt was deep, all the way from 30–90 feet, large pumps were required to keep the water down, often long bed rock ditches for discharging water were required, and expensive timbering was also necessary.

The timber, which was massive, cost 8c. per running foot, and lagging $7 a hundred pieces. The District was also far removed from any civilized centre, and provisions, supplies and transport were expensive, as may be seen from the following statement, which may be taken as an example of the highest prices paid at Cariboo at any time.

Flour	$1.50	per pound
Bacon	1.50	"
Tea and Coffee	3.00	"
Sugar	1.50	"
Beef (fresh)	0.60	"
Beans	0.75	"
Nails	0.75	"
Boards	0.25	per foot
Gum boots	$30.00 to $50.00	a pair
1 spool thread	$0.50	
1 clay pipe	$0.50	
1 needle	$0.50 to $1.00	
Wages per man per day	$10.00 to $16.00	

Packing from Quesnelle Mouth to William's Creek by man power cost from $0.85 to $1.00 per lb.

Exorbitant freight rates consequent upon the inadequate preparations for the great rush were the causes. "It is not the first cost of the goods," said a trader to a miner, when selling him a darning needle for a dollar; "it is not the first cost of the goods, mine friend, it is the freight."

The distance to Cariboo via Harrison River was 520 miles. Lillooet was the headquarters for the pack trains, which were inadequate to accommodate the great numbers, who, therefore, had to resort to all kinds of devices, packing on the back, with dogs and with oxen. Mr. Cannel, who is well and favourably known at Kamloops, told me that he bought an ox at Lillooet, which was the first pack animal to go into William's Creek, where it was killed, dressing some 900 lbs., and sold for 60c. per lb. Camels were also imported for packing purposes, one of which was still alive, and to be seen not far from Kamloops in 1887. The wagon road to Cariboo was finished in 1865. Stages were run, carrying passengers, mail and express, and easier access and cheaper supplies were the result.

The telegraph line was also bought by the Provincial Government about the same time. This telegraph line is famous, for it formed part of the line built by the Western Union Telegraph Co., which was to have crossed at Behring's Strait, and which was rendered useless as a transcontinental line by the successful laying of the Atlantic Cable.

A somewhat detailed description of the Cariboo District has been given because it was the most important of the British Columbia discoveries, and it gives, at the same time, a good example of typical life at a successful mining camp. As might be expected, lawless characters congregated, and gambling and kindred vices were prevalent. A Spanish packer, being asked if the Cariboo diggings were rich, answered that he had doubted it till he saw $27,000.00 gambled away in one sitting by three miners. But wise, just and capable men were in charge, and not a single case of murder is said to have occurred in Cariboo, which is an agreeable contrast to the scenes enacted at the mining camps in the neighbouring Republic. Chief Justice Begbie was a terror to evil-doers, to whom sure and speedy punishment was administered. Crime became comparatively unknown, and fire arms were practically discarded. This is all the more surprising, when we consider that the yield of gold was measured, not by the ounce, but by the pound; it became so plentiful that it was troublesome to guard, and miners returned ragged and rough, with so much gold that men and mules had to be engaged to transport it. According to Macfie's estimate of those who went to Cariboo in 1861 one-third made independent fortunes, one-third made several thousand dollars; and one-third returned unsuccessful.

During the Cariboo excitement, mining camps of less importance were almost depopulated, and were only worked during later years when the Cariboo excitement had subsided. Among these were Tranquille Creek, Louis Creek, Jamison Creek, Barrière River, Adams River and Lake, Deadman River, Nicola River, Scotch Creek, and, in fact, nearly all the streams running into the Thompson River in the vicinity of Kamloops. They were discovered principally in 1858 and 1859, and, in many cases, have been worked almost without intermission ever since, principally by Chinese.

ROCK CREEK AND SIMILKAMEEN DISTRICT.

Discovered in 1859 and 1860, and mined to some extent at that time and then abandoned for Cariboo.

Between 1882 and 1888, mining was renewed, and many new discoveries made. The principal streams worked up to date are as follows:—

Similkameen River,	Cedar Creek,
South Fork, Similkameen River,	Slate Creek,
Whip Saw Creek,	Bear Creek,
Nine Mile Creek,	Rock Creek,
Tulimeen River,	Boundary Creek,
Granite Creek,	Mission Creek,
Collins' Gulch,	Cherry Creek.

This district yielded between 1885 and 1888, $553,500, out of which Granite Creek produced $383,000. The latter creek was discovered in 1885, and caused quite an excitement for a time.

Cherry Creek also yielded well, and has been worked almost without intermission ever since; in later years, principally by Chinese. The author saw a piece of ground in this stream which had been worked over three times in seven years, and was then, according to Chinamen working there, yielding from $3 to $5 a day per man.

EAST AND WEST KOOTENAY DISTRICT.

First discovered in 1863. In 1865, 1,000 miners at work, getting from one to three ounces a day per man. The yield between 1874 and 1888, after the more successful days, was $582,878. This also includes returns from the Big Bend country.

The principal streams were:

Wild Horse Creek,	Toby Creek,
Bull River,	Cañon Creek,
Findlay Creek,	Quartz Creek,
Dutch Creek,	Perry Creek.

The streams were discovered at various times between 1863 and 1888. Wild Horse Creek produced, between 1878 and 1888, $255,780.

BIG BEND DISTRICT.

The principal streams mined were as follows:—

French Creek,	Carnes' Creek,
McCulloch's Creek,	Smith's Creek,
Downie Creek,	Fernie Creek.

It was discovered in 1865, and the principal mining was carried on in 1866, and in that year French and McCulloch's Creek each produced about $100,000, and four, six, and twelve ounces per day per man was not uncommon. One nugget worth $253.00 was found.

OMENICA REGION.

Discovered in 1869. The principal streams were:

Vital Creek,	Lost Creek,
Silver Creek,	Black Jack Gulch,
Omenica River,	Finlay River,
Germanson Creek,	Bars on Peace River.
Mansen Creek,	

This district produced between 1874 and 1888, $350,000. This does not include the first and more prolific years, the yield of which is unknown.

CASSIAR DISTRICT.

The Stikeen River was first discovered in 1861 and worked for a time, but not with great success.

Cassiar proper was discovered by Thibert and McCulloch, who came overland from the Red River country. The district yielded, between 1873 and 1888, about $5,200,000. The principal streams were:

Dease Creek,	Walker's Creek,
Thibert Creek,	Snow Creek,
McDames' Creek,	Quartz Creek,
First North Fork of McDames' Creek.	

Miners went to Cassiar by ocean steamer from Victoria to Fort Wrangell, at the mouth of Stikeen; then up the latter river for a distance of 150 miles to Glenora Landing by river steamers. Then across an 80 mile portage to Dease Lake, where a small steamer had been built.

The Stikeen River runs within three miles of Dease Lake; but it is not navigable on account of the great cañon of the Stikeen, about 90 miles long.

A trail was cut from Quesnelle Mouth to Dease Lake, a distance of about 425 miles. During the first year, freight across the 80 mile portage was 50 cents per pound, and poor pack-horses cost $250 each.

YUKON DISTRICT.

Though this is beyond the boundary of British Columbia, it has been included here because its discovery is due to a great extent to the miners from Cassiar.

The principal streams are:

Sayyea Creek,	Ross River,
Finlayson River,	Stewart River,
Lewes River,	Forty Mile Creek,
Big Salmon River,	Sixty Mile Creek.
Upper Pelly River,	

Rich diggings have been discovered, but, owing to the remoteness of the district, difficulty of obtaining supplies, and shortness of the season, it has not been worked to a great extent as yet.

SKEENA RIVER AND STREAMS OF THE COAST RANGE.

These include:

Skeena River,	Lorne Creek,
Seymour Creek,	Bones Gulch,
Prospect Creek,	Douglas Creek.

Lorne Creek was the best, and produced as follows:—In 1884, $17,000; 1885, $18,000; and in 1886, $12,000.

VANCOUVER ISLAND.

Leech River,	Nanaimo River,
Sooke River,	San Juan River,
Jordan River,	Cowachin River,

were the principal streams; of these, Leech River is said to have produced $150,000, and Jordan River about $35,000.

A tabular statement from Mineral Wealth of British Columbia, shewing the total estimated yield of gold between 1858 and 1888, is as follows:—

GOLD PRODUCTION.

TABLE shewing the actually known and estimated yield of gold, the number of miners employed, and the average earnings per man, per year, from 1858 to 1888, in the Province of British Columbia.

YEAR.	Amount actually known to have been exported by Banks, &c.	Amount added to represent gold carried away in private hands.		Total.	Number of Miners employed	Average yearly earnings per man.
	$		$	$		$
1858 (partial return.)	543,000		......	*705,000	3,000	235
1859...........	1,211,304	1-3rd	403,768	1,615,072	4,000	403
1860...........	1,671,410	"	557,122	2,228,543	4,400	506
1861...........	1,999,589	"	666,529	2,666,118	4,200	634
1862...........	1,992,677	"	664,226	2,656,903	4,100	648
1863...........	2,935,172	"	978,391	3,913,563	4,400	889
1864...........	2,801,888	"	933,962	3,735,850	4,400	849
1865...........	2,618,404	"	872,801	3,491,205	4,294	813
1866...........	1,996,580	"	665,526	2,662,106	2,982	893
1867...........	1,860,651	"	620,217	2,480,868	3,044	814
1868...........	1,779,729	"	593,243	2,372,972	2,390	992
1869	1,331,234	"	443,744	1,774,978	2,369	749
1870...........	1,002,717	"	334,239	1,336,956	2,348	569
1871...........	1,349,580	"	449,860	1,799,440	2,450	734
1872...........	1,208,229	"	402,743	1,610,972	2,400	671
1873...........	979,312	"	326,437	1,305,749	2,300	567
1874...........	1,383,464	"	461,154	1,844,618	2,868	643
1875...........	1,856,178	"	618,726	2,474,904	2,024	1,222
1876...........	1,339,986	"	446,662	1,786,648	2,282	783
1877...........	1,206,136	"	402,045	1,608,182	1,960	820
1878...........	1,062,670	1-5th	212,534	1,275,204	1,883	677
1879...........	1,075,049	"	215,009	1,290,058	2,124	607
1880...........	844,856	"	168,971	1,013,827	1,955	518
1881...........	872,281	"	174,456	1,046,737	1,898	551
1882...........	795,071	"	159,014	954,085	1,738	548
1883...........	661,877	"	132,375	794,252	1,965	404
1884...........	613,304	"	122,861	736,165	1,858	396
1885...........	594,782	"	118,956	713,738	2,902	246
1886...........	753,043	"	150,608	903,651	3,147	287
1887...........	578,924	"	115,785	693,709	†2,342	296
1888...........	513,943	"	102,788	616,731	2,007	307
1889...........	490,769	"	98,154	588,923	1,929	330
1890...........	412,029	"	82,406	494,436	1,342	423

Total known and estimated yield of gold, 1858 to 1890..	55,192,163
Average number of miners employed yearly	2,706
Average earnings per man per year......................	607
This does not include yield of Silver from Quartz.	
Mines in 1889-90 amounting to.....	$122,000.00

* Waddington's estimate.

† Exclusive of a number of men working on or prospecting for quartz.

From it, the total yield of gold is $55,192,163. Assuming that the average value of the gold was $16.75 per ounce, this gives 3,295,055 ounces, or 274,600 lbs., and, taking the specific gravity of the gold as being 16, a cubic foot weighs 1,000 lbs. This gives 274.6 cubic feet, or it may be represented by a solid pyramid, with a square base, whose sides are six feet and height 23 feet.

Of this amount, Cariboo is credited with producing about one-half. According to this statement, the average earnings per man, per year, for thirty-three years, was $607. Another average is from 1,200 miners, who crossed the bridge at the mouth of the Quesnelle early in 1861. Twenty soon returned, discouraged; the remainder returned in the fall, bringing down as their season's earnings, $1,500,000—or say, an average of $1,272 each.

From the foregoing you may, perhaps, imagine that placer mining has ceased in this province; this, however, is not the case—it has certainly fallen off from the yields in the palmy days, but, as may be seen from the statement, it still produces annually nearly $800,000 worth of gold.

The shallow placers are, of course, practically exhausted; but, with better roads, cheaper supplies, improved machinery, and the method of working by hydraulic power, the miner still obtains a good return for his labours, and will for many a year.

There is little doubt, also, that during the course of the next few years much of the deep ground in the Big Bend, Kootenay, Similkameen, Cassiar, Cariboo, and other districts, which, from its remoteness, was abandoned during the early days, will be tested and yield rich returns.

It is quite in the region of possibilities that new and rich placers may be discovered. The district between the head waters of the North Thompson and Cariboo is looked upon as being one of great promise.

Dr. Geo. Dawson, and other authorities of the Geological Survey, also consider that it is quite possible, if not likely, that rich placers may be discovered belonging to older formations and periods than those which have been worked. Such, for instance, as the extensive gravels of the Middle Tertiary, which were afterwards covered by basalts and other igneous rocks, and there is reason to suppose that the modern placers have been considerably enriched by the robbing of these old gravels. Still older conglomerates, as far back as those of the Carboniferous, have been successfully worked in several countries. These considerations are not merely of a theoretical nature, but are warranted by experience gained in California and other localities in the United States, in Australia, in New Zealand, and in Nova Scotia.

This part of the paper has been treated more in detail than was first intended, but it deserves attention because, as far as the author is aware, it is not generally known that the Province of British Columbia has and still is producing gold in such quantities; and, in view of the discoveries of quartz within the past few years, it is only fair that attention should be directed to this point.

Before going on with the paper, it is, perhaps, not out of place to say a few words regarding the origin of the gold in the sand and gravel.

One theory is that, through the action of *organic acids* and *alkalies*, the gold is brought into a state of solution, and in this condition is carried by streams to other localities, where it is re-precipitated in the form of nuggets by organic matter, such as fragments of coal, etc. In a geological sense, then, gold may be, and probably is, largely distributed in this way. The usual theory, however, is that, through the agency of air, frost, etc., pre-existing vein matter and rocks containing the gold became decomposed and destroyed, and the indestructible gold is then deposited in a concentrated form in the various localities, where it has been found by the following agencies:

(1) The present system of water courses.

(2) Older systems of water courses, following the same general directions as the present systems, and in many places coinciding with the latter.

(3) Still older water systems.

(4) By the action of glaciers.

By these agencies, then, the gold is deposited with varying richness in many localities. In the beds of modern streams, in the older channels, on benches, in gulches, valleys, and ravines; sometimes near the surface, but often deeply buried under barren soil or igneous rock. Being found under so many varying circumstances, much must be left to the ingenuity of the miner. The general principles, however, for working are about as follows:—

METHODS OF WORKING PLACER MINES.

The following tools, appliances, and requisites are used in one form or another in placer mining, though, in individual cases, all may not be required. A plentiful supply of water, picks, shovels, axes, drills, hammers, crowbars, wheel-barrows, hoisting bucket, rope, nails, magnet blow-pipe, cross-cut saw, whip saw, small car, miners' pan, cradle, quicksilver, pumps, derricks, water-wheels, sluices, wing dams, etc.

Most of the above appliances are in such general use that a description is unnecessary; with the following, however, it is not out of place:—

The *Miner's Pan* is made of pressed sheet iron, is circular in form, about $9\frac{1}{2}$ inches in diameter on the bottom, 16 inches on the top. and 3 inches deep. It is used for separating the gold from the gravel by a sort of circular motion, given to it in water, the pan at the same time being held in a sloping position. By this means the lighter sand and gravel drops over the lower side, while the black sand and gold remains behind. The remainder is then dried on a shovel or fry-pan in the fire, and the black magnetic sand is then removed with the blowpipe and magnet. The pan is also used for cleaning concentrates from sluices and cradle, and also for washing gold amalgam where mercury is used. It is especially useful as a prospecting tool.

The *Cradle* or *Rocker* is also of more importance as a prospecting tool. It is a rough wooden box, say 40 inches long, 20 inches wide, and 20 inches deep. On the bottom it is fitted with rockers like a baby's cradle, and it is slightly inclined, say two to four inches. At the upper end, and on the top, is a hopper, or coarse sieve, into which the gravel is thrown. The finer portion of the latter passes through and falls into the apron usually made of blanket. On the bottom, below the apron, riffles are placed, and the lower end is left open. The dirt is shovelled into the hopper, water is poured in with one hand, while the rocking motion is given with the other hand. The fine dirt and gold passes through, some of the gold is caught in the nap of the blanket, the balance on the riffles, while the water and waste dirt runs out at the lower end. The following is a sketch shewing a section of the rocker.

A *Puddling Box* is sometimes used, especially if there be much clay. It is a box of any size, and has an auger hole about four inches from the bottom. The auger hole is plugged, the clay put in and puddled with plenty of water. The water and suspended clay is then run off through the hole, leaving the black sand and gold as before.

The *Wing Dam* is to turn the water from the claim. It starts at the head, runs in a slanting direction across the stream till about one-half is taken in, and then runs straight down for the remaining distance. The whole is weighted with heavy stones to keep it in place, and filled with soil and gravel to make it water-tight. It is built of timber. The space behind the dam is then worked down to bed rock, and the dam is finally changed over to the other side, which is worked in the same way.

The *Water-Wheel* is used for hoisting purposes and for pumping water. In shallow places it is an undershot wheel, projecting over the side of the dam into the water, and running the pump which is attached to it on the inner side.

The *sluice boxes* are made from boards which are generally sawn by the miners themselves with the whip saw. The planks are usually 12 feet long and 1 to 2 inches thick. These are formed into boxes 16 to 20 inches wide and 12 inches deep for ordinary placers, and larger for more extensive workings. They are made a little narrower at one end so as to fit into each other, and soon become water-tight. These boxes are then set in strings supported on trestles, and are given an inclination of from 2 to 10 inches per box of 12 feet, depending upon the character of the gravel and gold, and the available grade which can be given them.

The boxes are provided with riffles of various forms to catch the gold, which is generally coarse; quicksilver is therefore not much used. Where fine, both quicksilver in the crude state and amalgamated plates are used.

Placer mining may be divided into the mining of

(1) Shallow placers.

(2) Deep placers.

Shallow placers are such as are opened from the surface, the whole of the dirt being washed down to bed rock, the latter being not more than, say, 12 feet deep. They include the shallow beds of permanent streams and dry gulches, ravines and valleys carrying water only during part of the season, or perhaps carrying none at all. They may thus be subdivided into

(*a*) Wet diggings.

(*b*) Dry diggings.

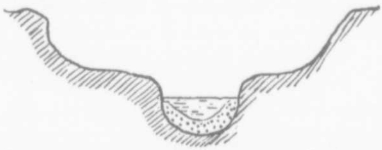
Deep placers, on the other hand, are such mines as are opened from beneath, or both from beneath and above as in the case of hydraulic mining. The pay dirt is deeply buried under barren soil so that it would not pay to remove the latter, and mines are therefore opened by shafts, tunnels and bed rock flumes, which require to be heavily and securely timbered. Mining of this description may also be classified under two heads, viz.:—

(*a*) Deep placer mining by hand.

(*b*) Hydraulic mining.

Let us first take a case of shallow placer mining under class (*a*) or wet diggings.

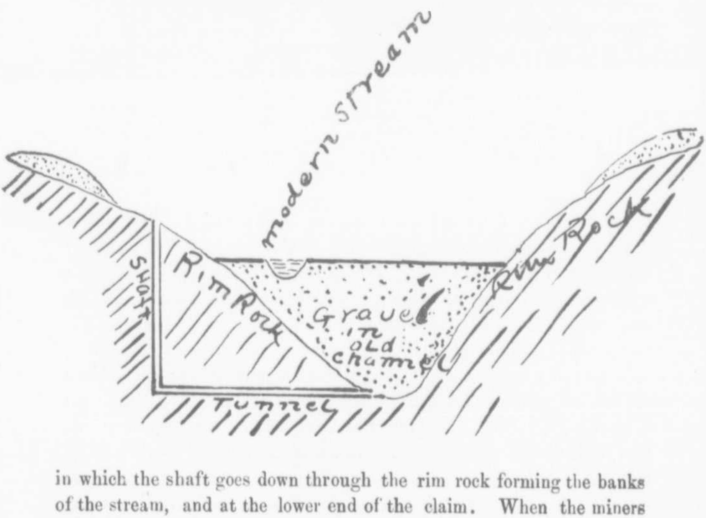
Fig. 1 represents a cross section of the stream, say 50 feet wide, showing the surface of the water, the gravel beneath, the bed rock, the steep banks of the stream with benches on either side.



A plan would be something like the following, in which, as is usually the case, the claim is 100 feet long.

The boundaries having been staked out, the wing dam is first put in and is either closed across at the lower end of the claim, or, as is usually the case, carried on far enough to keep the claim clear of water. The water wheel and pump are then put into position, the wheel projecting over the side of the dam into the water, the axle of which actuates the pump, which in this class of mining is usually of a primitive character, consisting of a wooden box through which a series of canvas buckets are carried on an endless band. The sluice boxes are then strung out in position, the slope and length depending upon the character of the goid, the available grade, and the means of the miners. As a general rule, the longer the string of boxes the more thoroughly is the gold saved. The riffles are then put into the sluice boxes. All then being in position, water is admitted into the sluices, the pump is set in motion, and the process of shovelling in the sand and gravel goes on. The latter is carried through the sluices by the force of the water and goes off as tailings, while the gold and heavy black sand settle into the riffles, from which it is removed at stated intervals, usually at the weekly clean up. The process of working a shallow dry placer is much the same, save that, as water is absent, enough to supply the sluice must be brought by ditches, and the wing dam is unnecessary.

Mining laws in British Columbia limit the size of placer claims, which can only take in 100 feet in length of stream in the case of creek and bar diggings, and 100 feet square in bench and dry diggings. Where a new stream is discovered these claims, as above, are staked off, and if the ground is shallow it is worked as has been described. If, on the other hand, the ground is deep, as is usually the case in the old channels and also in many of the modern streams, such methods would be too expensive to employ, and in such cases deep placer mining by hand is resorted to. This consists essentially either in running a drift or bed rock flume to strike the bed rock, or in sinking a shaft at the side of the stream in solid ground and drifting out to strike the bed rock, as is shown in the following sketch,



in which the shaft goes down through the rim rock forming the banks of the stream, and at the lower end of the claim. When the miners think they are deep enough, a trial drift is run out to strike the bed rock of the present stream or old channel, as the case may be; and when this is struck, the gravel is hoisted through the shaft to the surface, and washed in sluices as before. These underground workings require to be heavily and securely timbered, for the life of the miner to a great extent depends upon this. Powerful pumps are also required to keep the drifts clear of water. The hoisting and pumping gear is usually actuated by water power obtained from water wheels; and if the height to which the water has to be lifted is too great, flumes from one claim to another, the expense of which is shared by the various companies, require to be built. A better plan, when practicable, is to run a tunnel with sufficient slope for drainage to strike the bed rock at the required place; the sluices are then set in the tunnel if water can be admitted; if not, at the mouth of the tunnel, and washing goes on as before. Bench claims being in dry ground, and often high above the level of the streams, are easier to work. The main difficulty there is to bring water to the ground; to do this, long ditches are often required. Water wheels are utilized when practicable, one such wheel on Quesnelle River being 60 feet in diameter. In the vicinity of Clinton, in a piece of ground where water was difficult to obtain, it was brought across the Fraser river in rubber hose. We can thus see that much ingenuity is exercised by the miner in accomplishing his end.

Such methods as the above are utilized when the diggings are shallow or reasonably so, and when they are rich enough to bear the expense of such costly work. When this is not the case, or when the richer ground has been exhausted, the ground can only be profitably worked by hydraulic power. In view of the fact that much of the mining ground now left in British Columbia is of this character, I propose to give a more detailed description of this method of mining, from which, in the course of the next few years, much in the way of developments can reasonably be expected.

In such cases small claims as specified above could not be profitably worked; and to encourage the industry, leases of mining property are given as follows:—

In *dry diggings*, 10 acres.

In *bar diggings* unworked, $\frac{1}{2}$ mile in length along high water mark.

In *bar diggings*, worked and abandoned, $1\frac{1}{2}$ miles in length along high water mark.

In *Creek claims* on abandoned streams, $1\frac{1}{2}$ miles.

In *Bench Lands* adjoining unworked or abandoned streams, 160 acres.

Hydraulic Mining is that process of extracting gold from auriferous gravel by means of water under great pressure, discharged through pipes and nozzles against the bank. Or, in other words, the same agency which originally buried and concentrated the gold in the gravel is by this method forced to strip and separate it again.

It is absolutely necessary that there should be :—

(1) A plentiful supply of water under pressure.

(2) Good facilities for grade and dump.

The richest deposit of gold is found usually in a stratum eight to ten feet thick immediately over the bed rock of the old channel; and if this is slate, as is generally, though not necessarily, the case, it also penetrates into the crevices, seams and holes; so that such bed rock is more likely to be rich than smoother and harder rocks. Such a deposit being suspected or known, it is first necessary, or at all events desirable, to explore the ground by means of shafts and drifts to learn something about the depth, extent, character and richness of the deposit. A plentiful supply of water must also be provided for, and brought to the ground by ditches, flumes, or pipes.

The *site of the tunnel* is then chosen, giving due regard to the disposal of tailings, and the grade which should be given to provide for the drainage of the mine and the economical washing of the gravel. The *size of the tunnel* must also be decided. This depends upon the extent of the deposit and how it is to be worked; that is to say whether a single or double line of sluices is to be employed.

The *sluices* and riffles must also be prepared—no small undertaking, when it is remembered that, in some cases, they are over a mile in length. They may range in size from 16″ in width and 12″ in depth, to five feet or more in width and three feet in depth. They are made from planking, one to two inches thick, securely and tightly put together, and must be strongly mounted on sills and firmly supported by trestle work where necessary, to withstand the great pressure of water. The *riffles* are of various forms, and differ materially from those employed in ordinary placer mining, some of the more common and better forms being as follows :—

Block Riffles are of two kinds, namely *Square Block Riffles* and *Round Block Riffles*. In the first case, the blocks are sawn good dimensions, being 10 x 10 x 10 inches, but the size, of course, may vary; these are placed in position, with spaces between, in much the same way as block pavements on our roads are laid. The round block riffles are blocks sawn square off from the trunks of trees and set on end in the sluices.

Rock Riffles are stones laid in place in the same way, and are durable, effective, and cheap; but are more difficult to remove when cleaning up. They can be very profitably employed in the lower part of the sluice, where the catch of gold is not so great.

Rail Riffles made from scantling, built in sets usually of about eight feet long; the upper part is protected by strips of iron, and the whole is laid lengthwise in the sluice. Or the riffles, as a whole, may be a combination of the above methods.

The length of the sluice depends mainly upon the disposal of the tailings, for all the coarse gold and a large percentage of the fine gold is found in the first 400 feet of the sluice. The slope given to the boxes depends upon the character of the gold and the gravel in which it is found, heavy material requiring more slope and water than lighter material. If the grade is too great, the sand is apt to pack in the riffles, and a slope of about seven inches to the box of 12 feet generally works well.

Grizzlies and *undercurrents* are also used. A *grizzly* is put in when a drop can be given to a line of sluices, and is especially necessary when cement and pipe-clay are present. They consist essentially of parallel iron bars, such as pieces of railroad iron, set with spaces between, which allows the finer material to pass through, the cement and clay being pulverized by the fall into the sluice or undercurrent below, while the heavy boulders go over the side.

Undercurrents are large settling boxes, say 20 x 40 feet (the size varies), set to one side of the line of sluice boxes, and with less slope than the latter. They are provided with riffles as in the sluices. The water enters at the upper end and re-enters the sluice at the lower end. Most of the remaining gold is caught in these undercurrents.

These preliminaries having been settled, the work of opening the claim begins as follows :—The tunnel, or open cut and tunnel combined, is started with the proper grade to strike the deposit, say 20 feet below bed rock to provide for contingencies, such as holes, etc., and also to make sure of being below bed rock ; otherwise, it is money and labour lost. The tunnel is securely timbered as the work progresses, and is carried well into the bed rock under the deposit, curves being avoided as much as possible. A shaft, usually vertical, is then sunk either to strike the tunnel directly, or at a short distance to one side, and, in the latter case, the two are connected by a short drift. The shaft must be securely timbered and lagged throughout to within about eight feet of the surface. The ditches, or sluices, carry the water to a distributing point, usually some high point convenient to the claim, where the pressure box is situated ; from the latter it is carried by iron pipes or canvas hose to the claim, nozzles being provided to direct the water against the bank. Good forms of the latter are fitted with ball and socket joints, so that they may easily be turned in any direction. The pipes are made of light sheet iron, and fit into each other like stove-pipes; or they may have lead joints, if thought advisable. All being in readiness, water is turned on and washing through the shaft begins. The first washings must be made with care, and all the soil or gravel within as great a radius as possible carefully sloped and drawn toward the mouth of the shaft before the timbering is removed. By this means, caves and washes are avoided. As the work progresses, the timbers are removed till bed rock at the bottom of the shaft is reached, and, finally, an open cut in front of the tunnel is made. The mine may then be said to be opened. The bank is undermined, caved, and washed into the bed rock flume, here taking the place of the sluice boxes, and the latter is carried forward as the bank recedes. *Quicksilver* is largely employed, the charging being done at the head of the sluice. It is added at intervals, as required, being regulated by the amount in view in the riffles. The quantity used depends upon the length of the sluice.

Hydraulic mining is a development from California, and it has been largely employed both there and elsewhere in the States, where long and expensive lines of ditches and iron pipes have been built, the latter being provided with automatic air valves, distributing gates, and improved nozzles. Immense dams, forming storage reservoirs for use during the dry season, were also built. By this method, large quantities of gravel, up to nine and ten thousand cubic yards, can be run through the sluices in a single day. The average cost is about six cents per cubic yard; so that gravel yielding only 10 to 20 cents per cubic yard can be profitably worked.

Hydraulic mining is successfully carried on in British Columbia, but in a more primitive and very much less extensive manner than above. The expensive preliminary work is unnecessary, for the process, so far, has been carried on in a small scale in Cariboo and elsewhere, where, from previous workings, the ground is known to be at least rich enough to yield fair returns; water is also plentiful. Against these advantages we have the shortness of the season to contend with.

The disposal of such quantities of gravel is a serious question: streams become choked up, and bottom lands are buried under the rush, and in many parts of the States it has become illegal to mine in this way. But we need never fear that this will be the case, at all events in the northern parts of the province; and the successful operation of mines by this method will, there is no doubt, open and develop parts of the province otherwise useless, and foster and encourage an industry furnishing a livelihood and independence for many miners.

VEIN MINING.

For convenience the various discoveries of minerals in British Columbia have been classified under the above heading. The term is not strictly accurate, notably so in the case of coal and iron, and is adopted for description only, for it is beyond the scope of this paper to speak of the treatment of ores and methods of mining as the industry is in its infancy still. The author wishes merely to give a brief account of some of the more important discoveries of minerals in the Province.

As has been stated before, the placer miner is, so to speak, the pioneer of the quartz miner. It is only reasonable to suppose that in the case of rich placer deposits surmises should be made as to the origin of the gold, and if the latter is found to have a coarse unworn appearance with fragments of quartz adhering we may safely take it for granted that this source is not far distant; and when, in addition to this, fragments and nuggets of other minerals, such as silver, copper, lead, platinum, etc., are found in the sluice boxes, we know, with a fair amount of certainty, that rich discoveries are likely to be made. This has been the case in British Columbia, and such discoveries of ledges and veins of quartz and minerals as above were made in many localities shortly after the discovery of the placer deposits, and though such finds from the remoteness of the localities have up to the present time not been tested, still they are valuable and interesting as indications of future developments which are bound to come.

As may be noticed in every case, almost without exception, where placer deposits have been worked, promising ledges and veins have been discovered, and this over a mountain district extending from the International Boundary on the south, to the Youkon River and beyond in the north, a distance of over 1400 miles, and there is little reason to doubt but that as the country becomes opened up the mineral deposits of this vast region will become extremely valuable.

For convenience this region is divided into districts as follows:—*Southern, Cherry Creek, Kamloops, Yale, Kootenay, Lillooet, Cariboo, Omenica, Cassiar.* In some of these districts, from their accessibility or from other favoring circumstances, more development work has been done than in others; such localities the author purposes to treat more in detail, not because they are likely to prove richer, but simply because in such cases results may be submitted to you.

In the *Southern Division* is included all that country to the south and in the vicinity of Okanagon Lake. In this district a great number of promising locations have been made at the following camps and places :—

Camp McKenney, about 12 miles from the placer mines on Rock Creek and not far from the boundary. A working test from a quantity of ore sent to San Francisco from these mines gave returns in gold of $62.00 to the ton.

Camp Fairview, on Okanagon River.

Copper Camp.

Boundary Creek.

North Fork of Kettle River.

Tulemeen River.

Wolfe Creek.

Keremeos.

Amelia.

Maple Leaf.

Bear Creek.

Toad Coulée.

Newton District, near Granite Creek.

In all of these localities promising ledges have been discovered, and a considerable amount of development work done with satisfactory results so far as they go, but the district is out of the regular line of travel and the mines are not being developed as they would be were the country made more accessible by the building of railroads or wagon roads.

Cherry Creek Division.—In this locality we find two ledges upon which a considerable amount of work has been done. One is silver bearing, and crosses Cherry Creek near the placer mines. Assays from this mine shew it to be extremely rich, one made by the author yielding 1205 ounces of silver to the ton, and a working test from two tons of ore sent to San Francisco giving 625 ounces to the ton. The other ledge, known as the McIntyre ledge, is situated about 12 miles further on, on Monashee Mountain, and shows gold visible to the naked eye. A quartz mill has been erected at this mine, and both localities are reached by a good wagon road.

Kamloops Division includes the Nicola Mines and those claims situated at Jameson Creek and vicinity, and elsewhere on the North Thompson River.

The Nicola Mines are situated about 30 miles south of Kamloops, in the vicinity of Stump Lake, and on Idaho Mountain. A good wagon road connects them with the above place. The principal mine owners are as follows:—

Nicola Mining and Milling Company (English capital).

Star Mining Co.
Mary Reynolds Co.
Wright & Fletcher.
Silver King Mining Co., and others.

A company was formed about 1882 to prospect these claims. About 1886 they sold out to the Nicola Mining & Milling Co., an English syndicate, who have expended a large amount of money in a systematic and business-like manner, principally on three of their claims, known as the King William, Joshua, and Tubal Cain, which claims the company are testing thoroughly preparatory to erecting extensive reduction works. These mines deserve special mention, for the amount of work done by this company far exceeds that done by any other company in the province. They employ a large force of men, are using improved machinery, have run, including drifts and shafts, up to 1890, some 3400 feet, and the future of the camp as a whole depends to a great extent upon their developments, with which they have so far been well satisfied.

The *Star Mining Company* have also done a considerable amount of work on their claims, and have also erected a small concentrating plant, and shipped some 16 tons of ore to San Francisco, yielding $75 per ton.

Other mine owners, as above, have also prospected their claims, and are well satisfied with the results. The principal minerals are lead sulphides and carbonates, rich in silver, and also carrying a percentage of gold.

Many claims have also been located in the vicinity of Jameson Creek which from surface indications promise well, as do other claims located further up the North Thompson and Clear Water Rivers. But as yet little development work has been done to prove the future value of these claims.

Yale Division.—By this is meant that section of country in the vicinity of Yale, Hope, North Bend, and Siwash Creek. In this division a number of claims have been developed to a considerable extent. Some of them are known to be rich, such for instance as those south of Hope, which have been known for a number of years, and upon which difficulties regarding ownership have prevented development.

The ore on two of these claims, known as the Eureka and Van Bremer, is described as being principally argentiferous grey copper and silver chloride, and assays varying from $25.00 to $2,400 to the ton in silver are obtained. Promising indications are also obtained from other claims, but, as in other localities, lack of means prevents developments.

Kootenay Division is traversed by the Canadian Pacific Railway, and important water stretches, such as the Columbia and Kootenay Rivers and Lakes, also exist, so that prospectors have been able to travel about in the mountains, and the result of their labour is shown by the large number of rich and promising ledges discovered in the following localities :—

Illecillewaet,	Deception Creek,
Field,	Windermere,
Fish Creek,	Big Bend,
North Arm of Arrow Lake,	Bugaboo Creek,
East Arm of Upper Arrow Lake,	Horse Thief Creek,
Toad Mountain,	Toby Creek,
Eagle Creek,	Otter Tail,
Hot Springs,	Findlay Creek,
Hendryx Mines,	Copper Creek,
Spillemcheen Mountain,	Bull River,
Jubilee Mountain,	Goat River,
McMurdo District,	Trail Creek.
Lordeau River.	

Of these localities only brief mention can be given, referring more particularly to those which have been developed to the greatest extent.

The *Illecillewaet Mines* are situated near the station of that name on the Canadian Pacific Railway, and are within a short distance of the track. The Selkirk Mining and Smelting Co. own a number of claims, and have erected sampling works, offices, boarding houses, etc., and have also built roads to their mines. They shipped, in 1887, some 300 tons of ore to smelting works in Omaha, the average value being 70 ounces of silver and 44% of lead to the ton. This company is now confining itself chiefly to developments in the Lanark Mine.

Corbin & Co. also own a number of valuable claims upon which they have expended a large amount of money in developments. Mr. McKinnon holds the Maple Leaf Mine, adjoining the Lanark, at $80,000. Claims at Cariboo Creek are said to be equally rich.

At the *Field Mines*, close to the Canadian Pacific Railway station Field, a large amount of development work has also been done; ore houses, offices, etc., having been built, also a tramway along the vein and down to the railway track. They have shipped a large amount of ore to smelting works. The ore is lead carbonate, and a low grade, but as it is easily smelted, and conveniently situated on the railway, the mines are certainly valuable. To the other localities, passing notice only can be given, attention being directed mainly to working tests on shipments of ore made from various mines.

At McMurdo's we find galena ores, rich in silver, and apparently in well-defined veins. Two car loads of ore shipped from the Wells, Pollock and Aylmer property averaged 100 ounces of silver and 63% of lead to the ton.

There is also a well-defined gold belt which is said to average about $20.00 to the ton. A stamp mill is now at Golden awaiting shipment in the spring to this field.

The *Spillemcheen and Jubilee* districts also promise well, and are conveniently situated near the Columbia River. The ore bodies are enormous, and are chiefly sulphides of copper and lead, which, however, are of a low grade character.

The *Hot Springs* are situated on Kootenay Lake, about 30 miles from Nelson. The parallel lodes exist in tiers on the mountain side, the lower ones being low grade galenas, which become richer as the mountain is ascended, till the summit lodes are reached, where we find rich carbonates and sulphides of lead containing Wire and Ruby Silver.

Hendryx Mines are just on the opposite side of the lake from Hot Springs. Development work is being vigourously pushed on by means of an Ingersoll drill. The lode is said to be a mass of galena, 86 feet wide, which assays about 20 ounces of silver and 23% of lead to the ton. Perhaps the best way to convey an idea of the richness of these claims is to give the following milling tests from various mines in 1889 :

No. 1 claim...	146 tons,	87 ounces of silver per ton.				
Little Donald.	85 "	90 ounces silver	35% lead	per	ton.
Silver King....	40 "	299 "	"	20% copper	"	"
" "	30 "	230 "	"	20% "	"	"
Spokane........	65 "	40 "	"	70% lead	"	"
Della...........	20 "	120 "	"	....	"	"
Skyline.........	15 "	225 "	"	....	"	"
Gallagher......	14 "	119 "	"	$14.00 in gold	"	"
Krao..........	12 "	95 "	"	50% lead	"	"

Or altogether 427 tons, yielding 50,393 ounces of silver.

Big Bend Mines are situated on the bend of the Columbia River, and are gold-bearing, though galena is also found. From the richness of the placer deposits, there is every reason to suppose that they may be valuable. But as the region is inaccessible, and as little development work has been done, it is impossible to say much about their future. For the same reason little can be said about the other localities mentioned in the list, excepting that good assays are obtained and the surface prospects are promising.

Lillooet Division.—In this division the principal discoveries have been made in the vicinity of Cayoosh Creek, where a great number of claims have been staked off. The ledges are gold-bearing, and the gold seems to be uniformly distributed through the quartz in a fine condition, as colors can be obtained almost everywhere. The average assay value is said to be about one ounce to the ton. These veins are undoubtedly the sources from which the rich placer deposits of this locality obtained their gold, and there is therefore a strong probability that they will prove remunerative in the future. Ledges have also been discovered in the vicinity of Seaton and Anderson Lakes, that at Anderson Lake being described as a strong lode of quartz carrying galena assaying $46.00 in silver and $14.00 in gold to the ton. In a few of these claims a considerable amount of prospecting work has been done, but in the great majority we find nothing beyond assessment work.

Cariboo Division, from the richness of its placer deposits worked in early days, has always been looked upon as a locality from which much in the way of developments in quartz might reasonably be expected. Many ledges were known even in these early days, from which in several instances $3.00 to $5.00 a day per man was made by washing the decomposed and oxidised rock matter at the surface of the veins. We accordingly find that in 1877–8 companies were found to operate mines here; but from exaggerated ideas of the richness and erroneous views regarding the methods and cost of working the ores, these efforts failed, and quartz mining received a severe check. Within the last few years, however, attention has been again turned to these ledges with what now appears to be a fair chance of success. From what is known of the district, it is clear that a great number of well defined quartz ledges exist, from which good prospects are obtained. As is well known, much of the gold obtained from quartz is contained in sulphurets, which on the surface has become oxidised, allowing the free gold to escape, and on several of the veins such bodies of sulphurets have been discovered. The Government has established a small testing plant in this neighbourhood, to assist the development of the mines, and several small stamp mills have also been erected. From the Black Jack Mine, two lots of ore have been worked as follows:—No. 1 of 100 tons yielded $523.00 in free gold and 12 tons of sulphurets, worth $24.00 to the ton; No. 2 of 202 tons, yielding $4.50 in free gold and $13.00 in sulphurets per ton. By means of these stamp mills and testing works the miners will be able to realize from their ores, and thus obtain money to go on with development of their mines, and there is every hope that in a short time they may be able to prove the value of their own claims, and with them assure success of quartz mining in the district as a whole.

Omenica Division.—The remote situation of this district will for the present prevent the development of vein mining, but there is no doubt that it is rich in minerals. Its placer deposits would seem to indicate the existence of both gold and silver bearing ledges. On Vital Creek, $\frac{1}{10}$ of the metal found was arquerite or silver amalgam. A large number of ledges containing highly argentiferous galena ore in large bodies are also known to exist, which assay from 30 to 130 ounces of silver to the ton. A number of these claims were at one time taken up, but have since been abandoned. When taken in connection with discoveries in more accessible regions, the probability is that nothing will be done to develop this district till it can be reached in a more convenient manner than it now is.

Cassiar Division.—Almost the same remarks may be applied to this district, in which many well defined ledges are known to exist, on which surface indications are promising, and from some of which rich assays have been obtained, indicating in connection with the rich placers which have been worked that the district in the future will become valuable from the mineral deposits in its veins and ledges. As regards its situation it could be made accessible with a comparatively small outlay.

The vast *Yukon District* to the north is apparently equally rich in mineral deposits.

In addition to the minerals enumerated above, many others are also to be found; such as molybdenum, mercury, antimony, plumbago, bitumen, asbestos, mica, platinum, coal and iron.

The *platinum* is found associated with the gold in placer mining in many localities throughout the province; but its principal source is Granite Creek, where, since 1885, some 4,000 ounces have been collected. It is the most important field for this mineral which has been discovered in North America.

The deposits of *coal* in the province, as is well known, are of vast importance. The mines on Vancouver Island were worked before the discovery of gold in the province. They are important, both from their extent, quality, and favourable position. The output for 1889, from the various mines in operation, was as follows:—

Nanaimo Colliery	223,870 tons.
Wellington "	273,383 "

East Wellington Colliery.........	51,372	tons
Union "	31,204	"
Total........................	579,929	tons.

The total output of coal for the province, up to the end of 1888, was 4,358,221 tons.

These coals are of the age of the cretaceous formation, and they are now admitted to be superior to any other coals on the Pacific Coast.

In addition to the above, we find tertiary deposits scattered throughout the province, both along the coast and in the interior. The tertiary area in British Columbia is estimated to be 12,000 square miles.

Deposits of *iron* also occur in many places in British Columbia. At present, only such as are situated on the coast are available; but, as the country becomes developed, the others will also be valuable. In some cases, they occur as clay ironstone in the coal series; but principally in the form of magnetites. Little attention, as yet, has been devoted to this branch of mining. The only ores being worked are those of Texada Island, which is magnetite of excellent quality. The mines are most favourably situated, either for shipment or smelting, as the Comox coal fields are only about twenty miles distant. The following shipments have been made :—1885, 190 tons; 1886, 3,941 tons; 1887, 1,410 tons; 1888, 7,300 tons. Similar deposits occur elsewhere along the coast, also favourably situated as regards shipment.

As may be seen from the foregoing, the province possesses important mineral deposits in many different localities, and extending over a vast extent of country. It may very reasonably be asked, then, how so little has been done towards the development and working of these deposits!

Want of capital and the inaccessibility of the country have been, and still are, the principal reasons. The completion of the Canadian Pacific Railway has opened the Kootenay District, and witness the developments and discoveries which have been made since that time. The discoverers, almost without exception, are poor men, and development of quartz mines requires capital; for, in most cases, no returns can be obtained, even when valuable ore is lying on the dump: the great hope, then, is that monied men may be induced to invest and help in the development. In many cases, the miners are themselves to blame—they give exaggerated values to their properties, based upon fictitious results obtained from picked assays, or hold undeveloped property at fabulous prices. This is more likely to do harm than good, and is bound to delay developments. Average results are what are required, and if these can be obtained from a quantity of ore, they give undoubted proof as to the value of the mines. But, in the absence of capital, these working tests can only be obtained under favourable circumstances, both as regards situation and richness of ore, which has usually to be packed for long distances to the nearest shipping points. Low grade ores cannot be tested in this way, except when reduction works are near, even though such deposits are equally as valuable as the richer ores. The following examples will give an idea of the present cost of shipping ore from mines which are favourably situated :—Silver King Mine, Toad Mountain to Nelson, a distance of seven miles, by pack train, $10 per ton, and from there to Butte, Montana, including smelting, $47 per ton ; in all, $57 per ton. The cost of transportation from Hot Springs to the same destination, including smelting charges, $40 per ton. This does not include the cost of packing from the mines to the water edge, which, of course, varies with the distance. The erection of such reduction works in the province, then, is of great importance : First, because it allows miners to receive some returns from their ore, and thus aids them in going on with development. Second, the erection of such works by experienced men is a direct proof that the importance of the deposits are recognized. It is not out of place, therefore, to shew what has been done in this way.

In the *Cariboo District*, stamp mills have been erected as follows :—

Island Mountain Mining Company.—One ten stamp mill, operated by a fifty-horse power engine, with the view of working a larger number stamps as required.

British Columbia Mining and Milling Company, Stout's Gulch.—One ten stamp mill and engine (on the ground, but not erected).

Black Jack Quartz Mining Company.—A one stamp test mill, capable of working 1½ tons of ore per day (operated by water).

Nason & Co., Conklin's Gulch.—One four stamp mill, worked by water.

In addition to the above, the Government, with the view of encouraging and assisting the miners, has erected a small testing and chlorinating plant, with a capacity of about three tons per day.

NEW WESTMINSTER DISTRICT.

At Vancouver, a smelter and sampling works, with a capacity of 50 tons per day. Through some faults in construction, not working at present.

KOOTENAY DISTRICT.

At *Golden*, a smelter, 20 tons capacity per day, with roasting furnace, 14 tons capacity per day.

At *Revelstoke*, a smelter, owned by the Revelstoke Smelting Syndicate, capacity 60 tons per day; also, sampling works, having a capacity of 100 tons per day, operated by a 50 horse-power engine.

At *Summit of Toad Mountain*, the Collingwood Gold Mining Company has two Huntingdon Mills of five tons capacity each and two Frue vanning concentrators.

At *Eagle Creek*, one ten stamp mill and four Frue vanners, capacity 15 tons per day, operated by a Pelton water-wheel.

A stamp mill is now at Golden, awaiting shipment to mines in the spring. Capacity unknown.

In addition to the working tests already given, some 205 tons of ore were also tested, yielding 69,530 ounces of silver; or say, on an average, 340 ounces of silver to the ton.

In many of the localities the success of the camp as a whole depends to a great extent upon the successful development perhaps of single claims, where owners are more fortunate as regards capital and means to prove the value of their claims.

Another reason which has retarded actual working developments and erection of reduction works is the fact that a large amount of preliminary work is necessary, both to ensure a constant supply of ore, and also to determine the methods by which it is to be worked, for in many cases the character of the ore changes after a certain depth is reached. As the coarse gold of the placer deposits is derived from ledges in the immediate vicinity, we might fairly assume that these ledges would be gold-bearing. If this were the case, it would simplify matters considerably, and at the same time materially assist in the immediate development of mines throughout the province, for ores, if free milling, are worked by machinery—inexpensive when compared with the cost of reduction works required for the treatment of silver ores when associated with the baser metals. When a portion of the ledges is destroyed, the gold, from the fact that it is acted upon by few agents in nature, is left, while the more alterable associated minerals, copper, lead etc., are destroyed and carried away. In this way in many cases the gold of the placer deposits may be robbed from ledges which will in all probability turn out in many cases to be silver-bearing, the principal associated minerals being copper and lead, with the probability that silver bearing copper ores will be more plentiful than silver-bearing lead ores, though surface indications show the latter more abundant.

Next in importance to the mines themselves is the ways and means of reaching them.

The Columbia and Kootenay Railway is now under construction, and will be ready to carry ores early next summer. If so, in connection with steamboats, now built and operated on the Columbia River, miners will be enabled to ship ores direct to the smelters at Revelstoke and Golden at a comparatively small cost, and there is no reason to doubt that these smelters will be kept steadily at work and in a short time prove inadequate to treat the amount of ore coming in. In the Kootenay District at least, then, we may look forward to important developments in a very short time. Elsewhere throughout the country railroads, wagon roads, etc., for reaching the mines are badly required,

This paper has assumed dimensions far beyond what was intended. It has been impossible to mention individual claims, except where more important developments have warranted it. You will, therefore, understand that this has been avoided, not because they were unworthy of mention, but simply because space would not allow me to do so.

From the accessibility of the Kootenay district it has been given more space and attention, probably at the expense of other districts equally as promising and valuable, but at present not so favourably situated. This is simply because, in this district, as a whole, more developments have been made, affording more tangible proof to present to you.

Mining in British Columbia has now reached that stage when examination of its mines is courted and invited. Let us hope, then, that with the completion of the Canadian Pacific Railway, and improved facilities for travel, capitalists will visit the country and judge for themselves.

Let me state, in conclusion, that the existence of rich, valuable and extensive mineral deposits within the boundaries of British Columbia is now admitted, and that it is only a question of a short time till this will be definitely proved. The development and working of these deposits will create a vast and permanent industry, supporting a large population. Important towns and mining centres will spring up at various points, railroads will be built, and British Columbia will become one of the richest, if not the richest and most valuable province of our Dominion of Canada.

DISCUSSION.

Mr. Blackwell. Mr. K. W. Blackwell said he would like to ask the author of the paper if he could explain the reason why the output of the coal mines in British Columbia was so small, and what were the circumstances that limit their production.

The figures were about 1900 tons per day as an aggregate for all the coal mines in British Columbia, or about equal to the output of the Springhill mine in Nova Scotia.

Is it because it does not pay to haul this coal over the Rocky Mountain Division of the C. P. R. ?

Or, on the other hand, is the demand for this coal in California (where most of it goes) limited ?

Considering how favorably these coal seams are situated for working, how is it that more coal has not been produced ?

The demand and price for this coal on the whole Pacific coast have been looked upon as exceptionally good.

Possibly there were reasons of a commercial nature that limited the products of these most promising coal seams which the writer could explain.

Mr. Drummond Mr. Drummond in reply to Mr. Blackwell's remarks said :—

1st.—The whole of the available coal-bearing area of known value on Vancouver Island having been granted to the E. & N. Railway Company, the development of coal mining has been limited in consequence to their operations at the Union Mine in Comox, and the three other companies at that time in operation, the principal owners of this large grant of coal lands are also the owners of the Wellington Collieries. Competition therefore beyond that which existed between the three companies at the time of the transfer has been practically shut out for all time. The competition with which these companies are met in the San Francisco market is mainly from "ballast" coal, which at frequent and uncertain intervals flood that market. This coal is brought from England, Wales and Australia, as ballast, by ships seeking wheat cargoes in return. Our coal mining companies require to gauge the higher ratings of that market and to govern their output accordingly.

2nd.—The total output of the B. C. collieries for the calendar year 1890 was 678,140 tons, or 2,173 tons per day of 312 days in the year; and would, he had no doubt, have aggregated 2800 tons per day but for the Wellington strike, which extended over a large portion of the year.

3rd.—It will never pay to transport Vancouver Island coal forty miles by water and tranship by railway over the Rocky Mountains in competition for the markets of the N. W. T., against the collieries of those regions.

4th.—Yes, but gradually increasing.

5th.—Although the coal fields of Vancouver Island are favourably situated for working in so far as their products being shipped is concerned, yet the fields are so broken and irregular that the companies working them have to proceed with great caution in their development in order to guard their capital and mining machinery. Labor is far above the prevailing prices in Nova Scotia.

The appended tabular statement of the development of the mines shows an increase, not out of proportion to the increase of consumption of coal on the whole Pacific coast.

RETURNS FROM COAL MINES IN BRITISH COLUMBIA.

The development of our mines shows a healthy progress:—

			Tons.
In 1874	the total	output was	81,000
1875	"	"	110,000
1876	"	"	139,000
1877	"	"	154,000
1878	"	"	171,000
1879	"	"	241,000
1880	"	"	268,000
1881	"	"	228,000
1882	"	"	282,000
1883	"	"	213,000
1884	"	"	394,070
1885	"	"	365,000
1886	"	"	326,626
1887	"	"	413,360
1888	"	"	489,300
1889	"	"	579,830
1890	"	"	678,140

CORRESPONDENCE.

Mr. H. S. Poole said this paper must prove of undoubted value to British Columbia, and to those who may propose to aid in developing her mineral resources. It has an interest for the writer in recalling a limited experience in mining camps and with mining excitements in the West twenty years ago, at which time he visited the site of the latest rush in Utah, the district of Deep Creek on the western margin of the desert, where even then some fairly rich ore was known, but the known veins being small, the difficulty of access stood in the way of active development. Mr. Poole.

A special interest, however, lies in the reference to the origin of gold in the sands and gravel of modern and ancient streams, and the presence of gold in the carboniferous conglomerate of Nova Scotia. Having of late years confined his attention entirely to coal mining, he had not before seen any statement openly advocating the theory in question.

He had visited workings in an ancient channel high up on a cañon side, through which the present stream had cut its way, and left portions of the ancient bed in which gold was found on both sides of the present stream, and among the specimens which he had brought away and retained was one of native copper taken from the modern bed. The copper was as filaments through the tissue of half decayed bark, deposited evidently from the percolating waters by the action of the organic matter.

He had seen no such direct evidence of the deposition of gold, but he had been much struck with the form displayed by particles taken from the Gay's River deposit, and he had referred to them in an article published in the journal of the Geological Society of London.

When Inspector of Mines, and visiting this locality a dozen years and more ago, he had taken great interest in the formation, and noted that while the boulders and pebbles composing the formation resting on the Cambro-Silurian slates were well rounded and polished by attrition, the gold, although so soft and so much more easily worn than the silicious stones composing the matrix, did not present the same appearance.

As an illustration he showed a specimen, an irregular-shaped plate, three-quarters of an inch long by half an inch wide, the surface of which was studded with projecting particles, semi-crystalline almost in appearance and as accretions. It presented no similarity to that of a piece of coarse gold from a vein flattened and rubbed down by contact with hard material, such as would be expected from the debris of a vein containing gold that had been broken down by atmospheric agencies and removed by flowing water. The surface had rather the appearance of a plate of copper thrown down by an electric current.

Mr. Drummond

Mr. Drummond said in writing this paper he wished to direct attention more particularly to vein mining, and it may therefore be said that too much space had been devoted to placer mining. For several reasons, however, he considered that this branch of mining deserves a somewhat detailed treatment. In the first place, the subject is interesting, and helps very materially to make the paper readable. It also plays an important part in the history, development, and exploration of the Province, for what is known of the topography of the country is largely due to the explorations of the placer miner. If gold had not been discovered, there is a strong probability that the Canadian Pacific Railway would still be a work of the future. But apart from these there are two principal reasons why this branch of mining is important enough to warrant a detailed notice: First, because placer mining by hydraulic power is likely in a short time to become a most important industry; and secondly, because the explorations of the placer miner point out almost with a certainty that the whole mountain range west of the Rockies between the International Boundary and the Yukon River will eventually become most important and valuable from the mineral deposits in its veins and ledges. As was stated in the paper, there is a large amount of ground in the vicinity of most of the old placer mining camps, which will at least yield a fair profit, if not more, when worked by hydraulic power. He referred either to places from which the richer deposits have been mined, or to localities such as many of the streams in the Cariboo district, where from various difficulties the deep channels have never been bottomed. These are now being tested, and in the near future from such ground alone the writer predicts that most important results may be expected. In addition to this there is at least a probability that new discoveries will be made. It must be remembered that the country is rough, mountainous and exceedingly difficult to explore, and that even if passed over by prospectors without results, this does not demonstrate definitely that there is no gold. A very good instance of this is the discovery of Granite Creek in 1885, after having been passed over by hundreds of miners and prospectors in the early days. An important discovery has been made on a branch of the Quesnelle, which bids fair to rival some of the old discoveries, and which is supposed to locate an old and extensive channel hitherto unknown. Several strong companies have located ground, and are now drifting to strike bed rock in this channel with very encouraging results. Only a few days ago the speaker saw an item in one of the papers, stating that a hydraulic "giant" of the largest and most improved type was now laying in the Canadian Pacific Railway sheds, Vancouver, awaiting shipment to Quesnelle River for the South York Hydraulic Mining Co. This is fitted with a ball and socket joint, 15 foot discharge pipe, deflector and 7 inch nozzle, which, it is claimed, will discharge 1,800 miners' inches, equal to about 36 cubic feet per second. The head is 300 feet, and the water will issue from the nozzle with a velocity of about 130 feet per second. The result of mining with such appliances and on an extensive scale, even in abandoned ground, will, the speaker considers, largely increase the annual yield of gold in the Province, and create an industry much more lasting and permanent than ordinary placer mining.

The discoveries and explorations of the placer miners are also valuable and important, as indicating with a fair amount of certainty that a large and extensive mountain district, extending from the International Boundary on the south to the Yukon River on the north, a distance of about 1,400 miles, will eventually develop rich and extensive mineral deposits from its veins and ledges. This is not merely a plausible hypothesis, but is largely borne out by facts from British Columbia itself, from California and elsewhere in the United States, from Australia, and in fact almost without exception from every country where gold has been mined on an important scale from alluvial washings. Such gold has been traced to its sources, and important quartz discoveries made and developed. So it is in British Columbia, in the southern and more accessible parts of the Province this has been proved, and promising ledges are known to exist in isolated parts of the same mountain range at Lillooet, Cariboo, Omineca, Cassiar, and further north on the Yukon River, and it can fairly be assumed that intermediate portions between these places, when explored, will show ledges and veins equally as promising. The connection between placer mining and vein mining then is stronger than would at first appear, and it was the author's wish to point out that placer mining is still going on, and that important developments are almost certain to follow when washing on an extensive scale by hydraulic power is adopted; and further, for reasons already given, that the discoveries of rich placers in the northern part of the Province indicate almost to a certainty that the same localities will prove equally valuable from their veins and ledges.

Thursday, 7th May.

P. W. ST. GEORGE, Member of Council, in the chair.

Paper No. 53.

RAILWAY CURVES.

BY H. K. WICKSTEED, B.A.Sc., M. CAN. SOC. C.E.

As railways have become more numerous, and have pushed their way into regions where traffic is thin or competition has become very keen, the study of the "economics" of operation has come to be more general among railway men, and the influence of the different elements of location on the cost of running and maintenance better understood.

The earlier railways built through districts where trade was already established, and having only waggon roads to compete with, had merely to secure a good safe road at some reasonable cost, and their traffic and dividends were assured; but with competition, and in the case of roads running in advance of settlement, it became often necessary to secure the very greatest operative economy in the one case and the very lowest constructive cost in the other, in order to admit of the road's becoming a financial success.

There are three elements in the location of a railway between two given points, which can be utilized more or loss interchangeably to reduce its cost below that of the straight line on plan and profile, which represents the perfect line.—increase in distance, curvature and gradients, and all have a more or less detrimental effect on the operative value. In all roads they all three are made use of to some extent, but even at the present day there is evidently a very marked difference of opinion as to their relative hurtfulness. In our older trunk roads, as in the English lines on which they were modelled, the first two seem to have been avoided at almost any cost. As nearly an air line as possible was obtained, and such gradients resorted to as would fit the ground without excessive work.

In the case of the English lines, the long rigid wheel base of cars and engines limited greatly the radius of the curvature, which could be used with safety, and with very flat curves, opportunities for reducing the pitch of gradients by lengthening the distance did not so often occur; but even since the universal adoption of the swivelling truck on all rolling stock on this continent, there still remained a marked repugnance to going even a very little way off the general bearing to secure an easier line, and railways even of the very cheapest class were run up hill and down, almost as the crow flies; and to bring the cost within the means of the promoters, such gradients were adopted as have in many cases completely ruined their earning powers for all time to come.

Far be it from me to urge the promiscuous use of sharp curves and the practice of running around every trifling obstacle, which is the opposite extreme towards which some engineers belonging to a later school have gravitated.

The best location for a road depends on many things—the purpose for which the road is built, the direction and volume of traffic, and the capital available, etc., etc., and no hard and fast rule can be laid down for general adoption. All I wish to point out is, that where, from financial weakness or other cause, it becomes necessary to choose between a somewhat circuitous route having easy grades and a comparatively straight one with heavy grades, the former will in a large majority of cases be the proper one to adopt, even if the difference in distance be quite considerable, and that where the choice is merely between sharp curves and heavy gradients, there can seldom be reason for any hesitation whatever.

The financial reasons for this are not difficult to understand. On a straight level track, train resistances at moderate speeds amount to about 6 lbs. per ton. On a 10° curve, this is about doubled, in other words, the increased resistance due to a 10° curve is only the same that we should have on a grade of $\frac{3}{10}$ per cent. or 16 feet per mile.

Yet how often we see grades of 60 to 80 feet per mile used in conjunction with curves of 3° or 4°, where the use of sharper curves would have made a longer rise at say one-half that rate practicable at the same cost and allowed of the train load being doubled. No railway manager needs to be told what an economy is effected by adding even 3 or 4 cars to his trains.

There are, however, other factors besides the low cost of hauling, which enhance the popularity and earning powers of a road—speed, safety and comfort in the running of trains and the cost of maintenance of track and rolling stock.

As regards the effect of curvature upon the first—speed,—10° curves can be traversed and are traversed every day at 30 miles per hour; and with modern air brake equipment the loss of time caused by slackening the speed, from the ordinary maximum of 50 miles for an occasional curve, a few hundred feet in length, is very small, while even with ordinary passenger trains the effect of steep gradients in retarding speed is constantly felt. Freight trains very seldom travel more that the 30 miles per hour in any case, so that the curve does not affect them at all, whereas the gradients are all important to them as limiting the weight and length, and practically fixing the minimum remunerative tariff.

2nd. Safety.—No one will or can deny that curves are more or less an element of danger—both in increasing the liability to derailment and in obstructing the view of the track ahead; but both theory and practice tend to show that while a mathematically straight track is undoubtedly a great boon—a very desirable thing indeed—the tendency to danger on curves from both causes is (within moderate limits) almost independent of the radius of curvature. Centrifugal force increases inversely as the radius; but it is a fact not generally or, at any rate, not fully realized, that centrifugal force accounts only for a portion of the derailing tendency, the balance being caused by the necessity for the wheels to slip on the rail, both in a direction parallel to the axle—owing to the want of parallelism between the latter and the radius of the curve, and also in a longitudinal direction, owing to the outside wheel being obliged to roll further than the inside; this slipping or sliding friction is in accordance with the laws of friction generally and practically independent of the speed, and at very low speeds there is practically no more flange pressure against the side of the rail on sharp curves than on flat ones. Sharpen the curve to the extreme limit possible, and the wheel will at last mount the rail, not because the directive force exercised by the rail is greater, but because the obliquity of the plane of the wheel to the rail becomes greater than the angle of friction between the two.

Turnouts with curvatures of 6° and more are traversed daily and hourly by express trains, at speeds of 20 to 30 miles an hour on our best roads, although there are in the case of the turnout the additional elements of danger caused by the break in continuity of the outside rail at the frog, and the absence of superelevation to counteract the centrifugal force, as also that the turnout is nearly always very nearly a reversed curve, the tangent from the point of frog being seldom more than 30 or 40 feet. A well laid 8° curve on the open road is vastly safer at 30 miles than the turnout at 20. Yet we constantly see this anomaly of 6° turnouts traversed by the same trains on the same roads where on the open road a 2° or 3° standard has been enforced at a heavy cost.

With regard to the obstruction of view by a curve, it needs no demonstration to shew that a rock bluff or building close to the track will limit the range of vision on a 2° curve to within a few feet of what it is on a 10°; and unless we can eliminate the curvature altogether, we can gain little in this respect by lengthening the radius. There are without doubt many accidents attributable more or less directly to curvature, but in very few of those which I have had an opportunity of inquiring into does it seem to me that the radius of curvature had much effect, and in many it would appear that some defect in the rolling stock was the *direct* cause, although perhaps even with this defect existent the accident would hardly have occurred elsewhere than on a curve. The recent accident on the Intercolonial at St. Joseph, for instance, is a case in point, and appears to me distinctly traceable to the manner in which the brake beams and shoes are generally hung on passenger cars. One shoe presses the front side of the leading wheel, and in a majority of cases at a point a little below (sometimes far below) the axle, the friction of the wheel tends to lift it; and once lifted, if the brake is below the centre, it cannot drop again until the brake is released. Now, imagine the car body inclined, owing to superelevation of the track, and bearing rather more heavily on the inside springs and compressing them, the brakes are applied and the wheel is clamped in this position. Before they are released the cant is reversed and the wheel is lifted, or at any rate the pressure on the rail is so reduced that it mounts the rail with great ease. The author has so often seen this lifting action where he has watched wheels to which the brakes were suddenly applied with full pressure, that he has no doubt whatever that this was the cause of the derailment in question, as of many other similar ones. We generally read in the evidence that the brakes have been applied, and that within a few seconds the derailment occurs. In the case of engine derailments we seldom or never hear of the leading truck getting off—there are no brakes on it; seldom or never of the leading truck of the tender leaving the rails—the close coupling to the engine prevents this; but the rear truck is constantly being derailed, and very often from the cause pointed out, and which, by the way, was very ably discussed, and the remedy pointed out in a recent issue of the *Engineering News*. So much for the elements of danger *inherent* in curvature.

On the other hand, some of the most terrible accidents which have ever appalled us have been directly caused by gradients. The Irish disaster at Armagh is one of the most destructive, and a similar one occurred some years ago on the Southern Pacific. These are directly chargeable to heavy grades, and a number of others are indirectly chargeable to the same cause in this way. A train is timed to make, say, 45 miles per hour between stations on a road having heavy undulating gradients. On the up grade this is, let us assume, impossible, and the speed falls to 25 miles at the head of it. Assuming the next summit to be of the same elevation, the speed at the bottom of the sag must be in order to keep up the average 65 miles per hour—this is so easy to attain on the down grade that it is very common indeed; but when, as is often the case, the line is complicated at the bottom by curves, structures, or by frogs and switches, it is by no means a safe speed, and the consequences are often disastrous. Breaking away is also a fruitful cause of trouble on steep grades.

3rdly. Comfort.—Probably the most serious argument of all against the use of sharp curves as commonly introduced is the discomfort which they cause to passengers (especially to those in sleeping cars) when traversed at high rates of speed. Travelling over a long stretch of one of our trunk roads not long ago, the author was several times hurled across the car while endeavouring to dress, and the impact was so violent at times that it was difficult to persuade himself that there was not something of danger as well as discomfort.

Steep grades, on the contrary, whatever may be their effects on the pockets of the shareholders or the safety of the passengers, do not influence the comfort of the latter, and the average one merely wonders why the train is moving so slowly at the top of a grade, or experiences a slight exhilaration when it nears the bottom, and that is all about it.

Lastly, maintenance of way and wear and tear.

There is certainly quite a difference in this respect between the curve and the straight line, but there is also a great difference between the grade and the level and between the heavy grade and the light. Creeping and buckling of rails, use of sand to aid adhesive broken links, frequent application of brakes, all tend to keep both the roadmasters and the mechanical departments busy, and run up the cost of repairs. And here again we find that it is *curvature* "per se" which makes the trouble, and the *radius* of curvature has a comparatively small effect. In other words, having 90° of curvature, it makes little difference whether it is present as 3000 feet of a 3° curve or as 900 ft. of a 10°, and it is constantly maintained that as far as repairs to roads are concerned, 3000 ft. of 3° curve is a little more expensive than 900 ft. of a 10°, and 2100 ft. of tangent. Without asserting this, the author is content to believe that under ordinary circumstances they are nearly equal.

We have seen then above that only in the item of comfort to passengers is there much to be said against the use of much sharper curves than those in ordinary use, say up to 8° or 10°.

Whether the author is right or wrong in his conclusions as above, it is certain that the tendency is towards their use, and towards flattening the grades as much as possible. This is a money-making age, and whereas the question of grades is one of dollars and cents from first to last, the objection to curves is admitted even by those most opposed to them to be largely a matter of sentiment. The average business man will buy an accident ticket, and risk his life on the crookedest of roads, but he will not invest his money in a road which, owing to the cost of operation, will not pay dividends.

When money is scarce, and heavy work cannot be resorted to to reduce gradients, we have no choice, therefore, very often between a crooked road and no road at all. And there is this strong argument on a new road in favour of adopting sharp curves rather than heavy grades, that having a rise of say 320 ft. in 4 miles or 80 ft. per mile, connecting two level or nearly level stretches, it is impossible to reduce this hereafter to 8 miles of a 40 ft. grade otherwise than by the complete abandonment of at least 8 miles of road,—no part of the original road will serve for the altered one. Whereas a few sharp curves can often be taken out or reduced by gradually cutting into a hillside at one point, and filling out at another; and the cost of doing this, distributed over several years, during which the road is earning money, will scarcely be felt, although it would have been serious and perhaps prohibitive if undertaken in the first place.

This practice of opening roads at the earliest possible moment, and improving them as growing traffic warrants the expense, has become so very common and is so eminently reasonable and sensible, that this is in itself in many cases sufficient reason to decide the choice between the two hurtful elements.

In a majority of lines the traffic is light in the first place, and gradually increases. Hence, for the first few years we must endeavour to keep the capital cost and fixed charges as low as possible, they being the heaviest charges against the revenue. As the traffic grows the maintenance account grows almost in the same ratio, and becomes of greater relative importance, hence we are justified in increasing the capital account to diminish it.

Without further discussion as to why and wherefore, when and where they should be used, which is a little foreign to the purpose of this paper, the author proposes to investigate, supposing sharp curves to be adopted, what their form should be, and how we may best make them as little hurtful and as comfortable to ride over as may be.

To overcome the evil effects of centrifugal force it is the common practice, as every one knows, to elevate the outer rail to an amount which varies with the speed intended. This amount is generally put down at .05 feet for every degree of curvature corresponding to a speed of 30 miles per hour, and the results are good for the ordinary range of curves. The author's own experience is that this gives rather too much for the very sharp curves, which are run over at low speeds, and not enough for the flat ones; but for curves from 1° to 8°, this rule is as good probably as any.

Once the car is on the curve, this elevation or cant is quite effective in counteracting the centrifugal force, and whether slightly too much or too little matters little, as the body quickly adjusts itself a little out of the perpendicular to correct the deficiency or surplus. With 6 inches elevation we may ride around a 10° curve at 30 miles an hour, and experience neither danger nor discomfort; but if we change abruptly from a straight line to a 10° curve, we must either have the track insufficiently elevated on the curve, or have 6 inches of elevation on the tangent, and in either case we have a sharp jerk as the car strikes the curve, after which it travels steadily enough until it leaves it again, when another minor lurch is experienced.

The reason for the harder lurch at the beginning of the curve, the author has never seen explained, except as the effect of insufficient elevation at the point of curvature; but an additional cause is as follows:

On the tangent the truck frame is parallel to the axis of the cars and both wheel flanges are travelling clear of the rail, and generally owing to play, slack gauge, and worn flanges an inch or more from it. A very simple calculation will show that with this 1 inch of play the truck will run straight on a 10° curve for some 10 feet before the flange will come in contact with the rail, and the change in direction is then angular instead of circular, hence the lurch which no amount of superelevation will counteract. It is on this account that widened gauge and derailments almost invariably occur at the ends of curves. There is not only an angular change in the motion of the car far more marked than at any other portion of the curve, but there is the impact of the flange against the rail, and the sudden almost instantaneous change in direction of the truck itself with reference to the car body. The want of freeness in swivelling motion of the truck, owing to an excessive bearing on the friction blocks or other cause, is another very fruitful cause of derailment.

To obviate this shock at the ends of curves, various forms have been proposed—parabolic, logarithmic and others; but these are not only so cumbersome to lay out as to be almost useless in practical location, but do not always effect the desired object.

It will be seen from the foregoing that the perfect curve is one in which the radius gradually and regularly diminishes from infinity to the minimum in such a distance, that the superelevation is not accomplished by a steep rise or fall in either rail. This minimum radius and maximum elevation is then retained to within the same distance of the end, when the reverse process takes place. At a gradient of 1 in 600 the maximum for a 10° curve of 0.5 feet will be attained at 300 feet, and at every 30 feet .05 feet corresponding to 1° curvature should be gained. The degree of curvature at any point on this 300 feet should be directly proportional to its distance from the point of curvature. Call the latter P. Fig. 1.* and the ends of the several 30 ft. Chords. P_1 P_2 P_3... P_{10}, then the curvature is represented at any of them by its corresponding index number, 1.° 2.° 3.° etc. This curve is luckily not only theoretically the best for the purposes, but easy to run in on the ground either with the transit or by offsets from the tangent and from the final curve produced, and the effect on the easy riding of the car is marvellous. Any length of chord may be used, the longer for flatter curves, on which high speed is contemplated, the shorter for sharper curves than 10°, when it is difficult perhaps to get sufficient room for the longer. For ordinary practice the 30 feet or 1 rail length will be found very convenient for use.

Let P P_{10} in Fig. 1 be such a curve uniformly accelerating from 0° at P to 10° at P_{10}, whence it remains constant. The mean curvature will be 5°, and the length being 300 feet the total deflection is 15°, represented by the angle T_1 I S. In like manner it may be demonstrated that the total deflection at P_2 is $1° \times .6 = 36'$, at P_4 144′ or 2° 24′, in fact proportional to the squares of the index numbers.

It can also be demonstrated that the tangential angles T_1 P P_1, T_1 P P_2, etc., T_1 P P_{10} are $\frac{1}{3}$ of the total deflections, and are also proportional to the squares of the index numbers, the series being 3′, 12′, 27′-48′, etc., up to 5°.

Here then we have the means of running in the curve with equal ease to a circular arc, setting the transit at P, and turning of the angles corresponding not to the distances themselves but to the squares of those distances. Arrived at P_{10} we put in a hub, move the transit up, and sighting back at P turn off 10° to the tangent P_{10} S, whence we can run the 10° curve in the ordinary way.

*See page 417.

Arrived at the other end of the curve, the process is quite simple, although a little more figuring is involved.

Suppose we have run the curve round to P_{10} from C, and we wish to run the transition curve from P_{10} to P. Producing the 10° curve towards P, it will be seen at once that the transition curve leaves it at precisely the same rate as it leaves the tangent in starting from P, and the series of angles will be the difference between those for a 10° curve and those given.

P_9 will be $5° \times .3 = 1°30$ less $3' = 1° 27'$ (I being 0)
P_8 " " $5° \times .6 = 3°$ " $12' = 2° 48'$
P_7 " " $5° \times .9 = 4°30$ " $27' = 4° 03'$
etc., etc. etc., etc.
P " " $5° \times 3 = 15°$ " $5° = 10° 00'$

If *tt* be the tangent to the 10° curve produced, until parallel to TT, it will be evident that the point of tangent is opposite P_5, or midway of the transition curve, and from the foregoing that P_5 is equidistant from the circular curve and from the tangent on either side of it. Mathematically, this is not exactly true, but for the purpose we are considering it is practically so. A little consideration will show that as in the circular curve the offsets from the tangent are proportional to the squares of the distances from the origin, so in this curve we are considering the corresponding offsets from TT to the point P_1 P_2 etc., are proportional to the cubes of the distances or to the cubes of the index members, and correspond to the series 1, 8, 27, 64, etc., 1000, the tangential offset for P_1 can be calculated to be .02615, hence that for P_5 it will be $.02615 \times 125$ or 3.27, and the rectangular distance will be between TT and *tt*1 double of this, or 6.54.

This property of the curve under discussion has caused Mr. Wellington, who first called attention to it in print, to designate it the "cubic parabola."

The circle being the "simple" curve, having the tangential angles proportional to the distances, this curve might, from the peculiarity mentioned above, be called the "quadratic" curve.

As the parabola is practically coincident with the circle for small arcs, so the cubic parabola is practically identical with the quadratic curve for small arcs, and the formulæ for either may be used interchangeably on transition curves of small total angle; but if carried on, the two will soon separate widely, as will the circle and parabola with the same initial radius of curvature.

This property of offsets suggests another method of running in the curve, which in certain situations is easier and more expeditious than the preceding.

Run the 10° curve round to the end at P_5, offset the tangent 6.54 ft., put in P on this tangent 150 ft. from P_5, and then offset the stakes P_1 to P_4 from the tangent and P_6 to P_9 by corresponding amounts from the curve.

In some situations, and notably where it is required to readjust old curves without incurring too much work, the displacement of $6\frac{1}{2}$ feet will be found too great. In such cases it should be remembered that with chords of even half the length assumed, or 15 feet, there would be a rise in the outer rail of only 1 in 300, which is by no means excessive. Dividing the chord by 2 has the effect of reducing the total displacement to $\frac{1}{4}$ of the original, or 1.6 feet, an amount which can generally be easily attained, half the displacement being placed on the curve and half on the tangent. To avoid cutting rails and altering the length of old track, the central portion of the curve should be sharpened and the crown thrown slightly outside that of the original curve. Fig. 2.

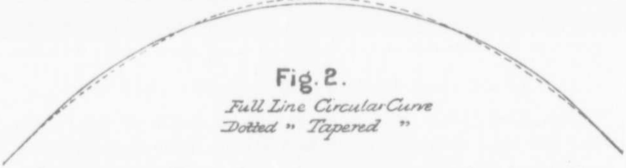


Fig. 2.
Full Line Circular Curve
Dotted " Tapered "

Let us suppose, Fig. 3, that we have a very common location problem —two fixed tangents intersecting at a given angle—it is required to fix the point of curvature P on each, of a curve of given radius connected with the tangents by transition curves.

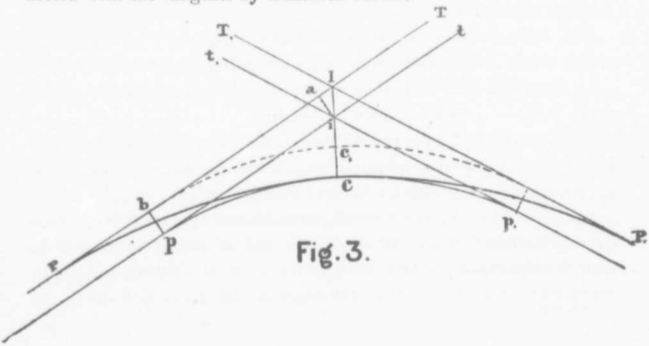


Fig. 3.

Let $P\ T$ and $P_1\ T_1$ be the given tangents intersecting at the point I with an angle of say 60°, it is required to connect them with a 10° curve tapered at the ends by transition curves of 300 ft. in length, as in Fig. 1.

We wish to find the distance P_1 or the subtangent of the curve. We have seen that the total displacement of the tangents from those of the simple curve produced is 6.54 ft.; produce the central curve both ways, and draw the parallel tangents $p\ t$ and $p_1\ t_1$ intersecting at i, draw the middle radius $I\ i\ c_1\ c$, and let fall a perpendicular $i\ a$ from i upon $P\ T$ and $p\ b$ from p upon $P\ T$, then

$$PI = Pb + pi + Ia, \ Pb \text{ is by Fig. 1} = 150 \text{ feet.}$$

$$Ia = ia \times \text{cotan } \tfrac{1}{2}\text{I} = 6.54 \text{ cotan } 60° = 3.8 \text{ ``}$$

$$\text{and—}pi = 573 \text{ tan } \tfrac{60°}{2} = 573 \times \text{tan } 30° = 330.8 \text{ ``}$$

$$\text{therefore } P\ I \qquad = 484.6 \text{ ``}$$

It will often be desirable to know how far the tapered curve falls inside the simple curve, connecting the same tangents represented by $C\ C$ in the figure; in other words, what is the difference in the crown distance $Ic_1 = ic$, since they both represent the crown distances for two curves of the same radius, and having the same central angle; therefore

$$CC_1 = li = ia \sin \tfrac{1}{2}\ P\ IP_1 = 6.54 \text{ cosec } 60° = 7.55 \text{ feet.}$$

A number of other problems might be given similar to those in the field books for circular curves; the figuring in every case is rather more complex than for simple curves, but the instrumental work is no more difficult, and once the reader has mastered the general characteristics of this form of curve he will readily solve them for himself, and probably be able to demonstrate the correctness of the results much more clearly than the writer.

The author wishes to say further that with compound curves the *modus operandi* is entirely similar, the tangential angles for each chord point being turned off from the corresponding points on the simple curve produced instead of from the tangent.

Suppose (Fig. 4*) we are running a transition curve between a 6° and a 10° curve, the difference is 4°, and the angles are precisely the same as those between a tangent and a 4° curve.

Let $P\ P_1\ P_2\ P_3\ P_4$ be the chord points, 30 feet apart as before. Then the angles from the tangent at P_1 the end of the 6° curve, will be those for the curve produced + those for the transition curve.

* See page 417.

P^1, $3° \times .30 + 0°03' = .54' + 3' = .57'$
P_2, $3° \times .60 + 0°12' = 1° 48' + 12' = 2°.00'$
P_3, $3° \times .90 + 0°27' = 2° 42' + 27' = 3°.09'$
P_4, $3° \times 1.20 + 0°48' = 3° 36' + 48' = 4°.24'$

Moving the transit up to P_4 the angle between PP_4 produced and the tangent at P_4 will be

$$3° \times 1.2 + 0° 48' \times 2 = 3° 36' \times 1° 36' = 5° 12'$$

In running a long curve over rough ground, it will often happen (perhaps owing to unavoidable errors in taking the notes off the platted plan) that the final tangent does not lie quite in the position we wish, but parallel to it. With a simple curve we should either start back to the beginning and try it again, or sharpen or flatten the end a little to bring it into position. The first course consumes much time, and the last state of that curve is sometimes nearly as bad as the first. The second method savours of patch work, and is never quite satisfactory. The transition curve, on the contrary, affords a means of adjusting such little differences with great accuracy, leaving the curve theoretically as perfect as if it had come out right in the first place.

Suppose again we have run the curve in Fig. 1 out to the end at P, and we wish to shift the tangent $2\frac{1}{2}$ feet further out or away from tt. The offset tt was 6.54, we wish to make it 9 feet. We have merely to increase the chord length in the proportion of the square roots of these offsets. C and O being the original, and C_1 and O_1 the new chord and offset;

$$\text{then } \frac{C^1}{C} = \sqrt{\frac{O_1}{O}} = \text{ and } C^1 = C\sqrt{\frac{O_1}{O}} = 30\sqrt{\frac{9}{6.5}} = 35$$

nearly, the initial tangential angle will be $3'.5$ the total length of transition curve 350 feet, and the total deflection $3'.5 \times 3 \times 10^2 = 1050'$ or $17° 30'$ instead of $15°$. We have merely then to set P_{10} in 25 feet further back on the curve, and proceed with the new curve in the same way as before.

It will be seen that tapered curves are considerably longer than simple ones with the same central angle, and consequently in readjusting a location having sharp curves of contrary flexure separated by short tangents, we shall have to still further reduce these tangents. This, however, matters not, for the objection to absolute reversed curves disappears altogether when they take this form. Calling angles to right + and to left — in the reversed curve, the curvatures at the successive chord points are 4,° 3,° 2,° 1,° 0,—1,°—2,°—3,°, etc., differing always by unity as before. In Fig. 5 we have a reversed transition, curve between two 5° curves of contrary flexure with the same pitch as in Fig. 1. Merely remembering that we are starting from a 5.° curve instead of a tangent, we can set up on P and run through to P^{10} just as easily as we could the constant curve in Fig. 1. The change in curvature is the difference between 5.° and—5.° or 10.°, consequently the total length and total offset are the same in both cases, the tangential angles at P will be

$$\left.\begin{array}{l} P_1,\ 2°30 \times .3 - 3' = 45' - 3' = 42' \\ P_2,\ 2°30 \times .6 - 12' = 1.°30' - 12' = 1.°18' \\ P_5,\ 2°30 \times 1.5 - 1°15' = 3.°45' - 1°15' = 2.°30' \\ P_{10},\ 2°30 \times 3 - 5°00' = 7.°30' - 5°00' = 2.°30' \end{array}\right\} \text{All positive or to right.}$$

And moving up to P^{10} we turn off for the tangent of the 5.° curve at that point $2°30 \times 3 = 7°.30 - 10^0 = 2°30'$ or $2°30'$ to left.

The author fears he has already exceeded the limits which such a paper as this should occupy, and will content himself with some remarks on the treatment of curvature, generally, without any further mathematical investigation, which he feels that a large number of the members of the Society are better qualified to make than he.

Where grades and curves occur in conjunction, it is good practice in location to flatten the former for the distance over which such curves extend by an amount sufficient to neutralize the extra resistance. On a 10° curve therefore the grade should be flattened $\frac{3}{10}$ or thereabouts per 100 ft. In all discussions of this question the train moving upwards only has been considered. Mr. A. M. Wellington, for instance, who has written more ably and exhaustively on location questions than any one who has preceded him, quite neglects to take into account the effect of this curve compensation on the swiftly moving downward train. He shows as others have before, and as any practical railway man knows for himself, the bad effects of a sudden change of gradient from steep to flat, in causing a "piling up" of the rear cars of a long train against the forward ones, which are meeting with more resistance, often causing derailment even on straight track; and he strongly insists on long vertical curves connecting these grades of varying pitch.

Now, with compensated curves, this retardation is doubled, for the engine entering the curve on its downward path experiences not only the loss of the accelerating force due to the $\frac{3}{10}$ per cent. grade, but the resistance of the curve as well, equivalent to another $\frac{3}{10}$ or $\frac{6}{10}$ in all, and the tendency to derailment is much more than doubled on account of the curved position of the train tending to force the center cars towards the outside of the curve, or in the same direction in which there is already a strong disposition owing to centrifugal force and the want of radiality in the axles. Here, the author thinks, is another fruitful cause of wreck, to freight trains especially, which has not been fully investigated before, and which has led to an unnecessary prejudice against curvature *per se*—unnecessary, because the cure is easy. And here again is another argument in favour of transition curves. Able authorities contend that the rate of change in the gradient should not exceed $\frac{2}{10}$ per 100. The total change being, as we have shewn, equivalent to $\frac{6}{10}$ per cent., the vertical curve would have a length of 300 ft., or precisely the same as the transition curve we have been considering; and not only is the accelerating force urging the downward train gradually diminished, so that its loss is unhurtful, but the resistance to the upbound train is at all points precisely the same, and we have neither in plan nor profile any sharp angles or transitions from tangent to curve or from steep grade to flat.

As to superelevation of outside rail, it is generally conceded that it is better to carry this to the full amount which theory demands for the highest speed practicable on the curve, and that it is better to have too much elevation than too little. The author's own opinion is that the ordinary rule of $\frac{1}{20}$ ft. for each degree corresponding to a 30 mile speed is rather too little for the flat curves from 0 to 4°, about right at 6°, and altogether too much for sharp curves from 10° to 20°, and that an excessive elevation is more dangerous than the reverse, causing as it does at low speeds a diminution of weight on the outside wheel, which is the only one which has anything to do with directing the train, and consequently rendering it easier for the flange to rise over the rail.

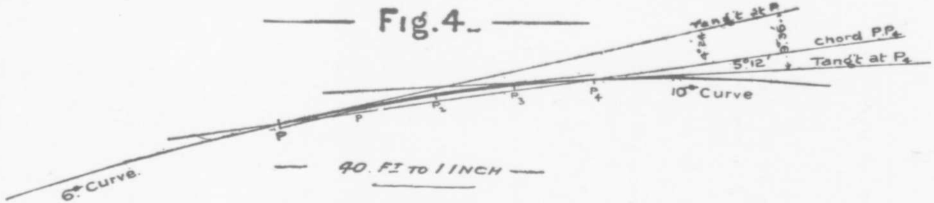
It should be remembered, too, that while the tangential tendency of the outside wheel merely causes grinding action of the flange against the side of the rail, and strains internal to that rail itself, the inside wheel is dependent on the thrust of the axle for guidance, and through it is constantly exerting a force tending to spread the gauge. Hence, from this point of view also, it is better to have at least an equal weight on both. The author has found also on sharp curves, only intended and used for low speeds with a high elevation, that there is a tendency in the track to move inwards, the ties sliding on the ballast.

Widening the gauge contributes to ease in traversing curves, and in track laying it is a matter still in dispute whether joints should be broken or square. On tangents the proper disposition of them depends in the writer's opinion very much on the quality of the road-bed and depth of ballast, &c. The best track is that with broken joints; but poor track will probably be less objectionable with square joints. However this may be, on curves the joints should undoubtedly be broken. The elastic curve is sharper in the centre and flatter at the ends than the circular, and bent rails on a curve will always tend to develop elbows at each joint. By breaking the joints the elbow is corrected by the unbroken rail on the opposite side and the track is rendered much easier to throw and keep in line. A combination of square joints on tangents and broken on curves is very simply effected in this manner, in the sharper ones is absolutely necessary; on a 10° curve $\frac{3}{4}$ of an inch is sufficient, but in order to obviate the shock which the author has dwelt on above, in entering the curve, the gauge should be tight and close at either end; with transition curves, it is easy to widen the gauge uniformly from the beginning of the curve to the point of constant curvature. Lastly, it cannot be too strongly insisted on that curves should be run accurately with the instrument, and centers placed permanently at short intervals, with fine brass tacks in their heads, marking the exact position of the line. The track gauge should have a notch marking its center, so that the foreman can at a glance see whether the track is centered or not, without the use of the tape, and the track level should have a sensitive bubble and an attachment for getting the superelevation exactly.

The outside rail should be kept equidistant from the center, and any variation in width of gauge thrown altogether on the inside rail. The folly, nay, wickedness, of leaving the lining of curves to the foreman's eye, and the elevation to his inner consciousness, is just as gross and unpardonable as would be regulation of the depth of cuttings and height of bridges by the same standard, and is very much more likely to lead to accident. Centers should never be more than 100 feet apart, and on curves never more than 50 feet; on 10° curves they should be placed at least every 25 or 30 feet, and more frequently on the sharper curves.

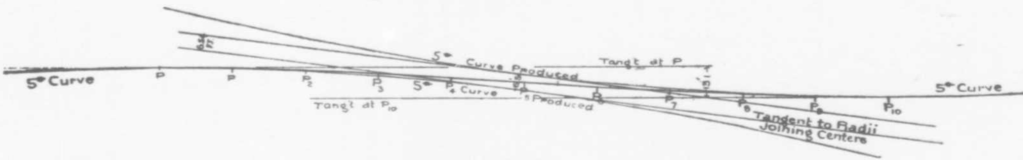
On a 20° curve, which the author ran in within the last few months, and which has been in constant use ever since by passenger trains, the centers were placed every 10 feet, and rigidly adhered to; the gauge was widened 1 inch, and the elevation is 3 inches, which is rather too much than too little. No spreading of the gauge has taken place, and on the greater portion not one dollar has been spent in repairs; such repairs as have been done were on account of subsidence of new bank, and they would have been equally necessary on tangent. Not the slightest difficulty or expense has been experienced in operating this curve for a year, either summer or winter. A stop is necessary for all trains within a few feet of one end, and all trains therefore traverse it very slowly; but the author would not hesitate to run over it at 15 miles per hour. While not advocating the use of such extreme curves on the open road, except temporarily and in extreme cases, the author feels satisfied that properly laid, adjusted, compensated, and tapered curves of 10° or even more might have been used to save money with much better results as to safety and economy, in many cases where heavy grades have been adopted to the same end, and that a great deal of the prejudice which is shewn, especially among the older men of our profession, against the free use of it, to save the capital account and increase the operative value, is to a large extent sentimental and groundless; and the author will be glad if this paper suggests anything worthy of discussion or comment, whether favourable to his views or the reverse.

Fig. 4



40 FT. TO 1 INCH

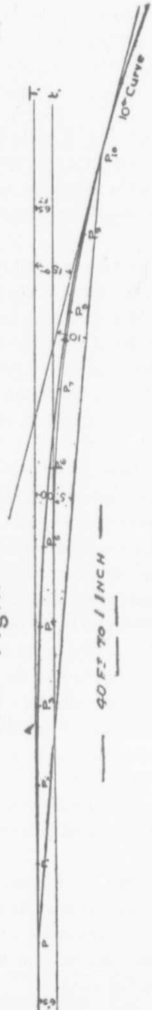
Fig. 5



40 FT. TO 1 INCH

STATION.	TANGENT'L. ANGLE.	TOTAL DEFLECTION.
P1	0.°45′—0.°03′=0.°42′	1.30— 0.°09′=1.°21′
P2	1.°30′—0.°12′=1.°18′	3.00— 0.°36′=2.°24′
P3	2.°15′—0.°27′=1.°48′	4.30— 1.°21′=3.°09′
P4	3.°00′—0.°48′=2.°12′	6.00— 2.°24′=3.°36′
P5	3.°45′—1.°15′=2.°30′	7.30— 3.°45′=3.°45′
P6	4.°30′—1.°48′=2.°42′	9.00— 5.°24′=3.°36′
P7	5.°15′—2.°27′=2.°48′	10.30— 7.°21′=3.°09′
P8	6.°00′—3.°12′=2.°48′	12.30— 9.°36′=2.°24′
P9	6.°45′—4.°03′=2.°42′	13.30—12.°09′=1.°21′
P10	7.°30′—5.°00′=2.°30′	15.00—15.°00′=0.°00′

Fig. 1.



40 FT. TO 1 INCH

STATION.	DIST. IN FT.	CURVATURE.	TANG'T. ANGLE	TOT. DEFLEC'N.	TANG'T. OFFSET IN FEET.
P.	0	0	0′	0′	0
P_1	30	1°	3′	9′	0. 03
P_2	60	2°	12′	36′	0. 21
P_3	90	3°	27′	1.°21′	0. 71
P_4	120	4°	48′	2.°24′	1. 67
P_5	150	5°	1.°15′	3.°45′	3. 27
P_6	180	6°	1.°48′	5.°24′	5. 65
P_7	210	7°	2.°27′	7.°21′	8. 97
P_8	240	8°	3.°12′	9.°36′	13. 39
P_9	270	9°	4.°03′	12.°09′	19. 06
P_{10}	300	10°	5.°00′	15.°00′	26.°15

DISCUSSION.

Mr. Irwin.

Mr. H. Irwin said there seems to be many points in Mr. Wicksteed's paper worthy of attention, and two are new to him, viz.: the possibility of breaks causing derailment on a curve, and the lurch caused by a wheel striking the rail when it has gone as far as possible on a curve, without changing its direction.

The speaker does not agree with Mr. Wicksteed's statement, that the tendency to derailment is almost independent of the radius of curvature. It has been sometimes said that track-spreading generally happened on curves. Track-spreading may be due to either of three causes, viz.: centrifugal force not properly balanced by elevating the outer rails, and which increases as the radius of curvature decreases; the hump in the curve made by the section men in easing off the ends of curves; also by the impact of the flange against the rail when entering the curve. In the latter case the change would be in proportion to the degree of curvature, and hence transition curves are advisable and would avoid the hump referred to. He considers that it would be as easy and as safe to run round a 10 degree curve with proper transition curves at the ends, as it is to run round a 6 degree curve without transition curves. The speaker's experience of the hump on entrance to curves convinces him that they are often worse than they appear. It is advisable to use transition curves when sharper than 1°. Theoretically, it appears to the speaker that Mr. Wicksteed's method of laying out transition curves is good, but in practice he thinks it would be attended with difficulties in bending rails to suit the curve, as the example given by Mr. Wicksteed would then amount to a transition curve of 30 feet each of 30′, 1° 30′, 2° 30′, 3° 30′, etc., up to 9° 30′, merging into a 10° curve.

The speaker has worked out a set of tables, mathematically exact, which give all necessary information for laying out about 80 different transition curves.

Using a set of tables, the only extra work required is to calculate the subtangent for a transition curve. To give an instance: It is proposed on a 4° curve to have transition curves in three pieces of 100 feet each of 1°, 2° and 3°. The length of the subtangent has first to be determined. Without tables this could be done as follows :—

Let LK′ and L′K be two tangents, the total deflection angle or the intersection angle being I. See Fig 1.

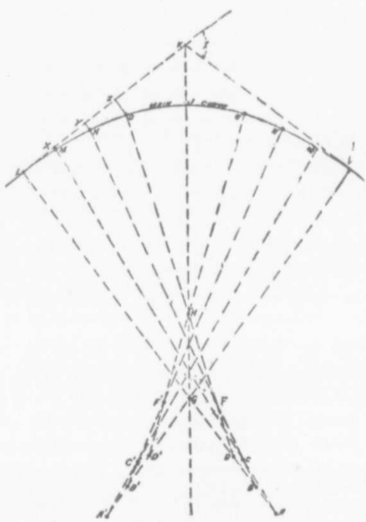
Let LM, MN and NO be each 100 feet long, of 1°, 2°, and 3° curves, the arc OO′ being the main 4° curve. Let A, C, F and H be the centres respectively of the arcs LM, MN, NO and OO.

Then, in the case stated, the angles at A, C and F are respectively 1°, 2° and 3°. The angle GBF is 3° and the angle GDF is 6°.

The angle LGH is equal to (GDF+GHD)=(GDF+OHJ), therefore the angle OHJ is equal to half the deflection angle I less the deflection of 6° between the points L and O.

Now, the length AC is equal to the difference between the radii of a 1° curve and a 2° curve, and the angles at A, B, and C are known, therefore AB and BC can be found.

Then in the triangle BDF, BC is known, and FC is the difference between the radii of a 2° curve and a 3° curve, therefore BF is known, and the angles at B, D and F are known. The lengths BD and DF can therefore be calculated.



Then in the triangle DGH, the length DF is known, FH is the difference between the radii of a 3° curve and a 4° curve, the angles at D, G and H are known, since LCJ is equal to half the total deflection angle I, therefore the lengths DG and GH can be found.

We have now AB, BD and DG, and therefore the total length AG, therefore LG can be found by subtracting AG from AL, which in the present case is the radius of a 1° curve.

The subtangent LK can therefore be calculated in the usual manner, since LK = LG × tan ½ I.

If it be desirable to find the apex distance, KG can be calculated, HG is known, and HJ is, in the present case, the radius of a 4° curve, therefore JK can be got by subtraction; JK being the apex distance, which is often very useful as a check on the accuracy of the work.

If it be necessary to find how far the compound curve lies inside a simple curve, the apex distance of the simple curve subtracted from KJ gives the required distance.

It will be seen that without tables the calculations, even in this simple case, are altogether too long to be performed in the field.

The speaker has, however, calculated for all the 35 cases above referred to, the lengths AB, AD, etc., BC, DF, etc., and also the angles at B, D, etc., these being independent of the intersection angle I.

It will be seen that no matter how many pieces the transition curve is composed of, the only triangle to be calculated in the field is the last, DGH in the present case, since all the other triangles are independent of the intersection angle I.

Having the tables, it is only necessary to find the difference between the radii of a 3° curve and a 4° curve, add that to DF to get DH, subtract the angle GDF, as given in the tables, from half the intersection angle I to get the angle GHD, and then calculate GD.

The length LG is then found by subtracting AG from AL, in the present case, the radius of a 1° curve. Then LK can be found in the usual manner.

Supposing that the intersection angle I be 46° 40′, then the calculation of the subtangent in the present case would be as follows, viz.:

Rad. of 3° curve =	1909.85	½ I =	23° 20′
do 4° do =	1432.39	GDF =	6° 00′
Rad. of 3°–Rad of 4° =	477.46	GHD =	17° 20
DF from tables =	956.43	GD =	1078.58
		From table AD =	2866.78
DH =	1433.89		
Log 1433.89 =	3.1565160	AG =	3945.36
Log Sin 17° 20′ =	9.4741146	AL =	5729.58

	12.6306306
Log Sin 23° 20′	= 9.5977827
Log GD	= 3.0328479
GD	= 1078.58

LG	= 1784.22
Log LG	= 3.2514459
Log Tan 23° 20′	= 9.6348378
Log LK	= 2.8862837
LK Sub. Tan	= 769.63

Should it be required to find the apex distance, the calculations would be as follows, viz.:

Log 1433.89	= 3.1565160
Log Sin 6°	= 9.0192346
	= 12.1757506
Log Sin 23° 20′	= 9.5977827
Log HG	= 2.5779679
Log HG	= 378.41
Log HJ	= 1432.39
Log JG	= 1810.80

Log LG	= 3.2514459
Log Sec 23.20′	= 10.1037055
Log GK	= 3.2885010
GK	= 1943.13
JG	= 1810.80
JK	= 132.33

Apex distance for a 4° curve with I = 46° 40′, from Shunk = $\frac{510.4}{4}$ } = 127.60

Transition curve inside simple 4° curve by 4.73 feet.

In addition to the necessary information for calculating the sub-tangent, these tables give the tangential angles from L to M, N, O, etc.

As it is possible that the whole of a transition curve could not be run in from the BC, the tangential angles from M to N, O, etc., are given in the tables, as well as the tangential angles from each point on all the transition curves to all the points ahead.

The angles to be turned off at M, N, O, etc., when sighting back to L, M, N, etc., so as to get on to the tangent at M, N, O, etc., are all given as well as the lengths LX, LXLZ, etc., along the tangent, and the offsets XM, XN, ZO, etc., to the various points on the transition curve, in case it should be more convenient to lay out the transition curve by offsets; these last mentioned lengths would also be very useful to plot the curve on a large scale, should that be necessary, as in the case of a bridge or trestle on a curve.

The speaker thinks it practicable to run in the transition curves from the main tangent at each end.

A transition curve had been worked out by the speaker, corresponding very nearly to the example in the paper; it is composed of 30 feet each of 0° 30′, 1° 30′, 2° 30′ &c......9° 30′ curve, leading up to a 10° 30′ curve; the tangential angles together with the distances along the tangent and the offsets from the same are as follows:—

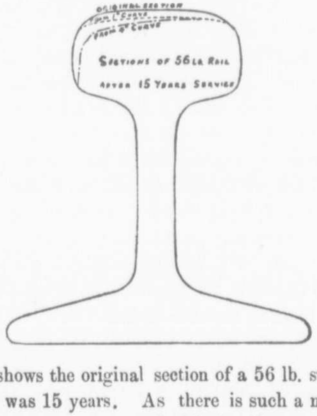
Tangential angles from the B.C.	Distances along main tangent.	Offsets from main tangent.
	feet	feet
$T_1 = 0°\ 04'\ 30''$	$D_1 = 30.00$	$O_1 = 0.04$
$T_2 = 0°\ 13'\ 30''$	$D_2 = 60.00$	$O_2 = 0.23$
$T_3 = 0°\ 28'\ 30''$	$D_3 = 90.00$	$O_3 = 0.75$
$T_4 = 0°\ 49'\ 30''$	$D_4 = 119.98$	$O_4 = 1.73$
$T_5 = 1°\ 16'\ 30''$	$D_5 = 149.93$	$O_5 = 3.34$
$T_6 = 1°\ 49'\ 30''$	$D_6 = 179.84$	$O_6 = 5.73$
$T_7 = 2°\ 28'\ 30''$	$D_7 = 209.65$	$O_7 = 9.06$
$T_8 = 3°\ 13'\ 30''$	$D_8 = 239.41$	$O_8 = 13.49$
$T_9 = 4°\ 04'\ 30''$	$D_9 = 269.12$	$O_9 = 19.17$
$T_{10} = 5°\ 01'\ 30''$	$D_{10} = 298.83$	$O_{10} = 26.28$

It will be seen that the tangential angles are all 1′ 30″ more than those given by Mr. Wicksteed, and that the last offset is only 1½ inches longer than Mr. Wicksteed's last offset, being the difference in departure for 1′ 30″ at 300 feet.

It has been said that it would be difficult to fit in transition curves on very rough ground; but the speaker would remark that the difference between a simple curve and a curve with transition ends is not great.

CORRESPONDENCE.

Mr. Duncan McPherson said he agreed with the author of the paper that looking to the earning powers and commercial value of a railway, moderately sharp curves of say 5° or 6° should be used in preference to such heavy grades as 75 to 80 feet per mile, if by using such curves the grades can be reduced to 50 feet or less per mile. He is, however, of opinion that for a standard gauge Trunk Line, where high speed and comfort are essentials, curves as sharp as 10° cannot be used unless at approaches to stations or other points where speed is necessarily reduced to not more than 20 miles per hour, also that a speed of 30 miles per hour would in his opinion be too fast for a passenger train to traverse a 10° curve, and would be inadmissible for a freight train at the same speed. His experience is that the cost of maintenance of track and rolling stock is greatly increased by the use of sharp curves, and is not, as Mr. Wicksteed considers, independent of the radius and due to curvature "per se." In proof of this he submits the sections of three rails taken from the same locality, having had the same length of service on approximately level portions of track. Mr. MacPherson



The full line shows the original section of a 56 lb. steel rail, and the length of service was 15 years. As there is such a marked difference of wear in the 1° curve as compared with the 4° curve, the inference is, that the increased wear on a 10° curve would be more than in proportion to the degree of curvature, and that it is not independent of the radius.

The great difficulty about elevation of the outer rail on curves on single track roads appears to him to arise from the great difference of speed of freight and passenger trains. The rule given by the author is a good general rule for 30 miles per hour, and the writer has found in practice that $\frac{3}{4}$ of an inch elevation per degree answers for a speed of 40 miles per hour with passenger trains, though it is rather much for freights at 20 miles per hour. All such rules, however, can only be general guides, and have often to be modified by circumstances of location and curvature.

The method given in the paper of laying out transition curves on the ground seems very good and simple to calculate, also to lay down, and quite as serviceable as the more cumbersome methods of laying out parabolic curves.

Permanent centres should certainly be put in for all curves, as trackmen never can be made to understand that a slight *throw* at the beginning of a curve increases rapidly towards the other end.

Mr. Wicksteed. In answer to Mr. Irwin's remarks, the author would say that that gentleman has misquoted his paper altogether in regard to tendency to derailment being independant of the radius of curvature. What the author did say is that the tendency to derailment, owing to want of radiality in the axles and to the longer path traversed by the outside wheel, etc., is independent, or practically so, of the radius, and that "at very low speeds" there is little or no more flange pressure on the sharp curves than on the flat ones. The mechanical law, that the centrifugal force is inversely, as the radius, would render the statement Mr. Irwin credits him with, an absurdity; but the balance of the same law should also be borne in mind, that the centrifugal force varies directly with the square of the speed. Hence we should infer that an 8° curve is as safe at 30 miles per hour as a 2° is at 60 miles, which the writer believes to be literally true, and practically proved every hour of the day.

Mr. Irwin says that he thinks there would be practical difficulties in the way of laying down the proposed transition curves, and gives another method of doing the same thing.

Without questioning the accuracy of Mr. Irwin's figures, or the practicability of his methods, the writer would merely point out that Mr. Irwin himself demonstrates that his method would give a curve differing infinitesimally from his own (the writer's), consequently any objections to the one must apply to the other. No practical or other difficulties have been experienced in the author's method, and he prefers a curve which he can work out in the field without the help of tables, for any possible case, and for which general laws may be laid down.

In reply to Mr. McPherson, the writer would say that he also would appear to misunderstand his remarks.

No person will deny that rails wear quicker on a 4° curve than on a 1°, or on a 10° than on a 3°. The question is, whether there is with the same total angle of curvature more expense in maintenance with sharp curves than with flat ones. Having 90° of angle for instance, the 10° curve would be 900 ft. long, and the 3° curve 3,000 feet long, the rails on the former would undoubtedly wear soonest, but there are fewer of them, the remaining 2,100 feet being tangent and showing much less wear than on the 3° curve.

The writer has heard it confidently asserted that the shorter and sharper curves and longer tangents involve less expense than the reverse, and his own experience is that the difference is slight one way or the other.

The maximum safe speed on a 10° curve, the writer thinks, must be again left to experience. Express trains are running round curves of 10°, and more, every hour, not only in the United States, but in Canada, and at high speeds. He would name the railways and trains, but that he fears to frighten over-nervous passengers who are now riding almost daily over these same curves in blissful ignorance of both the speed and the radius, but in perfect security nevertheless.

The balance of the remarks of both Mr. Irwin and Mr. McPherson are a hearty endorsement of the writer's own views, and he would wish to conclude by saying again, that he is by no means an advocate of the indiscriminate and unnecessary use of curvature. But merely wishes to give his reasons for the faith which is in him, that being obliged to save money by departing from a mathematically straight line on plan and profile, he would, in probably nine cases out of ten, recommend that departure be in the shape of horizontal rather than vertical undulations.

He would further say that, since his paper was handed in, he has further studied the lifting action of brakes on the wheels, and is only the more convinced of the truth of his views.

Within the last day or two he has seen on a four-wheel truck the springs over the leading axle compressed 3 or 4 inches by the friction of the wheel against the brake. In this case the truck merely tilted up behind and down in front, but in a six-wheel truck it is not always possible for this tilting to take place, as it could only do so by a great increase in weight on the centre wheel, and in any case there is undoubtedly a diminution in weight on, and consequently of the directive power of, the leading wheel.

In this connection it may be remarked that, as the writer believes, the cars which were derailed in the St. Joseph accident were carried on six-wheel trucks. The remedy would seem to be in having the brakes made so as to grip the opposite sides of the same wheel in every case, and exactly on a level with its centre. Or in some device bringing a portion of the weight of the car body directly on the rails, without the intervention of the wheels. There is no doubt whatever that there is here a great source of danger which has been quite unrecognized and unappreciated.

Thursday, 21st May.

P. W. ST. GEORGE, Member of Council, in the Chair.

The following candidates, having been balloted for, were declared duly elected as :—

MEMBER.

GEORGE MASSON.

ASSOCIATE MEMBER.

HENRY DISNEY ELLIS.

ASSOCIATES.

JOHN IRWIN DAVIDSON. OLIVER AITKEN HOWLAND.
JOHN HOSKIN. WILMOT DELAIN MATTHEWS.

STUDENTS.

WILLIAM ARCHIBALD DUFF. HELMANN GLAENZER.

The disscusion of Mr. T. Drummond's paper on "Mining in British Columbia"; of Mr. H. K. Wicksteed's paper on "Railway Curves," and of Mr. A. Macdougall's paper on "Sewerage and Waterworks of St. Johns, Newfoundland," occupied the evening.

THE INTERNATIONAL COLLIERY, BRIDGEPORT, CAPE BRETON.

Fig. 1.

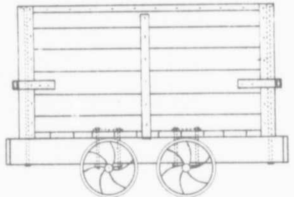


Fig. 2.

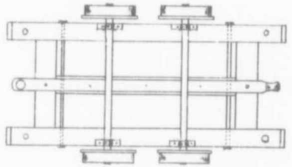
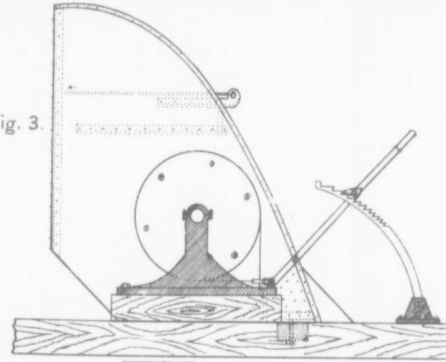


Fig. 3.



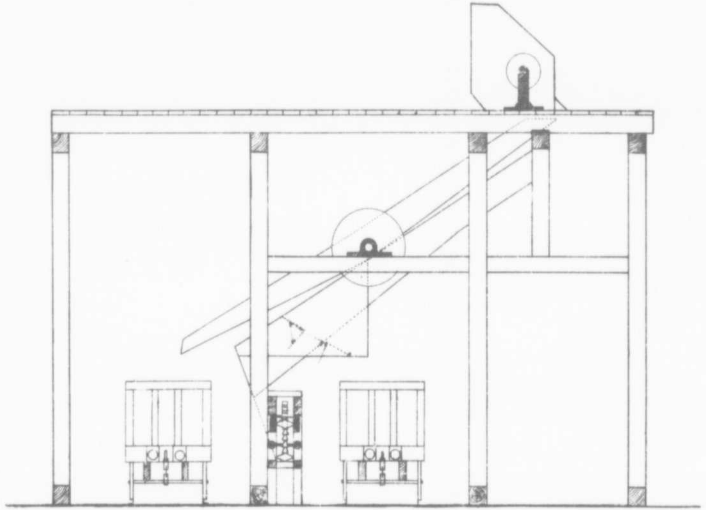


Fig. 4.

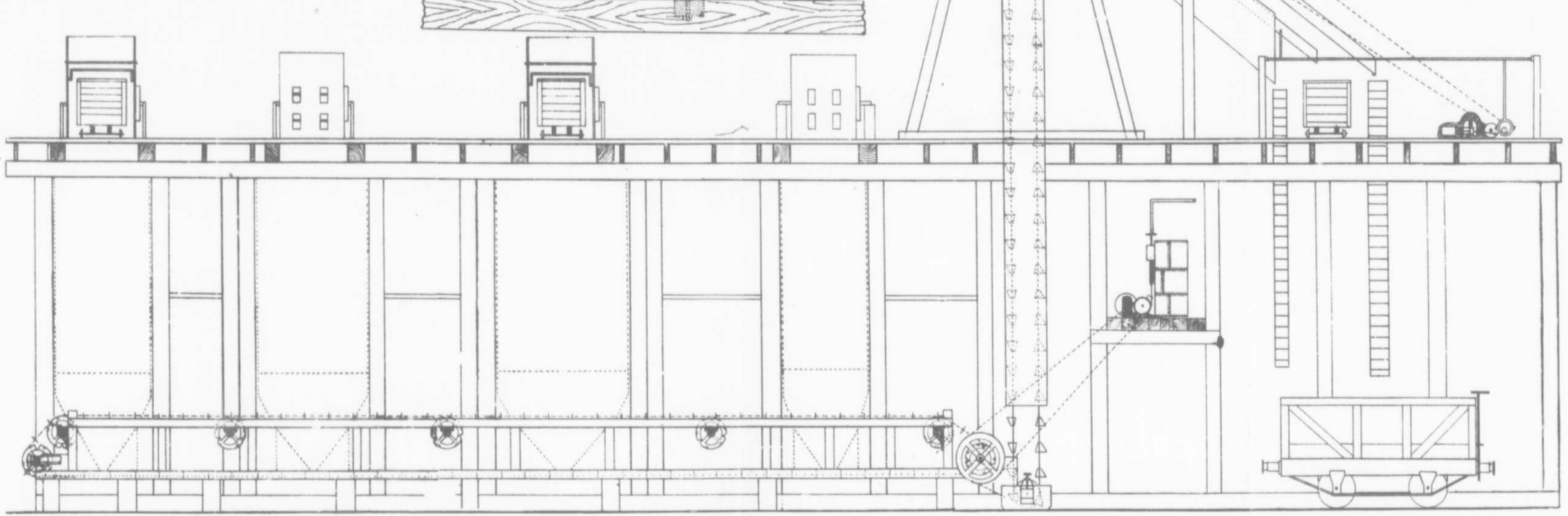
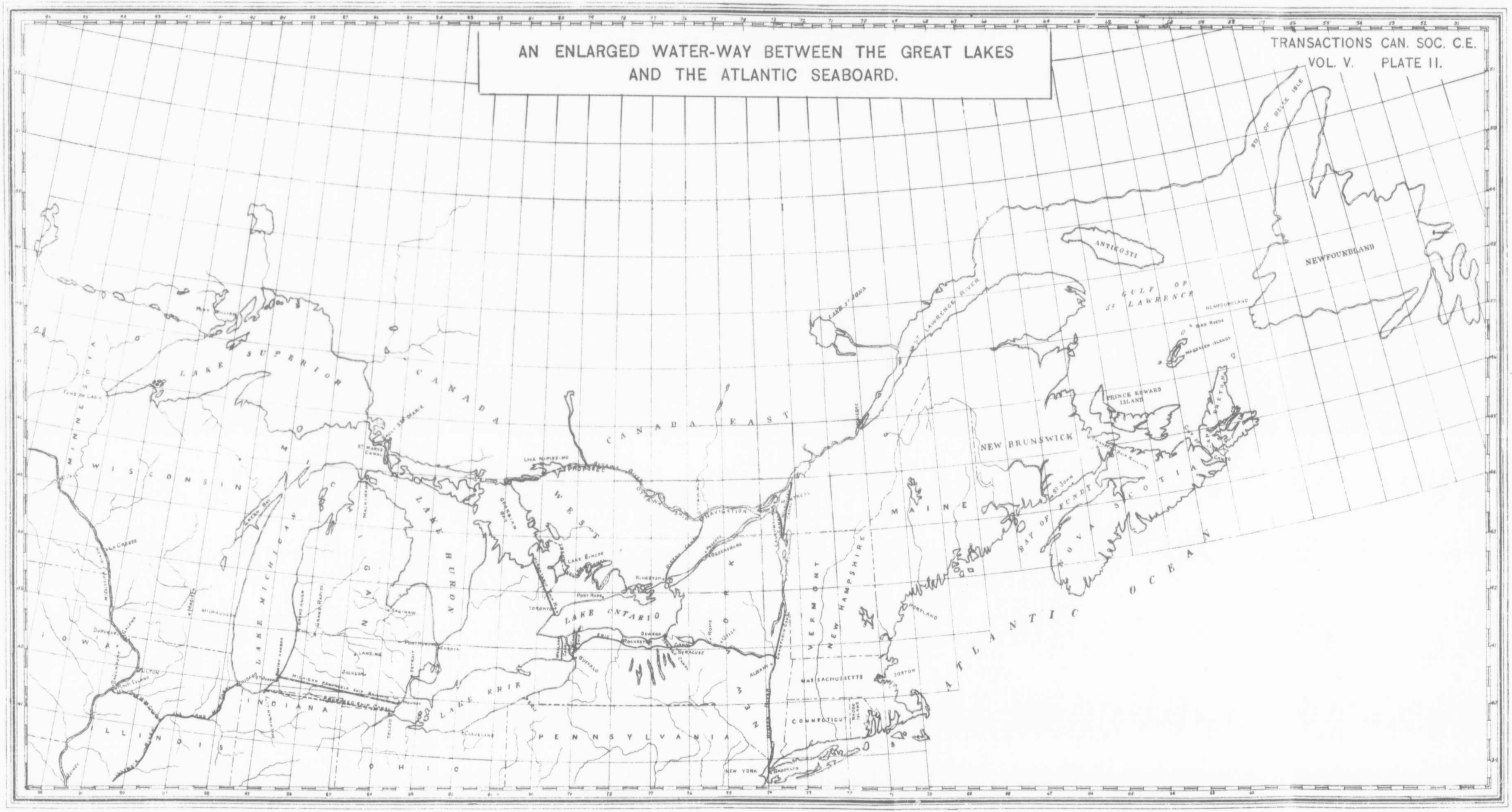


Fig. 5.

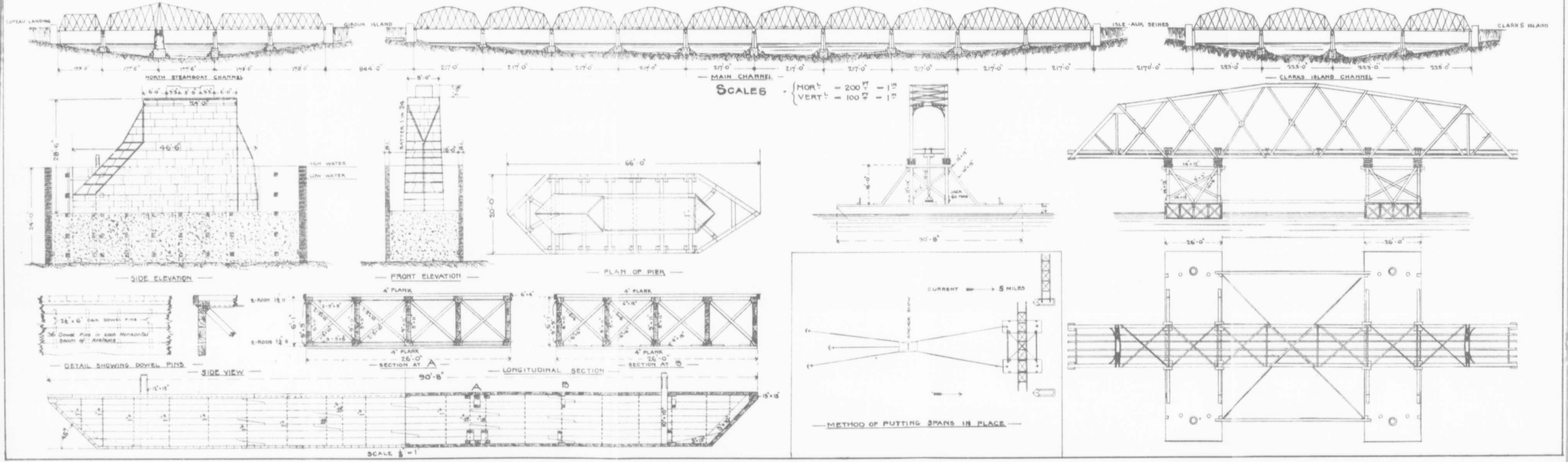


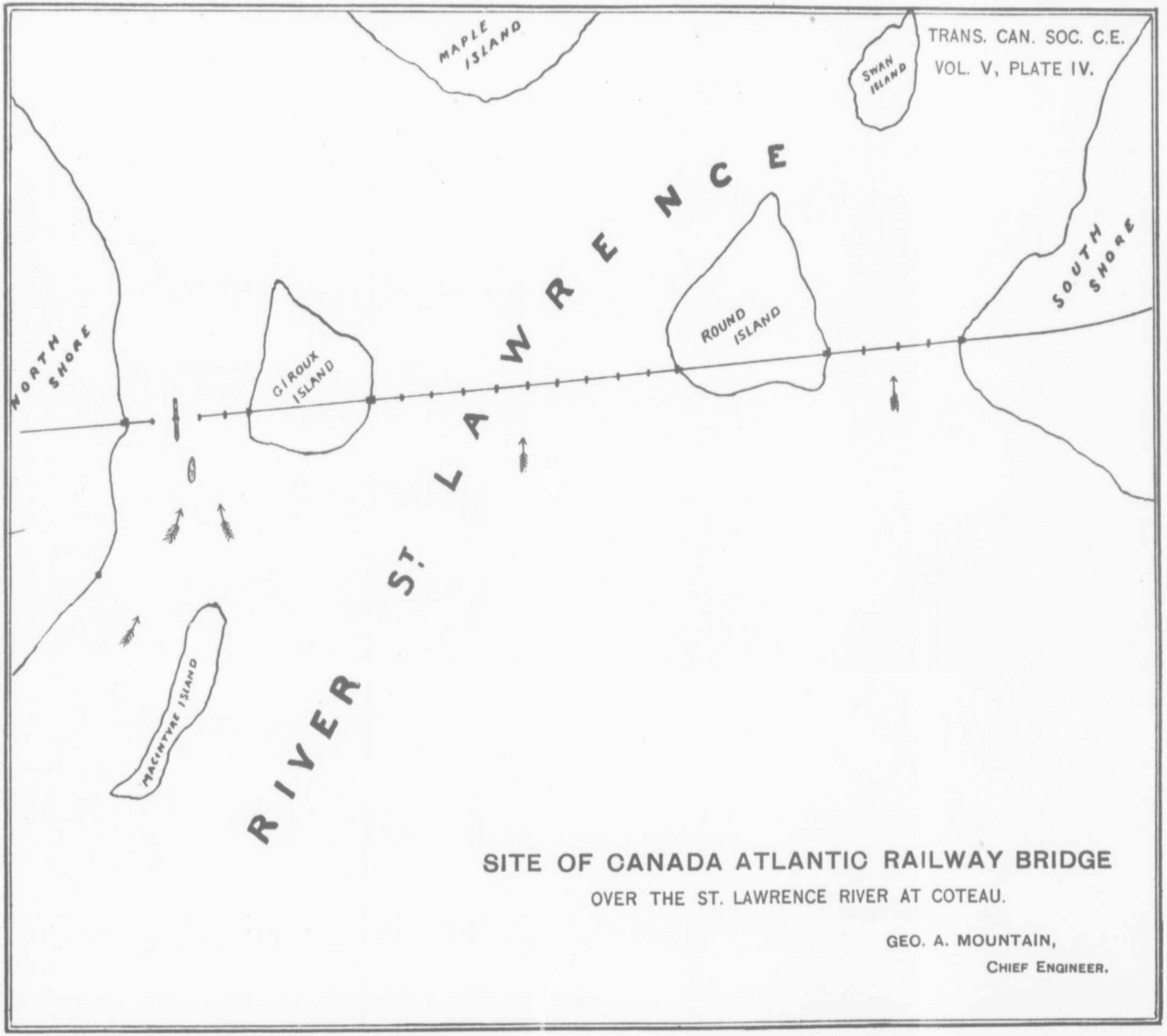
AN ENLARGED WATER-WAY BETWEEN THE GREAT LAKES
AND THE ATLANTIC SEABOARD.
TRANSACTIONS CAN. SOC. C.E.
VOL. V. PLATE II.
LAKE SUPERIOR
CANADA
CANADA EAST
WEST
MINNESOTA
WISCONSIN
MICHIGAN
LAKE MICHIGAN
LAKE HURON
LAKE ONTARIO
LAKE ERIE
IOWA
ILLINOIS
INDIANA
OHIO
PENNSYLVANIA
NEW YORK
VERMONT
NEW HAMPSHIRE
MAINE
MASSACHUSETTS
CONNECTICUT
NEW BRUNSWICK
NOVA SCOTIA
PRINCE EDWARD ISLAND
ANTICOSTI
NEWFOUNDLAND
GULF OF ST LAWRENCE
ST LAWRENCE RIVER
BAY OF FUNDY
ATLANTIC OCEAN
LAKE SIMCOE
LAKE NIPISSING
KINGSTON
TORONTO
PORT HOPE
BUFFALO
ALBANY
NEW YORK
PORTLAND
BOSTON
CLEVELAND
TOLEDO
LANSING
DETROIT
SAGINAW
MILWAUKEE
ST MARYS CANAL

CANADA ATLANTIC RAILWAY BRIDGE OVER THE ST. LAWRENCE RIVER AT COTEAU.

GEO. A. MOUNTAIN, CHIEF ENGINEER.

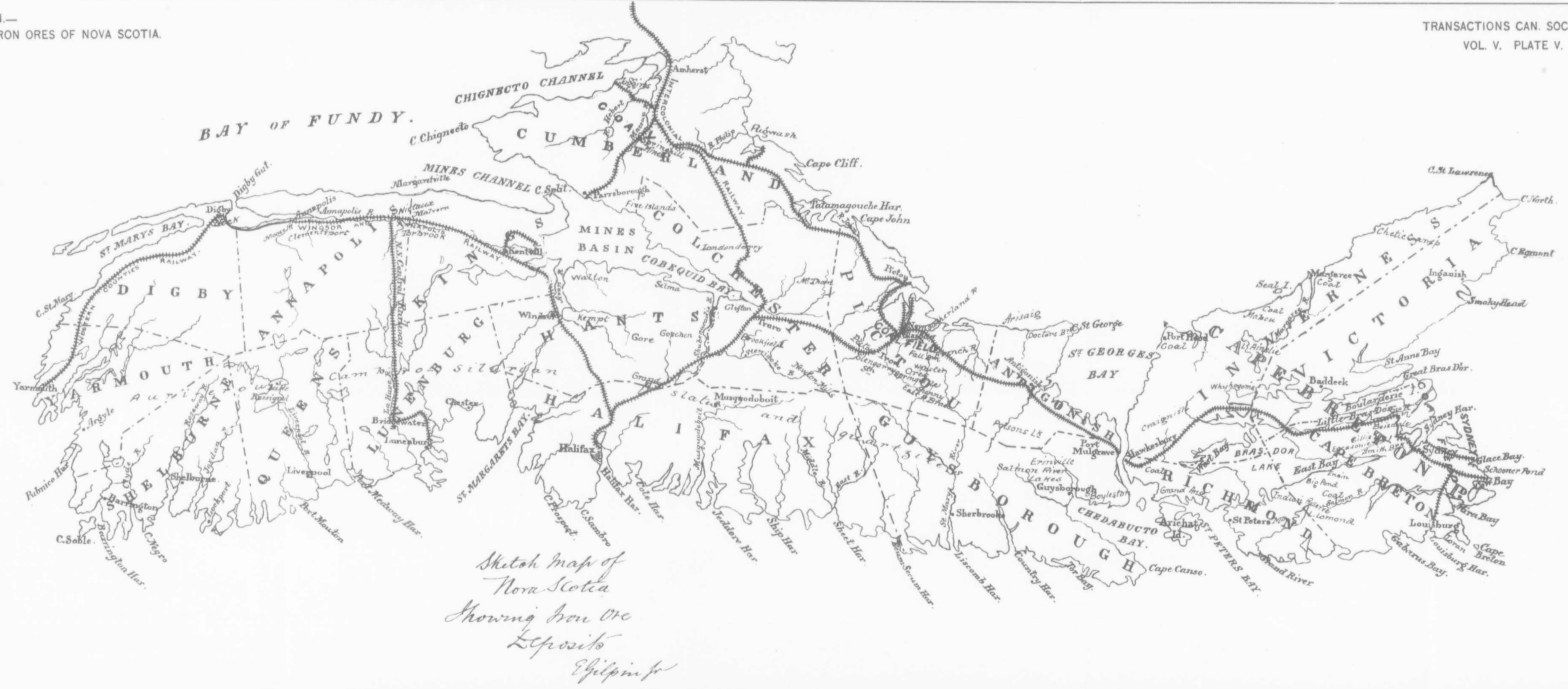
TRANSACTIONS CAN. SOC. C.E.
VOL. V. PLATE III.

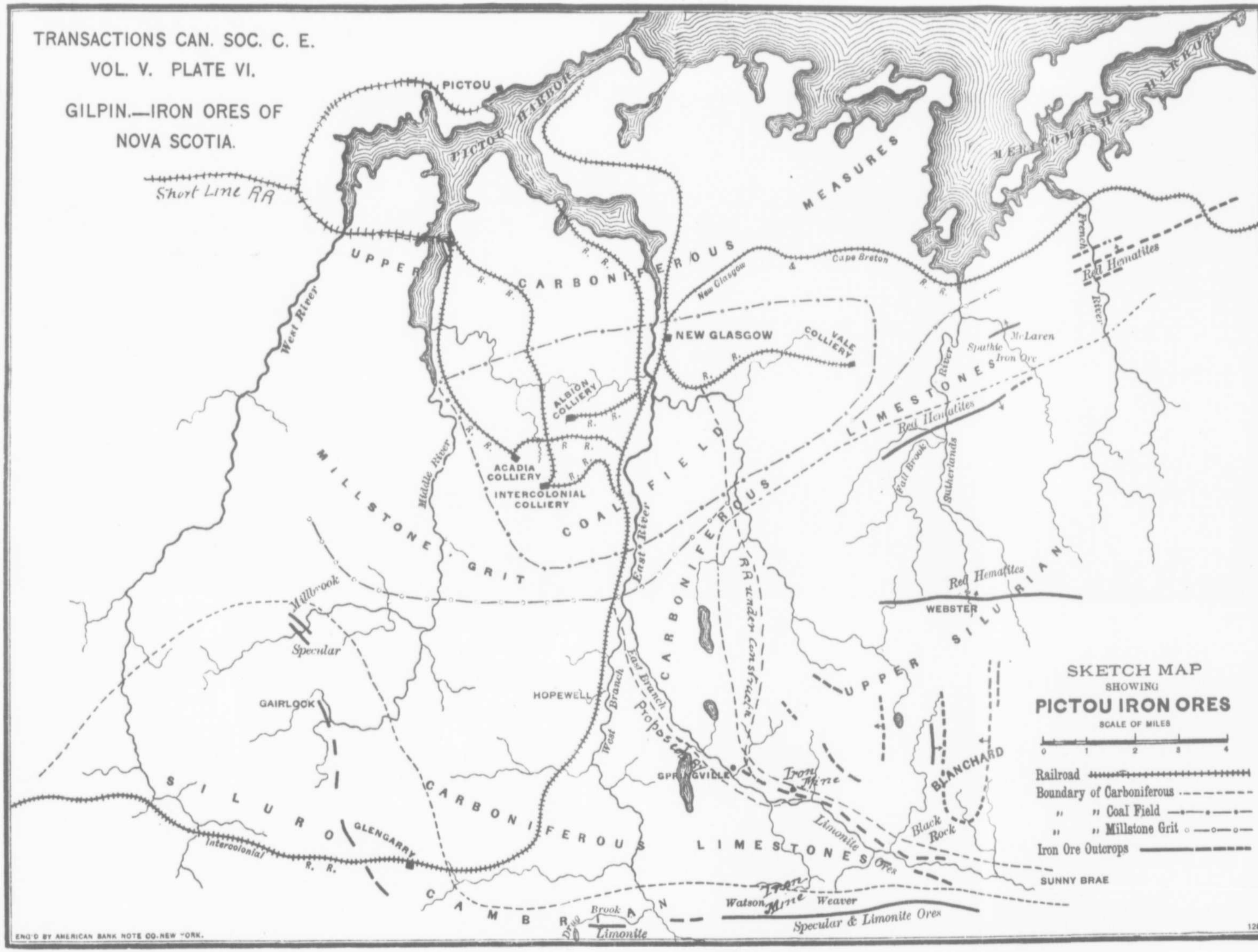




SITE OF CANADA ATLANTIC RAILWAY BRIDGE
OVER THE ST. LAWRENCE RIVER AT COTEAU.

GEO. A. MOUNTAIN,
CHIEF ENGINEER.


BAY OF FUNDY.
CHIGNECTO CHANNEL
MINES CHANNEL
MINES BASIN
COBEQUID BAY
CUMBERLAND
COLCHESTER
PICTOU
ANTIGONISH
GUYSBOROUGH
HALIFAX
HANTS
KINGS
ANNAPOLIS
DIGBY
YARMOUTH
SHELBURNE
QUEENS
LUNENBURG
INVERNESS
VICTORIA
CAPE BRETON
RICHMOND
ST GEORGES BAY
CHEDABUCTO BAY
BRAS D'OR LAKE
ST MARYS BAY
Amherst
Parrsborough
Truro
Pictou
Windsor
Halifax
Yarmouth
Digby
Annapolis
Kentville
Bridgewater
Lunenburg
Liverpool
Shelburne
Barrington
Sherbrooke
Guysborough
Port Mulgrave
Hawkesbury
Baddeek
Sydney
Louisburg
Arichat
St Peters
C. Chignecto
C. Split
Cape Cliff
Cape John
Tatamagouche Har.
C. St Lawrence
C. North
C. Egmont
Smoky Head
Ingonish
Cape Canso
C. Sable
C. Negro
Cape Breton
Glace Bay
Schooner Pond
Port Hood
Margaree
Seal I.
Arisaig
Musquodoboit
Londonderry
Five Islands
Walton
Gore
Kempt
Clifton
Chester
Malvern
Nictaux
Torbrook
Clementsport
Margaretsville
Digby Gut
Argyle
Pubnico Har.
Barrington Har.
Port Mouton
Port Medway Har.
St. Margarets Bay
C. Prospect
C. Sambro
Halifax Har.
Jeddore Har.
Ship Har.
Sheet Har.
Liscomb Har.
Country Har.
Tor Bay
St. Peters Bay
Grand River
Gabarus Bay
Louisburg Har.
Mira Bay
Sydney Har.
East Bay
West Bay
St Anns Bay
Great Bras D'or
Little Bras D'or
Boularderie I.
Salmon River
Erinville
Boylston
Doctors Bk
C. St George
Pugwash
R. Philip
Rivers Inlet
COAL FIELD
Ironstone
Clam Bay
Silurian
Slates and Quartzites
Sketch Map of Nova Scotia Showing Iron Ore Deposits
E Gilpin Jr


TRANSACTIONS CAN. SOC. C. E.
VOL. V. PLATE VI.
GILPIN.—IRON ORES OF
NOVA SCOTIA.
PICTOU
Short Line RR
PICTOU HARBOR
MERIGOMISH HARBOR
MEASURES
UPPER CARBONIFEROUS
New Glasgow & Cape Breton R. R.
NEW GLASGOW
VALE COLLIERY
ALBION COLLIERY
ACADIA COLLIERY
INTERCOLONIAL COLLIERY
COAL FIELD
MILLSTONE GRIT
West River
Middle River
East River
French River
Red Hematites
McLaren
Spathic Iron Ore
Sutherlands River
Fall Brook
LIMESTONES
CARBONIFEROUS
WEBSTER
UPPER SILURIAN
RR under construction
Millbrook
Specular
GAIRLOCK
HOPEWELL
West Branch
East Branch
Proposed
SPRINGVILLE
Iron Mine
BLANCHARD
Black Rock
Limonite Ores
SILURO CARBONIFEROUS LIMESTONES
GLENGARRY
Intercolonial R. R.
CAMBRIAN
Drug Brook
Limonite
Watson Iron Mine Weaver
Specular & Limonite Ores
SUNNY BRAE
SKETCH MAP
SHOWING
PICTOU IRON ORES
SCALE OF MILES
0 1 2 3 4
Railroad
Boundary of Carboniferous
" " Coal Field
" " Millstone Grit
Iron Ore Outcrops
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