FIRST ANNUAL REPORT

OF THE

ONTARIO DEPARTMENT OF MINES

1891

FIRST REPORT OF

THE BUREAU OF MINES

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FIRST REPORT OF

THE BUREAU OF MINES.

To the Honorable ARTHUR S. HARDY, Commissioner of Crown Lands:

SIR,—I have the honor to present herewith the first Annual Report of the Bureau of Mines. For reasons stated in the Introduction the Report is not as full or complete as is desirable that it should be. The subjects with which the Bureau should aim to deal require careful study and investigation, and I am deeply conscious how far the work I now submit falls short of an ideal Report. But with larger opportunities, and added knowledge and experience, I hope to make the Bureau of practical and growing service to the mining interests of our province.

I desire very heartily to acknowledge the valuable help I have received from Mr. Thomas W. Gibson, both in the performance of the office duties assigned to the Bureau in connection with mining lands and in the preparation of this Report.

A special paper by Dr. Robert Bell, of the Dominion Geological Survey, on the Geology of the Sudbury country presents in concise form the results of three seasons of field-work there. This paper and the accompanying map by the Director of Surveys, Mr. George B. Kirkpatrick, (prepared with the assistance of Dr. Bell) will it is hoped be found useful and instructive to prospectors and miners engaged in exploring and developing the mineral wealth of that region.

The second Report of the Inspector of Mines deals in detail with a number of mines and mining properties which he visited during the past year. It furnishes evidence of enterprise in the province in a number of new directions, but especially in gold and iron mining, and larger results in the present year may be looked for with confidence.

I have the honor to be, sir,
Your obedient servant,

ARCHIBALD BLUE,
Director.

Office of the
BUREAU OF MINES,
TORONTO, March 15, 1892.

REPORT OF

THE BUREAU OF MINES.

INTRODUCTION.

The Act which created the Bureau of Mines received the assent of the Lieutenant-Governor March 4, 1891, and on the 5th of the same month an Order in Council was passed which transferred me from the office of Deputy-Minister of Agriculture to the office of Director of the Bureau of Mines.

It became necessaay to enter upon the duties of the new position at once, but I continued to devote a portion of the time to the requirements of the old one until the appointment of my successor in June.

In the same month Mr. Thomas W. Gibson was appointed as clerk and shorthand writer in the Bureau, but he was also assigned certain duties in the Woods and Forests branch of the Department of Crown Lands. Mr. Gibson's former connection with the Department as secretary to the late Hon. Mr. Pardee gave him an experience which has proven of valuable service to the Bureau.

The increase in the volume of work of the Department of Crown Lands made it desirable that some readjustment should take place in connection with the sale of public lands, and accordingly it was arranged that transactions in mining lands in surveyed territory should be assigned to the Bureau of Mines. Unsurveyed territory was left as heretofore under the Director of Surveys—the Mining Act requiring that the plan, field notes and description of each location in unsurveyed territory be furnished so that it may be laid down on the office maps of the Department.

The provisions in sub-section 5 of the first section of the Act of 1891, whereby mining lands in certain cases might be obtained at the price and upon the conditions prescribed in the old Act, imposed a load of labor upon the Bureau at the outset. Many of the claims under this sub-section were of an intricate character, and evidence and information on many points had to be procured before they were ready to be cleared off. For this reason there was not much time left for undertakings which call for the visiting of districts in which minerals are found or in which mining operations are carried on.

Foreseeing that in the time at my disposal I could not hope to visit all the mining districts before the end of the year, I decided to confine my enquiries as far as possible to fields not covered by the Inspector of Mines, hoping that in this way the whole ground might be fairly gone over. In one instance only were visits to the same localities duplicated, viz: the gypsum mines on the Grand river. Having seen those mines in the month of November, and being impressed with the unsafe condition of some of them, I advised the Inspector to examine them and make an official report as called for by the Act respecting Mining Regulations.

In July I spent a number of days visiting the stone quarries and cement works along the mountain between the Niagara river and Hamilton, and at intervals in September and October the quarries along the escarpment from Hamilton to Owen Sound, the pressed brick and terra cotta works at Campbellsville and in the vicinity of Milton, and the Portland cement works in the township of Keppel, county of Grey.

The greater part of August was occupied in a visit to the Lake of the Woods district, when a journey was made to the head of the lake and up the Rainy river to Fort Francis and Rainy lake, and afterwards to Crow lake. Several gold locations were examined, but at that time only one was being worked. Since then greater activity has been displayed in this district and considerable quantities of gold-bearing ore have been taken out, as a result it is believed of the reduction works which have been erected at Rat Portage. These works were almost completed at the time of my visit and one or two test runs were made, one of which I witnessed. It is understood that they have since been improved and new machinery added, and hopes are entertained that this year they will be kept busy treating Lake of the Woods ores. Two or three stamp mills are also in course of erection, one at the Gold Hill mine south of Rat Portage and one at a location on the Canadian Pacific Railway a few miles east of the town. The reduction works will no doubt greatly aid in demonstrating the value of the gold ores in this region. Other promising gold districts upon which some development work was done last year are on the Vermilion river, west of Sudbury, and in the township of Belmont, in the county of Hastings. A report on a mine and new reduction works in the last named district is made by the Inspector.

In September the gas-producing district in the southern part of the county of Essex was visited, and to gain further information on this valuable fuel and the uses to which it is applied I spent a short time in the Findlay gas field in the state of Ohio. In the following month a couple of weeks were occupied in getting information upon the gas fields in the counties of Welland and Haldimand, where a number of wells have been bored and large flows of gas obtained, and in collecting facts on the existence of surface gas in the lake shore townships of the county of Kent.

The gypsum mines in the counties of Brant and Haldimand were visited in November, as also the salt regions in the counties of Huron and Lambton. In the following month I spent a few days in Frontenac, Lennox and Hastings, visiting among other places the Portland and natural rock cement works at Napanee Mills.

To collect and publish information and statistics on the mineral resources and the mining industries of the province will be one of the chief objects of the Bureau of Mines. Important discoveries are being made every year, and no doubt much of our wealth yet lies hidden in the earth. The deposits of iron ore on the Atik-Okan and Mattawan rivers, which are believed to be of vast extent, have for the most part been discovered within the last two years. The nickel ores of the Sudbury district were unknown six years ago, and during the past year many large and rich finds have been made. Promising gold leads have been found at various points between the Thessalon river and Temagami lake, as well as in the county of Hastings. Extensive beds of kaolin are now known to exist on the eastern and western tributaries of the Moose river, the Abittibi and Missinaibi, valuable for the manufacture of fine pottery, and perhaps more valuable still for the production of aluminium, a semi-noble metal that seems likely to become almost as useful in the arts as iron itself. Then it is only four years ago that we became conscious of having a clay suitable for the manufacture of pressed brick and architectural terra cotta of the very best quality, and we know now, what was not suspected at first, that a bed of it in the Medina formation is 400 to 600 feet in depth and lies exposed for more than a hundred miles within easy reach of the principal cities of the province. We know also that a lower formation (the Hudson River shales), upon which the city of Toronto stands, yields a clay which, if that be possible, is even superior to the Medina; but no one thought of experimenting upon the Hudson River shales for this purpose until a year ago. What the possibilities are for procuring natural gas no one is so bold as to conjecture. It has been demonstrated to exist in great volume in the Medina sandstone in the counties of Welland and Haldimand, and in the Clinton limestone in Essex, and three or four days ago a good flow is claimed to have been struck in the Trenton formation within a few miles of Toronto.

In this way we are being treated to a succession of surprises, and the work of prospecting the province for minerals has been scarcely begun as yet in a systematic and intelligent way. The Bureau of Mines has therefore a large field to occupy even if limited in its scope to the recording of progress and discovery alone. But the aim will be to deal with progress and discovery in the widest sense, and in the most practical way, in relation to geology, mineralogy and metallurgy, without which the Bureau would be of little service to its purpose as defined by statute, viz: "To aid in promoting the mining interests of the province."

Annual statistics of production are of the first importance, as without them we cannot know definitely the state and progress of an industry, nor the directions in which it may be moving, nor the effect produced upon it by legislation or public policy, nor the parts of it which are weakest and most in need of help and care. Statistics are to industry what pulse and temperature are to the human body; they enable us to observe symptoms and study conditions, and in an intelligent way to suggest and apply remedies when remedies are needed. And so the collection of mineral statistics will be made a prominent feature in the scheme of the Bureau.

The initial difficulty in gathering the mineral statistics of the province is to procure a full list of companies, firms and persons who are engaged in the mining industry, and especially of those engaged in the quarrying and manufacture of structural materials. Mines of the metallic ores, as well as of gypsum, mica and phosphate of lime, besides being comparatively few in number are required to be regularly visited by the Inspector of Mines, and little trouble is experienced in getting returns from these. There are also only a few salt, cement, pressed brick and terra cotta works in the province, and they are well known; but their statistics come in only in response to line upon line of effort and persuasion. The returns which have been obtained, however, are pretty full and complete. Stone quarries, brick and tile yards and lime-kilns are so numerous that a correct list of them cannot readily be made up, and the statistics of these works presented herewith are only estimates based on the returns which have been received.

Following is a summary of the quantity and value of mineral production in the province for the calendar year 1891, together with the wages paid for skilled and unskilled labor:

From eighty-four stone quarries was taken about $1,000,000 worth of building stone (including dimension stone, heads and sills, coursing stone and rubble), the labor upon which is computed at $520,000.

Five cement works manufactured 48,211 barrels of cement, valued at $44,501, at a cost for labor of $23,400. In this output is included 2,033 barrels of Portland cement, valued at $5,082, the first of this kind of cement produced in Ontario in commercial quantities.

One hundred and thirty lime-kilns burnt about 2,350,000 bushels of lime, valued at $300,000; the labor charge of which was $116,000.

Two hundred and fifty yards produced about 160,000,000 common brick, valued at $950,000, at a cost for labor of $400,000.

Seven establishments produced 12,647,909 pressed brick, 570,000 fancy brick, 400,000 roofing tile and a quantity of ornamental and porous terra cotta, the whole valued at $156,699. The cost of labor was $58,000.

Sixty yards manufacturing drain tile produced about 7,500,000 tile of various sizes, valued at $90,000; total wages for labor, $32,000.

Three sewer tile works turned out a quantity estimated at 1,375,000, of the value of $270,000, and at a cost for labor of $38,000.

Thirty pottery works produced ware to the computed value of $45,000.

Six gypsum mines yielded 5,350 tons, valued at $12,200, at a cost for labor of $5,500.

Eleven phosphate mines yielded 4,900 tons, valued at $50,800, the amount paid for labor being $29,500. Owing to a fall in the market price these mines were worked for only a short time and with a small force.

Seventeen salt works produced 44,167 tons of salt, valued at $157,000.

Four mica mines yielded 240 tons, more than one-half of which was sold in the raw state. The total value of raw and manufactured product is returned at $31,200, and the amount of wages paid for labor was $14,262.

The product of eight nickel mines operated by four mining companies was 85,790 tons, returned at the low valuation of $324,240. The total amount paid for labor was $322,201. These returns of course do not include labor for roasting and smelting the ore, nor its value when converted into matte. Of the latter product the United States government last year purchased for armour plate purposes 4,536 tons, containing about 900 tons of nickel.

Four silver mining companies have made returns of 14,925 tons of ore, valued at $64,475, with total cost for wages of labor of $100,278. Like nickel, the valuation of silver ore is made very low, being nearly $30,000 less than the sum paid for wages.

Gold mining was confined almost wholly to prospecting work, but about 2,000 tons of ore were raised. Operations were carried on upon two locations in Hastings, one in the Sudbury district and four in the Lake of the Woods region. Quantities of the ore were treated with apparently satisfactory results.

Iron mining was also of a prospective character only, the total quantity raised being about 200 tons. Explorations made with the diamond drill in the township of Belmont and on the Mattawan and Atik-Okan rivers are claimed to have demonstrated the existence of large bodies of excellent iron ore in those localities. It seems likely that a good start will be made on one of these properties during the present year.

The petroleum output is computed from the railway shipments of crude and refined from the oil district, the refined being given at its crude equivalent, and the value is calculated from averages of weekly quotations and the monthly shipments. The total output was 894,647 barrels, valued at $1,209,558.

The following table presents the mineral statistics of the province for the year 1891, giving (1) number of mines or works, (2) quantity of product, (3) value of product, (4) average of weekly wages for skilled and unskilled labor, and (5) total cost of wages :

Product.	No.	Quantity.		Value.	Wages of labor.		Total wages.
					Skilled.	Unskilled	
				$	$	$	$
Building stone	84			1,000,000	9.00*	7.00	520,000
Cement	5	bbl.	48,211	44,501			23,400
Lime	130	bush.	2,350,000	300,000	8.65	5.90	116,000
Common brick	250	no.	160,000,000	950,000	11 25	8.00	400,000
Pressed brick, roofing tile and terra cotta	7	no.	13,617,909	156,699	12.60	8.00	58,000
Drain tile	60	no.	7,500,000	90,000			32,000
Sewer tile	3	no.	1,375,000	270,000		8.50	38,000
Pottery	30			45,000			
Gypsum	6	ton	5,350	12,200	9.30	7.30	5,500
Phosphate	11	ton	4,900	50,800		6.00	29,500
Salt	17	ton	44,167	157,000			
Mica	4	ton	240	31,200	7.60	6.85	14,262
Nickel	8	ton	85,790	324,240	11.70	7.40	322,201
Silver	4	ton	14,925	64,475	13.50	12.00	100,278
Petroleum, crude		bbl.	894,647	1,209,558			

*This is for quarrymen. The average wages of stonecutters per week was $18.66.

The total value of mineral production for the year, as shown by this table, was $4,705,673, and the cost of labor exclusive of petroleum, salt and pottery was $1,659,141

OPERATION OF THE MINING ACT.

The Mining Act as amended by the Act of last year did not come into effect until the 4th day of May. Its chief new features are :

1. Increase in the price of mining lands ;
2. Option to take up lands under leasehold or fee simple ; and
3. Provision to impose royalties on ores or minerals.

SALE AND LEASE OF MINING LANDS.

The price of mining lands under the old Act in the districts north of Lake Nipissing and the French and Mattawa rivers was uniformly $2 per acre, and in districts south it was $1 per acre.

Under the amended Act prices are graduated according to the situation of lands with respect to railway lines and surveyed territory, ranging from $3 to $4.50 per acre in the districts north and from $2 to $3 in the districts south of Lake Nipissing and the French and Mattawa rivers.

But the new Act also contains a provision which enabled parties who had made application under the terms of the old Act and paid in money thereon, or who as prospectors or explorers had applied for and expended money or labor in proving locations, to acquire lands at the old price and free from royalties and working conditions, upon renewal of application and payment of the purchase money.

The following table shows by districts the area for which patents in fee simple were issued and the amount paid therefor into the treasury of the province for the year ending December 31, 1891 :

District.	No. of patents.	Acres.	$.
Rainy River	46	6,812	14,020
Thunder Bay	72	17,172	34,936
Algoma	130	29,580	59,519
Nipissing	20	3,364	6,349
Parry Sound and Muskoka	4	365	365
Elsewhere	17	2,096	2,325
Total	289	59,389	$117,514

Under the leasing clause parties may acquire mining lands in the districts north of Lake Nipissing and the French and Mattawa rivers at the rate of one dollar per acre for the first year and twenty-five cents per year thereafter, and in districts south of those waters at sixty cents per acre for the first year and fifteen cents per year thereafter.

This feature of the Mining Act is a novel one in this province, and in view of the tenure which so generally obtains in Canada and the United States leasehold from the Crown can only be regarded as on trial. So far it has been favorably received by all classes of mining men, as a large proportion of the applications for lands now being received are made under the terms of the leasing clause. Should it for any reason prove unsatisfactory to the holders they are free to change the tenure into fee simple, in which case the payment of the first year's rent would be applied on the purchase money.

In the state of Minnesota the leasing system was adopted three years ago, and is reported as working very satisfactorily alike to leaseholders and the state. In the Australian colonies and New Zealand all mining lands are leased, and the rental is a fixed one ranging from five shillings to twenty shillings sterling per acre for each year of the term.

The following table shows by districts the area of mining lands for which leases were granted last year under the terms of the new Act, and the amount paid into the treasury for the first year's rent :

District.	No. of leases.	Acres.	$.
Rainy River	2	129	129
Thunder Bay	11	1,267	1,267
Algoma	14	1,793	1,793
Nipissing	17	1,529	1,529
Parry Sound	2	205	123
Elsewhere	1	75	45
Total	47	4,998	$4,886

At the present date (March 15, 1892) thirty more leases are ready for execution covering an area of 3,500 acres.

ROYALTY ON ORES AND MINERALS.

The royalty provision has been more severely criticised than any other of the amended Act. It is, indeed, the only one to which strong objection has been taken, and many sins have been laid at its door by the opponents of the clause. But the subject has more than one side, and there has been much misrepresentation.

It has been charged, for instance, that the royalty has destroyed mining operations in the North Shore districts and driven capitalists and miners out of the country.

This assumes that the clause is already in force, and that it affects alike all mining lands, whether the title is in or out of the Crown. The facts are that it does not apply at all to any lands patented previous to the 4th of May, 1891, saving lands patented under the Free Grants and Homesteads Act ; and it cannot apply to any lands sold or leased after that date until seven years from the issue of the patent or lease except in the case of mines known to be rich in nickel, and as to these it cannot apply for four years. Moreover, the imposition of royalty could not be made retroactive, as has been shown by the attitude of the Minister of Justice towards the royalty clause of the Quebec Mining Act.

It is true that mining has been comparatively slack during the past year, but not in Ontario or Canada alone. In the United States and Great Britain there was a serious depression as an immediate consequence of the failure of large banking houses in both countries in the latter part of 1890 and the beginning of 1891. The falling off in the tonnage of Lake Superior iron ore in 1891, compared with the output of 1890, was greater than the tonnage of all the iron ore ever raised in the province of Ontario, if not in the whole of Canada.

In Great Britain inactivity continued throughout the year, but in the United States the industry revived in the last six months as a result of the good harvest in that country.

In Canada, and especially in the province of Ontario, we are dependent on foreign capital to open up and work our mines of iron, nickel, gold, silver, phosphate, etc. Our own capitalists are shy of such investments. Except in rare instances they cannot be persuaded to put their money into mines, or blast furnaces, or reduction works, or refining works, or rolling mills. Enterprise of this sort is a thing of growth and education, and inasmuch as hitherto we have had to rely upon British and American capital to buy and develop our mining lands it can readily be perceived how the financial failures of 1890-91 would affect mining operations in our country.

For more than twenty years miners were free from the payment of royalties to the Crown in Ontario, yet during that period the industry did not prosper. Silver mining was stirred into activity at one time, as an indirect consequence of the policy of putting a provincial tax on mining lands, but the iron, copper and gold mines were idle, and the phosphate and gypsum mines were worked intermittently, in a half-hearted way. We had neither capital nor skill to operate them, and the abolition of the royalties does not appear to have offered a new inducement to one or the other.

The discovery of nickel ore in vast quantities in the North Shore districts a few years ago, and the more recent discovery of the value of nickel as an alloy with steel, have done more than anything else to attract attention to the mineral resources of our province, and there is no evidence to show that the royalty clause of the amended Act has kept out skill or capital in so far as this ore is concerned. It probably did interfere with the plans of dealers, some of whom made fortunes by the sale or lease of undeveloped properties acquired under the terms of the old Act, and all of whom were sanguine of making larger fortunes had the Legislature not seen fit to consider the share of the public interests in that portion of the Crown domain as something apart from the interests of individuals.

A boom has been arrested, but not a mining boom. The men who complain most persistently of the Crown royalty are not miners or mining companies ; they are persons who lived in expectation of becoming "kings" themselves, with miners and mining companies paying royalty dues to them.

I have in mind one case in which an option sale of three small locations of nickel ore, situated eight or ten miles from a railway, was made to an English syndicate for a consideration of about $120,000 and a royalty of twenty-five cents per ton on a daily minimum of 200 tons of ore. A payment of several thousand dollars was made on the purchase and as much more was spent in exploring the property last summer, when the representative of the syndicate came to the conclusion that the price agreed upon was far too high in view of the terms upon which locations might be procured from other parties or from the Government. An effort was then made to buy the locations from the owners free from royalty terms, but the price demanded (a quarter of a million dollars) led the syndicate to abandon its option, and meantime they have withdrawn from the country.

Numerous instances of this kind might be cited, and there is no doubt but that the system of private royalties is in great favor with mineral land owners of speculative tendencies.

The iron locations on the Atik-Okan river, fifty miles from the nearest railway station, are understood to have been optioned to a Belgian syndicate subject to royalties ranging from twenty to twenty-five cents per ton ; another location in Hastings county has been leased subject to a royalty of forty cents ; a barytes mine in Lake Superior is leased at twenty-five cents, and a phosphate mine in the eastern part of the province at two dollars per ton, with a fixed minimum output in each case.

It would be easy to lengthen out the list if it was necessary, for the plan of making mineral land a source of revenue to the owner suggests itself naturally : it is the all but universal practice in Great Britain and the United States, as I shall show presently.

Now the rates of royalty provided for in our Act are on a more moderate scale, being three per cent. on silver and copper and nickel, not exceeding two per cent. on iron, and not exceeding three per cent. on all other ores of metals, calculated upon their value at the pit's mouth.

We do not know exactly what this value would be upon the several kinds of ores in Ontario, but in the case of iron ore we have the data furnished by Bulletin 113 of the United States census for 1890, showing the cost of production in the various states and of the value put upon the ore at the mines, based on the output of 1889. The following table gives the figures for a few states and the whole country, computed for the long ton.

States.	Cost per ton.	Value per ton.
	$	$
Alabama	0.82	0.96
Michigan	2.07	2.70
Minnesota	1.80	2.87
New Jersey	2.74	3.23
New York	1.64	2.49
Pennyslvania	1.10	1.96
Wisconsin	1.78	2.20
United States	1.71	2.30

For the short ton these averages of cost and value would be about one-ninth less, so that the value of ore at the mines of the United States in 1889 was $2.05 per short ton, in Michigan $2.40, in Minnesota $2.55, in New York $2.21, and elsewhere in the same proportion.

On this basis the royalty payable to the province would not exceed five cents per ton as against the royalties of twenty, twenty-five and forty cents per ton which by the terms of contracts are payable to private parties for iron ore.

For the ores of nickel and copper and of silver we have the returns of values made by mining companies to the Minister of Agriculture for the years 1890 and 1891, as required by the Mining Operations Act. These give averages of $7.60 per ton for nickel and copper and $15 for silver per ton, which at the rate provided for in the Act would yield a royalty of about twenty-three cents on the former and forty-five cents on the latter.

In the light of these figures it is perhaps not surprising if the private owners of mining locations should view with a jealous eye the conduct of the Government in reserving a small royalty on ores or minerals taken from lands sold or leased under the amended Act, at the low price fixed in the Act.

I turn now to deal briefly with the practice followed elsewhere in the matter of royalties, and the disposition made of the public interest in mineral lands.

Nova Scotia.

The law relating to mines and minerals in Nova Scotia provides for the issue of licenses to prospect, search and work lands for ores or minerals, for the leasing of lands at a rental, and for royalties upon ores or minerals removed from the mines.

On all leases of gold mines there is reserved a royalty of two per cent. upon the gross amount taken out, and upon coal the rate since 1885 has been seven and one-half cents per ton of 2,240 lb. Other royalties are provided for, but gold and coal are the only minerals which yield a revenue.

The following table shows the revenue of the province from mining rents, licenses and royalties, together with the revenue from all sources, for the seven years 1884-90:

Year.	Rents.	Licenses.	Royalties.	Revenue from all sources.
	$	$	$	$
1884	2,101	5,267.99	91,804.01	586,561.55
1885	3,596	6,726.60	108,033.16	613,026.27
1886	3,248	12,315.71	109,977.34	633,145.43
1887	4,212	13,320.81	126,930.78	656,639.11
1888	4,388	14,383.62	132,134.52	712,951.49
1889	6,325	22,795.58	137,399.36	713,941.82
1890	5,327	25,197.02	138,120.27	710,497.38
Totals	29,197	100,007.33	844,399.44	4,626,763.05

The revenue from licenses, rents and royalties in the seven years was an average of

21 per cent. of the revenue from all sources, being in the first three years of the period $18\frac{2}{3}$ and in the last three years nearly 23 per cent. of the whole.

The revenue from royalties alone in the seven years was an average of $18\frac{1}{4}$ per cent. of the revenue from all sources; for the first three years of the period 17 per cent., and for the last three years 19 per cent. of the whole.

Licenses and royalties show a continuous yearly increase, and rents an increase for every year but one. It will be observed also that the ratio of revenue from these sources to the total revenue of the province shows a constant increase.

The other most important source of the yearly revenue of Nova Scotia is the subsidy and interest paid by the Dominion, which is now about $433,000.

THE UNITED STATES.

The way in which the Government of the United States regards mineral property in public lands was very fully stated before the British Commission on Mining Royalties last year by Dr. R. W. Raymond, secretary of the American Institute of Mining Engineers. The Federal Government, Dr. Raymond said, never has exercised anything like the ancient right of sovereignty in the metals. The first cause of this fact, he explained, was the nature of the Federal Government when it was first established by the thirteen original states.

"Those states were colonies of Great Britain. They had all of them received by royal grant, in one form or another, a delegated sovereignty in the metals. That sovereignty at that time was much more extensively asserted by the English Crown than it is to-day, and its rights were given by the Crown in the original grants to the colonies, subject to certain royalties to be paid back to the Crown. The colonies were, in fact, concessionaires or sub-lessees under the grant of that sovereignty. When their independence was established at the end of our revolutionary war, and recognised by treaty, the separate colonies succeeded to all the rights of sovereignty which Great Britain had resigned. In forming their federal union at the end of the last century they created the constitution of the United States, which is solely an instrument of positive grants. . . . All the rights not ceded by the original states to the Federal Government were reserved to the states, or to the people thereof, by express reservation in our constitution. Now there never was any right of sovereignty in the metals so ceded by the states to the general government. Certain rights were given, but the right of sovereignty in the metals was not given, and as a matter of fact the original states have gone on since that time asserting that right and exercising it, although the laws by which they exercise it are mostly dead letters."

Upon the discovery of lead and copper in some of the western and north-western states Congress put into the hands of the Secretary of the Treasury the matter of mining on those lands and authorized him to lease mining rights, making concessions upon royalties. This experiment went on for about forty years with varied attempts to rectify the abuses and confusion which grew up, but it was finally abandoned, and it was the last attempt of the Federal Government to do anything with its mineral lands except to sell them in the old fashioned English way, top and bottom going together.

"A patent of land from the United States," according to a decision of the Supreme Court quoted by Dr. Raymond, "passes to the patentee all the interest of the United States, whatever it may be, in everything connected with the soil or forming any portion of its bed, or fixed to its surface; in short, everything embraced within the term 'land.'"

The patentees being therefore unqualified owners of the land and all that it contains are free to dispose of it as they see fit. If ore or mineral of any kind is found upon or under the surface, the owner may work it, or sell it for another to work and take it away, or lease it upon a royalty. The latter practice prevails widely in many states, especially as regards deposits of coal and iron ore. Sometimes the land is sold outright to a mining company, as in the case of a sale of coal lands to the Reading Railway Company for $50,000,000, mentioned by Dr. Raymond; but the interest on the purchase money is the equivalent of a rental or a royalty. On private lands the royalty charge on bituminous coal ranges from five to twenty-eight cents per ton, the average being about fourteen cents; on anthracite coal it ranges up to sixty cents, but the average may be between thirty and forty cents.

The census of 1880 shows that royalty was paid to private owners on more than one-quarter of the iron ore product of the United States in 1879, the average being 43.7 cents per ton of 2,000 lb., or 48.9 cents per long ton. The total quantity upon which royalty was paid was 2,334,524 tons, while the total of iron ore raised in the census year was 7,974,806 tons. The following table shows for four of the principal states the number of tons upon which royalty was paid, the range and average of royalty per ton, and the total amounts paid:

States.	Tons, 2,000 lb.	Range of royalty.	Average of royalty.	Total royalty.
		cts.	cts.	$
Michigan	392,251	31 to 76	43.88	172,145
New Jersey...............	364,945	22 to 89	54.46	198,391
New York...............	191,415	13 to 89	38.40	73,496
Pennsylvania	972,862	13 to 108	45.44	442,067

The report on iron ore for the census of 1890 by Mr. John Birkinbine, as published in Bulletin 113, is not so definite as the report of 1880 on the amount paid for royalties in 1889. The total output of iron ore that year was 14,518,041 long tons. After giving expenditure for wages, supplies and materials of all kinds and for contract work, Mr. Birkinbine says:

"Other expenditures include taxes and royalties amounting to $3,795,509. As royalty is only paid on a portion of the ore mined, and as the system of owners charging up a rate per ton against the mine as a sinking fund does not prevail to any extent, it would be unfair to form any conclusions as to the average royalties, namely, so much per ton, on the basis of the reports made."

But he also states that "in the Lake Superior region a large proportion of the mines are leased, and in other districts mines are worked under leases, a stipulated sum per ton, with a minimum yearly royalty provision, being paid to the owners of the fee."

Minnesota, Wisconsin and Michigan.

The provisions of the mining laws of the United States do not apply to mineral lands held by the Federal Government in the states of Minnesota, Wisconsin and Michigan, which by the Act of 1872 were declared to be free and open for exploration and purchase in the same manner, at the same price and under the same rights of pre-emption as other public lands. That is to say, all Federal lands in those states are subject to the laws which have been enacted for agricultural lands.

When part or the whole of a township is surveyed, the lands are divided into three classes, viz.: school, agricultural and swamp lands. All wet lands are returned by the surveyor as swamp lands, and are by law ordered to be patented to the state. Grants of agricultural lands to the state are also provided for under special Acts of Congress, and the proceeds of sales are applied to the objects of the grants.

Through the operation of those laws and grants the states above named have come into possession of valuable deposits of iron and other ores, and various plans have been tried with a view to advance the mining industry and guard the interests of the people.

In Minnesota provision for a state revenue from corporations organized to carry on the business of mining, smelting or refining copper or iron ores was made by an Act of the Legislature in 1881, whereby such corporations may pay into the state treasury annually in lieu of all taxes or assessments upon their capital stock, personal property, income and real estate a special tax at the following rates, viz: On each ton of copper fifty cents, and on each ton of iron ore mined and shipped one cent per ton, each ton to be estimated at 2,240 lb. One-half of the taxes so paid are credited to the general fund of the state, and the other half to the county in which the mines are located. Where corporations do not accept these provisions of assessment it would appear that they are liable to pay rates for municipal and state purposes in the same way as other owners of property.

Until 1889 lands containing minerals were disposed of in the same way and upon the same terms as agricultural lands, but in that year a new law was enacted by the Legislature which had in view the prospective revenue of the state. Under this law the Commissioner of the Land Office is authorised to execute leases and contracts for the mining and shipping of iron ores from any lands belonging to the state, subject to the following conditions:

1. The area covered by any one lease is limited to 160 acres of contiguous descriptions, but before a lease is granted the applicant is required to pay therefor the sum of $25. The holder may prospect for iron ore on the lands embraced in his lease for one year, and at any time prior to its expiration he has the right to obtain from the Commissioner a contract for a term of fifty years, binding the state and the lessee in a mutual observance of its obligations and conditions.

2. The contract provides for the payment of an annual rent of $100 up to the time when the first 1,000 tons of ore is mined and removed, and the lessee is bound within five years from the completion of a railroad within one mile of the land to remove at least 1,000 tons of ore therefrom, and at least 5,000 tons each year thereafter, paying therefor to the state a royalty of 25 cents per ton quarterly, the minimum of royalty being fixed at $1,250 whether the ore is raised and removed or not. The lessee also agrees to pay all taxes assessed against the lands, its improvements and product, just as though the property leased was owned in fee.

3. If the royalty remains in default for sixty days, or if the lessee fails to keep the conditions of the contract, the state may take possession of the premises; but the lessee has the right at any time to terminate the agreement upon sixty days' notice, and is allowed ninety days in which to remove all engines, machinery, railroad tracks and structures placed on the land.

The Act provides also that should copper or other valuable mineral be discovered on leased land the conditions on which it may be mined are subject to agreement or reference, and the Commissioner is empowered to reserve to the state all mineral rights on state lands sold or leased in those counties in which minerals are known to occur.

During the first year of the operation of this law 153 leases were issued and applications were received for over 600, the major portion being for the purpose of exploring for iron ore.*

In Wisconsin certificates of sale of public lands do not bestow the right to take the minerals. That right depends on obtaining the written consent of the Commissioner of Public Lands. Provision is also made by statute for the leasing of private lands for mining purposes by their owners, and payment of royalties by miners is very general.

In Michigan mining lands which are the property of the state are sold after valuation by state officers, and until recently minerals were subject to a specific tax in lieu of all other state taxes except taxes on capital stock. In 1890 the revenue from this specific tax on copper, iron ore and coal was in round numbers $110,000, but in the season of 1890-91 the Legislature repealed this tax and mines are now assessed at their real value and subject to the same rate as all other kinds of property for state purposes.

The price of mining lands last year ranged from $4 to $30 per acre according to locality, but while no royalty is reserved by the state there are many mines in which

*Referring to the operation of this law the Duluth Herald reports a recent interview with Mr. George C. Stone as follows: "Some two or three years ago I conceived the idea that the state would do better by withdrawing all her mineral lands in the Mesabi and Vermilion ranges from sale and leasing them on terms that would not hinder their development. And so a law was passed in accordance with a plan outlined by myself. This is the first and only state in the country to pass such a law, and already its benefit to the state and the public in general is to be seen in the fact that in a single day nearly $2,000 has been paid for leases. . . . The new law has already resulted in an enormous amount of prospecting and the discovery of several fine mines, which will pay annually great sums to the state. This is apparent when you remember that the Chandler, which occupied only two forties, has paid as high as $90,000 royalty a year. The new law ensures the exploration of every forty acres of state land in the two iron belts, and if there is any iron on any of them it will be discovered right away instead of lying unused for many decades."

tribute is paid to the private owners. On this subject the Commissioner of Mineral Statistics made the following remarks in his report for 1885 :

"The ore has been sold at a lower price than has ever before prevailed in the history of our Lake Superior mines, being about one-half the price received four years ago, while the cost of production has not correspondingly decreased, nor could the mining cost be reduced very greatly, although minerals have very much depreciated in value : but labor, the chief element of expense in the production of ore, has lessened about twenty per cent., and the royalty paid by these companies which mine on a lease remains in most cases the same as heretofore. Altogether it has been a discouraging year in iron mining.

"The matter of royalty, so-called, is one that needs further modification to adjust itself to the requisites of all parties concerned. Very many of the mining companies do not own the fee of the land in which the ore is mined ; they simply hold under a lease for a given period, which provides for the payment of a certain sum to the owner of the land by the company for each ton of ore that is mined. This payment is termed a royalty, and has usually heretofore been fixed at fifty cents per ton ; in some instances it has been seventy-five cents. Now, however, in the new leases that are made it is usually twenty-five or thirty-five cents per ton.

"Fifty cents per ton royalty is too much ; more than in most cases can be paid and leave any margin for the company. When soft ore sells as it does now at $1.60 to $2.50 per ton at the mine, the lessor has the best of it ; he has none of the trouble, none of the risk, and is generally sure of his pay. These leases require that a certain minimum amount of ore shall be mined annually, that is, that the company holding the lease shall pay at least a certain sum annually whether any ore is mined or not. Of course this is a burden which some idle mines have to bear, and which they do assume in preference to taking the risk of mining ore in the present state of the market. When the mining cost and the royalty exceed the selling price of the ore the result must be suspension of work in whole or in part of the mine until a better state of things exists."

New York and South Carolina.

The mining law of New York is antiquated and somewhat complicated, but it appears to err in reserving to the people of the state a right of sovereignty in mines which the state has not got—such as mines of gold and silver, and mines of all other metals discovered on the property of aliens (who by law are not allowed to own land property).

The state however has been for a long time in receipt of a revenue from a duty or royalty imposed on salt manufactured on the Onondaga salt springs reservation, a tract of land about ten miles square, including the city of Syracuse, one or two neighboring towns and Onondaga lake, which was ceded to the state by the Indians in 1795 in consideration of a cash payment of $1,000 and annual royalties of $700 and 150 bushels of salt. The reserve was divided into ten-acre lots and leased upon a royalty which ranged from three to twelve and-a-half cents per bushel down to 1846, when it was reduced to one cent.

The maximum rate was at first levied to aid in the payment of the Erie canal, and a total sum of $2,055,458 has been contributed from this source for the construction of canals in the state.

The total net revenue derived from the manufacture of salt in the sixty-eight years 1818-86 was $4,296,664.

In South Carolina a royalty is collected upon phosphate rock taken from the beds of navigable streams, from salt marshes between high and low water marks, and some additional swamps, lands and streams which have been claimed by the state. Phosphate is also found on higher ground which long ago passed into the hands of settlers, and it is therefore free from the payment of royalty to the state.

From 1872 to 1881, both years inclusive, the aggregate of royalty paid into the state treasury was $717,546, while the total revenue from all sources was $11,562,409. In the ten years 1882-91 the revenue from royalty was $1,820,350, and from all sources $9,843,286. In the first ten years of the period the phosphate royalty was six per cent. of the total revenue, and in the second ten years it increased to twelve per cent. But that it is steadily and rapidly increasing is shown by the fact that for the five years 1887-91 the royalty constituted eighteen three-quarters per cent. of the whole revenue. Had the output of last year not been arrested by a dispute between the government and the largest mining company, this percentage would have been considerably higher.

The royalty on river rock is one dollar per ton, which is about one-seventh of its market value, but in his message to the Legislature last year the Governor of the state recommended that the rate be increased to two dollars per ton. Referring to the Coosaw Mining Company, with which the dispute has occurred, the Governor said:

"The Coosaw river, to which this company lays claim, is perhaps the best phosphate field in the world, and the lease under which it has been mined for twenty-one years has made every stockholder wealthy. Their plant, which has been obtained from the surplus profits, is valued at $750,000 or over; and in the meantime by fabulous dividends the original capital of $275,000 has been returned to the stockholders, as I am informed, over and over again. When you are told that the output of this company this year has been 107,000 tons, worth $7 per ton f.o.b., and that the cost of mining this rock, including royalty, cannot exceed $4.25 per ton, and is believed by many to be much less, you will see that the margin of profit exceeds one hundred per cent. on the original investment."

It would therefore appear that the Governor was not far mistaken when he expressed the opinion that it is possible to double the income from the phosphate royalty, "without injuring the industry or interfering unduly with any vested right." His estimate of cost of production is fully substantiated by Dr. Francis Wyatt in his book on the Phosphates of America.

Great Britain and Ireland.

The question of mining royalties is now receiving careful attention in Great Britain and Ireland. A Royal Commission appointed in August, 1889, has made three reports to Parliament, covering 1,000 pages of evidence and other information, and its work is not yet finished. The special object of this Commission is—

"To inquire into the amounts paid as royalties, dead-rents and way-leaves on coal, ironstone, iron ore, shale, and the metals of mines subject to the Metalliferous Mines Act, 1872, worked in the United Kingdom, and the terms and conditions under which those payments are made, and into the economic operation thereof upon the mining industries of the country; and, further, to inquire into the terms and conditions under which mining enterprise is conducted in India, the colonies and foreign countries by the system of concession or otherwise, and the economical operation thereof."

The notes of evidence of witnesses examined by the Commission, the summaries of replies to questions addressed to mining proprietors and associations and various appendix papers in the reports already printed merit careful study by those interested in this subject in all its diverse relations.

If in Great Britain, where mining has been carried on for centuries, the royalties levied upon ores and minerals are deemed to be worthy of an exhaustive enquiry by a Royal Commission of twenty-one members, it ought not to be a cause of surprise if the question is not well understood in a country like ours, where the mining industry has hardly yet been established.

For this reason I have deemed it advisable to make such extracts from the reports of the British Commission as appear to me to present the subject from the various points of view in which it may be regarded by miners and mine owners, moneyed men and laborers, lawyers and law-makers—in short by representatives of every class directly or indirectly concerned in the prosperity and stability of the industry.

Extracts from the British Commission on Mining Royalties.

Alfred de Bock Porter, secretary and financial adviser to the Ecclesiastical Commissioners:

1. What position do you hold? I am secretary and financial adviser to the Ecclesiastical Commissioners.
2. And have they a large property in mines and minerals? They are, I suppose, the largest owners of minerals in England.
3. What kind of minerals do they possess? Coal, ironstone and lead; but coal is the principal mineral.
4. Besides being owners in their own right, have they any other control over minerals? No minerals belonging to the incumbent of a benefice can be worked without the intervention of the Commissioners. The lease is granted by the Commissioners with the consent

of the patron and of the incumbent, and the reservation of the royalties is made to the Commissioners.

5. Can you state what income is derived by the Ecclesiastical Commissioners from royalties, way-leaves and other profits? Roughly £300,000 a year annually.

19. Is there any certain or fixed rent reserved in your leases? Usually there is a certain rent determined either by the number of acres in the royalty or by the probable output of the mines. There is a tentale reservation which is liquidated by the certain rent.

20. Do your fixed rents depend generally upon acreage or upon other conditions? Usually upon acreage. There are, perhaps, some exceptions, where we have been able to ascertain the output for some years past, that has been an element in determining the certain rent.

21. Can you give us the maximum or minimum of your fixed rent per acre? What is the fixed rent? We have here an acreage of 1,200 acres and a certain rent of £1,500; and another case of 400 acres, and a certain rent of £500 a year.

22. But then the answer we received from the North of England Coal Trade Association is a certain rent of £1 to 30s. a year? That is about correct.

24. And then we come to the royalty on the tonnage? Our reservations are wholly by tonnage rents; they are reserved at so much per ten—which is 48 to 50 tons—but the modern leases have the tentale fixed at so much per ton, the average royalty ranges between 4d. and 5d. per ton.

25. Can you tell us what is the maximum or the minimum? Everything depends upon the situation of the colliery and its access to railways or staiths for shipping coal; it ranges, say, between 7d. and 2½d.

26. Do you ever make an arrangement to vary the tonnage rate by a sliding scale in accordance with the selling price of the coal? During the depression of the last few years, wherever a lessee has come for an abatement of rent, we have said that we can only grant an abatement on the condition that he accepts a sliding scale. The Commissioners were quite willing to meet their lessees in times of depression, on the understanding that, if they abated the royalty, then there must be a corresponding increase in the event of prices rising, and the larger lessees accepted the sliding scale.

99. You have not stated anything about the royalty charged in lead mines? We have put those on a sliding scale. When lead is £20 per ton we have a fixed fraction; and between £20 and £17; £17 and £14; for every £3 we reduce it until it gets below £10, and the extreme range is about one-tenth to one-eighteenth.

100. Then how long are those lead leases granted for? 60 years. There is a large amount of capital involved in them.

Robert Ormston Lamb, chairman of the Northumberland Coal Owners' Association:

138. When you speak of an average rent at 5d., I suppose you mean royalty? Yes. In the other colliery in which I am interested our lowest rents were 5d. per ton for round and 2d. per ton for small coal, and the highest 8¾d. per ton for round and 4d. per ton for small coal, while the average on round and small together was about 4½d. per ton. For a number of years previous to 1888 the Northumberland coal trade was in an extremely depressed condition. In that year, compelled by the depression, we made application to all our lessors to have our rents either permanently reduced or put upon a sliding scale, varying with the price of rent of coals free on board, and, in many cases, these applications were acceded to. For the first year after these scales came into operation the price of coal ranged very low, and in that year the result of the sliding scale was that our average rent became about 3½d. per ton. Since that time, and rising with the price of coal, the rent has increased to 6d. per ton. The rate of graduation in these scales is on an average of about one-fourteenth of each advance in price from the standard price and basis rent. All these rents are paid clear of all taxes or deductions except the landlord's income tax. We pay all local rates, and these, on our total output, amount to about 1¼d. per ton. So far as my knowledge and information go with respect to the rest of the collieries in Northumberland, the sliding scale is not universal, but there are several instances during the last three years in which it has been granted. In my opinion the system of fixing rent by a sliding scale, varying with the price of coal, is fairer to the lessee than the system of a uniform fixed rent per ton, and is also fairer to the lessor. The advantage seems to me to be, that when prices are low the sliding scale is lower than a uniform rent, while it is higher when prices are higher. When prices are low and the profits are small, if any, a difference in rent is more felt by the lessee, while, when prices are better the advance in rent which the lessee pays the lessor is less appreciably felt.

251. Would you be in favor of a sliding scale without a minimum rent? I do not think it really matters, because if you go down to a certain price, say in Northumberland, where the minimum figure quoted is 7s. 6d., practically, if you are getting below that price, the coal-field there would cease to be worked, because you could not possibly live, you would become bankrupt. It is the very lowest price you could live at. If you get, for instance, 6s., unless an entire change of cost comes over the scene, you would absolutely not work the pit at all.

304. Would you say that there is a general aversion on the part of landlords to give a sliding scale? No, I think in Northumberland and Durham many of the leading viewers favor the principle of a sliding scale, and in consequence of that being so my belief is that the lessors will grant sliding scale leases. Their advisers, as a rule, are strongly in favor of the principle of a sliding scale.

308. I am not sure that the Commission understand exactly what is meant by a sliding scale. It means, does it not, a certain proportion of the selling price? It means paying the rent to the landlord on the realised ascertained price obtained by the lessee.

Lawrence William Adamson, chairman of the Hollywell Coal Company and director of the East Hollywell and Ryhope Coal Company, East Hollywell:

436. Have you any information to give us about the principle of the sliding scale? Yes; I may say that, generally, I entirely concur with Mr. Lamb's views as to the very material advantage which the sliding scale confers on lessors, lessees and miners. As to the lessees, for whom, of course, I am most interested, it enables them to do this: it enables them in time of depression to work more regularly, thus it confers a material advantage upon the miner by ensuring more regular employment. With regard to the lessor, although apparently it may in time of depression decrease the revenue derived from his royalty, I think the swing of the pendulum when times improve brings it practically to something like a fair average. He also enjoys the advantage of having his coal more equably and regularly worked. I think, therefore, on the whole it confers a most decided advantage on all three.

440. I believe that there is something else that you wish to say with regard to the general principle? With regard to the general principle of the sliding scale, as I have said, the great point I imagine is this, that during bad times it enables you practically to continue working when you could not do so otherwise; it lightens the burden at the time of depression, and in the time of comparatively good trade it is not severely felt, and in time of really good trade the royalty rent can be paid though it may be even double what it is in the depressed time. The mean point between the two times of depression and flood practically gives the lessor over a series of years the same advantage that he would have had had he had an uniform rent during the whole period, but the relief is most material to the lessee.

612. You referred to some cases where, under certain circumstances, mines were worked at a great loss, for some years perhaps, by the lessees? I referred to two cases in which, ever since I got into them, they have been working at a loss until just this last year or so.

613. I would ask whether in those cases the lord or proprietor continued to receive his royalties? The lord or proprietor in every instance that I detailed? No. Once he became convinced that our representations were correct, he made most important abatements. Had he not done so the pits would have been closed. In one instance we gave notice to close the pit of one small subsidiary royalty owner in Northumberland who refused to comply with our terms, whose coal was exhausted, and wanted unreasonable terms for an underground wayleave. We did without it, but then it might have been that we could not have done without it, and then we should have had to pay the demand. Personally, I think the landlords do not behave badly. I ought to say that in one colliery that I mentioned, in which very heavy losses were incurred, the landlord in one year gave up the entire rent—every farthing of it.

614. But he could have enforced it if he had chosen to do so? Yes; but then we should have given notice, and given up his pit, though we would have lost the whole of our capital.

615. On the termination of the leases, the lessees I understand have no right of renewal? No absolute right.

616. Do you think it would be desirable that they should have a right of renewal on reasonable terms? I should think so, decidedly, as a rule. The longer the term and the greater the privilege conferred on the lessee, unquestionably the more beneficial it is to him.

William H. Hedley, chief viewer of the Consett collieries belonging to the Consett Iron Company:

734. What is your view of the economical effect of a fixed royalty, as compared with that of a sliding scale royalty? A fixed royalty might be expected to operate in restraint of a free and continuous working when prices became so depressed that continued working would involve a loss to the lessee. The cases are probably not numerous, however, in which with a royalty fixed at a fairly moderate figure this effect would be experienced. Of course, generally speaking, if the royalty were much above the average then a stoppage in bad times would be likely to take place, but these are just the sort of instances that many lessors have shown a willingness to meet by temporary reductions of rent.

745. Are you of opinion that the law which governs royalties is the same as the law which governs the rent of land? I think the principle that governs the letting value of coal is very much the same as that which governs the letting value of the land; it is a ques-

tion of supply and demand, I suppose. The lessor seeks to get the highest rent he can, and the lessee seeks to arrange for the lowest rent he can on his side, in the same way that a tenant wishing to take a lease of a farm would seek to get it on the best terms.

746. Are you of opinion that the amount of the royalty enters into the price of the coal or not? Of course to the extent of it it does enter into the price of coal, and if it were entirely done away with coal could be sold so much cheaper.

747. In that respect then you would think the principle would differ from the principle of the rent of land, because it is supposed to be a sound doctrine of political economy that the rent of land does not enter into the price of agricultural produce? I do not see how that can be argued. We have argued, for instance, that if the easement charges were entirely done away with that would affect the price; and the same would hold as to royalty rents; if they were entirely done away with I suppose it would affect the price to the consumer.

Sir Isaac Lowthian Bell, president of the Cleveland Mine Owners' Association:

1040. This Commission is not instructed, and has no desire to enter into all those general questions which you dealt with in your paper and in your evidence before the Royal Commission on Depression of Trade and Industry; but we should desire very much to have your opinion in respect of that part of your paper and of your evidence which touches the question referred to us, namely, the question of royalties. I think you dealt with it in the 74th paragraph of your paper at some length, and in your evidence? Yes, that is so.*

1041. Perhaps you would give us shortly what your opinion upon that part of the subject was and is? I would say, generally, that what I mentioned in the evidence your lordship has spoken of has been confirmed since that time by daily experience. I do not know whether it is the wish of the Commission that I should say anything about the nature of the royalty itself, in respect of which a good deal of difference of opinion prevails; although, practically, I do not think it is of much importance in the present inquiry. It may be quite true, for example, that a royalty will only be payable when the demand for minerals exceeds the supply which can be procured at the cheapest cost, and therefore the royalty will be the difference in cost between that of production and the placing of the product in the common market of the most favorably situated mine. Well, that is a condition of things which really very rarely obtains. It would be impossible to lay your hand on any district that I am acquainted with in which the conditions exactly responded to the law which has just been laid down. If the Commission would fancy the position

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*Extract from statement put in by Sir Lowthian Bell relative to his evidence before the Royal Commission on Depression of Trade and Industry, and referred to above:

Royalties.—These not only differ in different districts, but they vary in mines situated in the same locality. These irregularities may have arisen from the leases having been granted when trade was prosperous or the reverse; or from the mining difficulties being greater in the one case than in another; or from differences in the quality of the mineral; and lastly, from the geographical position of the field containing it.

It is not intended to deal with any extremes, but to take an average of what is usually paid in different districts.

In the United Kingdom the property of the minerals is, unless other arrangements have been entered into, vested in the owner of the soil; in any case the person so working them has to pay for the right of so doing.

To prevent the mine owner leasing large areas of ground and leaving it unworked, fixed rents are charged whether any mineral is worked or not; such fixed rents being regarded as payments on account for future workings. The lease sometimes permits the lessee to set such payments against the mineral taken away during any period over which it runs. At other times this privilege lapses at fixed dates as may be agreed to by those concerned. The amount involved in these fixed rents is sometimes very unconvenient to the lessee. The ironmaster may have to contend with adverse times when the state of trade would suggest either a reduction of make or its entire discontinuance. He has, however, not only to face this fixed payment, but he has to keep his mines free from water and the machinery, etc, in good repair. I could name cases where £20,000 or £30,000 a year would barely suffice to meet the expenditure under these two heads.

The royalty dues paid in Cleveland for ironstone are about 6d. per ton. In Lincolnshire and Northamptonshire they are sometimes double this sum, because, instead of expensive shafts and machinery being required, the mineral lies near the surface with a covering of greater or less thickness of sand or rock. In such cases it is got by simple quarrying. Coal varies in different places, but 6d. to 1s. per ton may be regarded as common rates. A common rent for limestone is 1d. to 3d. per ton. In addition to these charges the lessee has to pay double rent for all surface damage and to restore the soil at the end of his lease or pay its value.

In Germany the ownership of coal and iron ore is vested in the state. The royalty paid on the former is 2 per cent. on the profits. I suppose that at a selling price of 6s. per ton the profit will be such that 1½d. per ton will cover this payment. For iron ore nothing is paid for the right of working. No objection on the part of the owner of the soil is allowed to prevent the minerals on his property being worked, such prohibition being considered as inconsistent with the interests of the nation.

In the United States the ownership of the minerals goes with that of the surface, and as coal and iron ore lands have been and still are sold for a few pounds or even shillings per acre, the royalties on the minerals like the agricultural value of the surface cannot be compared with what is paid for similar proof a navigable river, for example, which separated a large coal district on one side from an iron ore district on the other, probably the works would be placed on the river itself, but it is quite clear that there would be no parity between or among works there placed if every portion of that district were taken up successively by different people at greater distances than the river. You would have, of course, the district next to the river in the most favored position, and every time a fresh adventurer made his appearance he would have to content himself, of course, with an inferior position. The minerals might be equally good all over the district; but still it would be absurd to pretend for one moment that they were all equally well situated. Now that is a condition of things which in my opinion would always produce a system of royalty; that is, there would be a preference shown for works the most favorably situated in this imaginary mineral field; and in the event of the owner wishing to sell a work of that kind, he undoubtedly would command and be able to obtain a very much higher price than would another owner situated, say, 10 miles from the river. It might not be a question of sale, but one of rental, and there you have at once the system of royalty springing up, because instead of a capital sum his advantageous position would be represented by a rent, in other words, by a royalty. I do not say the change would grow up the next day, but it would very speedily grow up, and in point of fact that would occur which, as I have shown in the book your lordship has mentioned, has occurred in countries where the minerals, being the property of the state, were handed over, practically without any payment, to adventurers who began to work them. The government in those countries acts in the interests of the commonwealth; it expects, and by offering facilities for capitalists to settle within their territory, they are promoting the prosperity of the district or the country at large. But no sooner does a private individual obtain a concession such as that described than he does one of two things. He either works it himself and looks to obtain all the profit for himself, or else, as is very frequently the case, he sells it and reaps his profit at once. Now on Lake Superior, which is one of the richest iron ore producing fields in the world, not only in extent but also in the quality of the ore it produces, that has been the universal practice. An individual received a concession when the country adjacent to Lake Superior was, as a great deal of it still is, primeval forest; but of course this rich deposit attracted speculators, and these mines were in many cases subsequently sold at very high prices. The same prevails here in Europe. In Spain, for example, you have Bilbao, a recently developed dis-

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perty in older countries. Further on it will be explained that notwithstanding this state of things royalties are often as high in North America as they are in any part of Europe.

In France all ironstone, save a trifling amount which is of an illuvial character, and all coal since 1810 have been claimed by the state. Concessions to applicants are granted on an annual payment of about 8s. per square kilometre (about 243 acres). In addition a tax is levied not exceeding 5 per cent. on the profits. If the latter amounted to 2s. per ton the royalty would be below 1¼ per ton.

In Belgium before 1830 the iron ore was the property of the state, when it was transferred to the owners of the soil by whom leases are granted on payment of from 4⅗d. to 2s. per ton. Inasmuch, however, as very little ore is now worked in Belgium the question of royalty is unimportant. Coal remains the property of the state. The rent on it is 1d. per annum per hectare (a little above two acres) with 2½ per cent. on the annual profits. This on an assumed profit of 2s. would be under ⅗d. per ton.

The minerals in Spain also belong to the state, concessions being granted on nominal terms.

From the data already enumerated in reference to the royalties it may be assumed that the charges are as follows:

In Great Britain—Pig iron per ton, Cleveland, 3s.; Cumberland and Lancashire, 6s. 3d.; Scotland, 3s., using clay ironstone, and from 5s. to 6s., using black band ironstone—the average being 4s. 10d. On iron ship plate 5s. 9d. will represent a common charge for royalty; and 3s. 8d. to 7s. 3d. on steel rails according to the ore from which they are made.

Germany—6d. on pig iron; 1s. on iron ship plates; 8½d. on steel rails.

United States—The royalties vary from nothing to 6s or 7s. per ton for reasons to be given hereafter.

France—On pig iron, 8d.; on iron ship plates, 1s. 1½d.; on steel rails, 11d.

In the present depressed state of the iron trade in this country, while ironmasters and mine-owners are working at a rate which practically gives no profit to the capital employed and in many cases results in a loss, it is widely felt by workmen as a grievance that the landowners to whom royalties are payable receive the full amount reserved by the leases.

It is contended by some that should the present low prices continue those engaged in mining in this country must be reduced to bankruptcy, and a great industry must be extinguished unless the receivers of royalties are willing to abate something of their legal rights, which now give them about 3s. on every ton of the cheapest kinds of pig iron made, or very nearly 10 per cent. on the gross price of the manufactured article.

Royalties on minerals resemble in their relation to the cost of production and the price paid by the consumer, the rent paid by agricultural land. That is to say, a royalty will only be payable when the demand for minerals exceeds the supply which can be procured in the easiest and cheapest manner, and the theoretic royalty will be the difference in cost between the cost of production and placing in the common market of the more favorrably situated mine and that which is the most expensive to work and which yet can be worked at a profit. But in practice most leases of mines are in the enjoyment of a beneficial lease, not a rack rent, for mining leases are necessarily usually for a longer period than agricultural tenancies owing to the need of the lessee for security of tenure on account of the large amount of fixed capital required in opening up a new mine. Thus as a new mining district is opened up the more remote or poorer deposits in a growing trade will be leased possibly at as high a royalty as the richer or more accessible mines which were leased when the prospects of the districts were less assured. But even now the trict, where the same system has prevailed; in Germany, in Russia—in point of fact wherever minerals can be cheaply obtained. I may mention that within the last month or two a small patch of land near a foreign port, I believe, not exceeding 20 acres in extent, and containing iron ore of very good quality, but no better than a great deal of the same mineral found elsewhere in the same district, has changed hands, and I understand there has been paid for it nearly a million sterling.

1042. Then I take it that the gist of what you have told us is this, that under any system, whether a system of law under which the proprietorship of the minerals rests with the proprietor of the surface or under which the minerals belong to the state, the effect would practically be the same, because if the state makes a concession of these minerals to any individual that individual practically stands in the same position as the proprietor of the land in this country, and will get the most he can for the advantage which he receives from the concession? That is certainly my opinion. Human nature will have to change very much indeed before anything but that result can happen, I think.

1043. I think the other opinion that you gave was this: that, as the value of different properties that the man would possess depends upon natural circumstances, it can by no law be equalized? Impossible.

1044. Those natural circumstances being the more or less productiveness of the matter below the soil, or the more or less nearness to the market? Certainly; these are the two circumstances which regulate the value. There is, of course, a third; that is, the facility with which the mineral itself may be extracted. But if it is equally cheaply worked all over the district, and if it is of equal richness, then of course the geographical position is the only thing to consider. But that identity very rarely happens, and a complete equalization of position becomes a very complex question. In Cleveland, for example, the iron ore there gradually diminishes in productiveness as we travel from the banks of the Tees, and at the same time that it does that the railway charges for conveying an inferior material from the more southern parts of the district increase.

1045. Am I to understand then that your conclusion would be, although in your paper and in your evidence you showed this anomaly, that the royalty paid upon pig iron, for example, in England is 3s. per ton, and in Germany 6d. per ton, and in Spain nothing, we may say that, practically, in respect of those mines that are being worked there would be no substantial difference in the actual amount paid by the people who are working the mines? I do not say that there are not cases where the contrary prevails. Supposing the original holder of the district were working it himself, then he would have an advantage over any-

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owners in the less favourably situated mines are forced in a losing trade to make concessions to their lessees, though they are able if they hold out for their full legal rights to see all the capital of the tenant made valueless before the loss begins to fall on themselves in respect of the royalty.

The subject in question has been receiving some attention of late in the press, and the injustice as it has been termed has been remarked on of the workmen having their wages reduced and the railway companies their rates lowered, while the landowners remain unaffected during the long-continued depression in the iron trade. The remedy recommended in some instances has been a drastic one, viz., confiscation of the landowners' rights. I have not in my experience met a single lessee who dissociates the right of his landlord to the minerals any more than he would question his title to the surface. As is known, when the profits were very high the landlords had to be content with the same rents they received under a very different state of things. It has, however, to be remarked that the present royalties were arrived at by previous experience of the value of the produce of the mines, and there is no doubt that had the present prices of iron been contemplated as possible when the leases were entered into some provision would have been made for such a contingency. It would seem therefore open to consideration whether by means of a sliding scale the payments to the landlord should not be made dependent on the market value of the mineral, a system which in some cases has already been adopted.

With regard to confiscation itself, the only ground upon which it could be recommended would be, not for the advantage of the lessee but for the good of the commonwealth. But in many, indeed I suspect in the majority of cases, both would prove illusory. Let us take the case of the Bilbao mines. The value of their produce was practically settled by the nature of the competition which they would have to encounter from the hematite mines in existence at the time the concession was granted. The Spanish government handed over its rights to certain individuals without any reference to the value of the ore or having any other object in view than those of attracting capital to the place and of providing employment for its subjects. They who had been judicious and fortunate enough to be the first to embark in mining adventures there looked upon the affair from an entirely different point of view. A large tract of mineral property was transferred by the original holders of the concessions to new parties at a high price, who, under the conditions of the transfer, have no other alternative but to charge a royalty which never reaches the national exchequer of Spain. I met with many similar instances in the United States. The mines on Lake Superior are rich in them. Skilled geologists with energetic minds pushed on into this then unknown region, indeed so little known at the present day that I found the native Indians still living in its vast tracts of unclaimed land. One enterprising speculator purchased from the state a property of 40 acres for a few thousand dollars. By him it was let to a second who agreed to pay a royalty of 2s. per ton on the ore to the original purchaser; and the new owner, after an expenditure of £3,000 to £4,000, passed the property on to a third, who paid for the privilege of working the ore in addition to the royalty of 2s. per ton the sum of £75,000, leaving thus a profit to the second holder of £71,000 or thereabouts. Again, in Pennsylvania there is the Cornwall mine, for which I was informed that the owners refused from the Philadelphia and Reading Railway Company a million sterling. I do not vouch for the accuracy of the sum, but I believe a very large amount was actually offered.

one who had to pay a royalty; but in order to gain for his works a position as a commercial undertaking he might have to sacrifice a part of that advantage, but he could afford to undersell a man who was paying a royalty to an original holder who had acquired a concession for a nominal sum.

1062. Then, speaking of how royalties are charged in Spain, I think you said that somebody gets a grant from the government, and by-and-by does not work it himself, but lets it to somebody else? He may or may not; he may have worked it himself, and in some cases has done so.

1063. Do you think that makes a condition of things on the continent, so far as Spain is concerned, exactly similar to the condition of things prevailing here? Practically it is so.

1070. Do not you think these leases in Spain could be regulated in such a way as to make the terms equitable for lessees, while permitting a considerable sum to go into the national funds in the form of taxes? I think if I were at the head of the Spanish government and I saw foreigners coming in and reaping very large sums of money from mining enterprises there, I should begin to inquire whether a reasonable portion of it should not go into the national exchequer.

1071. Do you think it would regulate the conditions and make them equal all round by imposing a higher tax on a mine situated nearer that river to which you have referred than on another mine more distant? I think that would be perhaps interfering with a principle of political economy which I am not prepared to admit, because you want to level the bad mines up to the position of the good, or to level the good mines down to the position of the bad. I think you cannot do that.

1080. I understand you to say that the royalties were very much regulated by the amount that lessees were inclined to offer? They are regulated no doubt when there is competition for them, then they will rise like any other commodity. I know of minerals in good times being undoubtedly taken at a much higher rent than the same minerals would have commanded in very bad times.

1081. Exactly; they are regulated by supply and demand, just as other commodities? Yes, more or less they are.

1101. Now, some reference has been made to the sliding scale system; should I be correct in saying that the sliding scale would, as a rule, adjust the actual rent paid more closely to the rent that the mine could bear than a fixed royalty? I do not suppose that we should get our ironstone any cheaper than we are getting it now; that is, it would be, I suppose, unjust to ask a mine owner to reduce his price below the present standard without at the same time agreeing to increase it in the event of iron being higher; so that I think you would find probably there would ultimately be an adjustment. At the same time it is difficult, and so far as I am concerned impossible to predict what effect the future would have in case of royalties being abrogated. If you take some of the diagramatical charts of prices, you will find that there has been a constant wave up and down over the last fifty or sixty years in the price of iron. But if you draw a line from the top of one elevation to the top of an elevation which took place fifty years after that you will find that there has been a gradual descent in the extent of the highest prices. The waves continue, but the amount of travel that they have is very much decreased, and this has taken place without any alteration in royalty dues.

1102. Has any difficulty been found in Cleveland in depressed times owing to the royalties being fixed in amount? Of course, everything that goes to increase the cost has its effect in increasing cost.

1103. I rather mean has it led to the closing of mines or to the reduction of wages? No; the price of iron has led to that, but it would be very difficult to say that it was the royalty which had put 1s. 6d. per ton on a material which cost you more than twenty times that. Of course it played its part. The 1s. 6d. is for ironstone royalty. I am taking it at 6d. per ton, and it takes about 3¼ tons to make a ton of pig iron.

1109. If the minerals of a country could, on an average under the world's competition, be worked just to a sufficient profit to ensure working if no royalty rent were charged, what would be the effect if these minerals belonged to the state as compared to their belonging to private persons? Well, I do not know that it would be very different. There are certain minerals belonging now to branches of the state, and I cannot say that I find the state is a much better landlord than anybody else.

1112. But it would not, of course, be worth the while of any private owners of minerals to let them be worked for nothing? Certainly not. And that is what I venture to say was in the mind of the Spanish and other governments where they look for their remuneration in the increase of prosperity to the country. They look upon it as a national question.

1117. If the minerals of a country could, on the average under the world's competition, be worked just to a sufficient profit to ensure working if no royalty rent were charged, what would be the effect if those minerals belonged to the state as compared to their belonging to private persons? I cannot see that there would be any difference.

1118. I am asking you what would be the effect under those two conditions? In the one case paying no rent, and in the other case paying rent?

1119. In the one case belonging to the state, and in the other case not belonging to the state? Well, I think if I were the landowner under the circumstances and I was going to get no rent for my minerals, I would let them lie there until the time came when I I could get it.

1120. And if you were the nation what would you do? If I were the nation I should be in an entirely different position, because the nation's interests are very much wider than those of individuals.

1121. Do you think the state would give the permission to work the minerals in the interests of the community? Yes, in the interests of the community.

1122. Even without exacting a royalty? Yes; I think it would do so, because in Prussia, for instance, the state has an undoubted right to the iron ore of Prussia, but it allows it to be worked in the way we have been speaking of, namely, by concession, for which nothing is paid.

1125. Take two states beside each other, in one of which private ownership prevails, and in the other the minerals belong to the state, and the two compete with each other? Very well, then I think either the community or the individual who is working the minerals would profit to the extent of the royalty.

1126 You think the private owner, if his interests were not to be served, would not permit the coal in his fields to be developed, but you think the state, in the interests of the community, would encourage the development, even although there were no immediate profit? I think the state might do so.

1127. I will put another question, because I think it will reconcile the two views. If the industry in a country where the minerals belong to the state will bear a royalty rent at all in the world's competition, the highest royalty rent that the minerals will bear will in all probability be paid by the ultimate worker, no matter what the terms are on which the state concession is given? Yes, I think so.

1128. That is to say that if the commodity will bear a royalty rent at all and the state grants those minerals free of rent, what ultimately happens is that in the transmission of that royalty from year to year it ultimately bears to the actual worker whatever royalty rent it is capable of bearing in the world's competition? Certainly.

1129. That is not irreconcileable, of course, with the other hypothetical position? Of course the position upon which you are basing the problem is an extremely difficult one. To day it might not bear any royalty at all. For example, the ordinary royalty of the Blackband ironstone in Scotland before 1824 or 1828 perhaps was about 6d. per ton. The hot blast was discovered and it enabled them to treat the Blackband with great ease and readiness, and the consequence was that an estate belonging, I think, to Sir William Alexander, was let at a fixed rent of £12,000 a year and 7s. 6d. per ton royalty. In 1862, for minerals on the west coast of England, the hematite iron ore of Lancashire or Cumberland, I forget in which county it was, which was usually let at about 2s. per ton was let at 7s. 6d. per ton; and all this would affect very greatly the position of affairs when they came to be discussed in the future under an entirely different state of things.

Marshall Nicholson, of the West Yorkshire Coal Owners' Association:

1287. Have you at all thought of the usefulness of a sliding scale as compared with a fixed system? Yes, I have considered that. I consider that it is of very little moment, because if you were under a contract and you had a sliding scale you would feel the benefit in depressed times, but of course whatever benefit you got then you would have to pay back in better times. Therefore on the whole I do not see much advantage in it.

John Devonshire Ellis, chairman of the South Yorkshire Coal Owners' Association:

1434. Now, so far as South Yorkshire is concerned, as far as you know, is there any reason to complain of the actual royalty charged for coal let? No, it is a matter of bargain of course, and the bargain is almost always very honorably carried out on both sides. I do not think it is a matter of any complaint whatever.

1435. Then, as far as you know, and speaking for colliery lessees, is there any desire in that respect to interfere with the present system or to disturb it? I think, as a rule, they would be very sorry indeed to get into any other hands.

1436. Do you mean by that the state, for instance? Certainly, I think that would be a great objection. Most of the coal fields in our district are in the hands of large landed proprietors, such as the Duke of Norfolk, Earl Fitzwilliam, the Earl of Effingham, and Mr. Foljambe; they are all of them most liberal, honorable landlords, and I scarcely ever hear the slightest complaint made by anyone. The difficulty always arises, I think, when the property is in the hands of either trustees or of small holders. That is my experience on this matter.

1493. Can you tell us what is the quantity of coal produced in Yorkshire last year? It would be about 23,000,000 tons in 1889 for the whole of Yorkshire About 13,000,000 were produced in South Yorkshire and about 10,000,000 in West Yorkshire.

1494. I think you said the average royalty was 6d. per ton? Yes.

1495. Is that upon the gross output, or after deducting anything for the free use of the colliery? It is taken on the gross output, I think.

1496. Do you think that that would give a fair approximation to the amount of royalties paid in South Yorkshire? I think it would. We pay about £20,000 per year.

Francis Abigail, member of the New South Wales Legislative Assembly and Minister of Mines in the years 1887-89:

1529. Will you be so kind as to tell us what the law in New South Wales is as regards the property in minerals; whether, for instance, the same law affects all minerals, or, if not, with what difference. I am referring to the law of property in minerals, and to the laws under which the mineral industry is generally conducted? Perhaps I can best do that by referring to the state of the law and dealing with the sections which refer to these questions. By the Crown Lands Act of 1884, section 7, in the case of all lands granted for settlement the minerals are reserved to the Crown, and persons taking up the land actually for settlement only take the surface, the Crown reserving all rights to give authority to mine under that land for the minerals. This 7th section sets it forth; it is not necessary, perhaps, to read it, but it is in very clear terms that "all grants of land issued under the authority of this Act shall contain a reservation of all minerals in such land, and shall contain such other reservations and exceptions as may by the Governor be deemed expedient in the public interest. Provided that wherever it shall be found that land alienated under this or any of the said repealed Acts contains any mineral, and such land has been alienated subject to the minerals being reserved to the Crown, the Governor may permit the owner of such land to remove such mineral upon payment of such royalty, and upon such conditions as may be prescribed."

1535. Is the Crown Lands Act of 1884 applicable to all your minerals? Yes, and always has been, because the provision I have read is simply a provision transplanted from the 1861 Act into the 1884 Act.

1536. Therefore, practically you have no such condition as that which exists in this country, in which the proprietor of the soil has the right to the minerals underneath it? No, except in very special cases.

1537. Are those cases of any importance commercially? Yes; the A. A. Company obtained, very many years ago, a grant of a million acres, and in that grant there was a reservation of minerals. After they had been in possession for some considerable time they applied to Parliament to cancel that reservation, and I am very sorry to say that Parliament allowed the cancellation to go. The A. A. Company now stand out as being possessed of large valuable mineral lands containing coal and other minerals without the reservation.

1546. Are there any other exceptions, or is that the only important exception? There are other exceptions. Those other exceptions have been obtained by the passing of what we call the Mineral Conditional Purchase Bill. There were a number of parties in New South Wales who saw that they could obtain advantages if they could pass a law to evade that reservation principle, and this Mineral Conditional Purchase Bill was passed, which enabled them to take up both surface and minerals upon payment of £2 per acre, which was double the rate for settlement under our Land Bill. Under the Land Bill you can take up the settlement of land for £1 per acre, but under the Mineral Conditional Purchase Bill they obtained the land at £2 per acre, with a condition that they would spend another £2 per acre on improvements. That was in force for a short time, when we found that it was being worked very prejudicially to what we consider the public interest, and we repealed that bill, but not before a number of people had obtained possession of the mineral lands.

1547. Will you now explain to us the general method of dealing with minerals under the Act to which you have referred? Section 45 of the Crown Lands Act deals with Crown lands within proclaimed gold fields. That section sets forth that "Any Crown land within a proclaimed gold field which, after the 25th day of May, 1880, has been sold conditionally or by auction, or in virtue of improvements or otherwise, as well as any such land alienated under this Act, shall be subject to the following condition, namely: any person specially authorised in the prescribed manner by the Minister shall be at liberty to dig and search for gold within such land, and should it be found to be auriferous the Governor may cancel wholly or in part the sale of such land, and upon the notification thereof in the *Gazette* the proprietor shall be entitled to compensation for the value of the land as if it were not auriferous, and of the improvements thereon as appraised by the local board, and such land shall thereupon become Crown land within the meaning of the 'Mining Act, 1874.'" That, of course, gives the government the power, if the settler finds that it is gold land, to resume it for mineral purposes, but the settler has the right to make the first application for mining rights upon that land when it is resumed by the Crown.

1548. Is there a similar provision in respect to other minerals? Yes; section 91 of this Act says, "The Governor shall, notwithstancing the provisions of the 'Mining Act of 1874,' impose a royalty of not less than 6d. per ton on coal raised from land which may be hereafter leased ; and such royalty shall be in addition to or in substitution of any rent payable by such lessee under the said Act, but shall not affect or prejudice any other condition of the lease."

1549. Does that mean that the government raises a tax of 6d. per ton on all the coal raised? It simply means that they charge a royalty of 6d. per ton on the coal raised from Crown leased lands.

1558. On what terms are these leases given? A gold lease is from 1 to 25 acres, and the rent is £1 per acre per year ; under a lease for minerals other than gold the rent is 5s. per acre per year.

1559. Is there any limitation of the area for the other minerals? Yes ; you can take a lease for the other minerals up to 640 acres, but for a gold lease, as I say, you can only take an area of from 1 to 25 acres—that is for reefing gold, but for alluvial gold you have to take it in blocks of a very much smaller area.

1564. Am I to understand that the rent for minerals other than gold is a fixed rent? Yes, of 5s. per acre.

1565. And that it has no reference to the comparative value of the minerals beneath the surface? No ; there is one fixed rent for those, and the Crown makes no difference. Their desire is not to make so much capital out of the land as to get their mineral wealth developed and their people employed.

1566. Returning to a question which you answered just now : in the case of coal did you mean to tell us that where an individual or a company has taken a certain quantity of acres for the purpose of working coal, the royalty of 6d. per ton is chargeable upon all coal raised by that company? Yes, it is so.

1567. So that, in point of fact, this 6d. per ton is in the nature of a government tax upon the produce of coal? We do not look upon it as a tax. We simply look upon it as a small equivalent to the Crown for great benefits granted to private people.

1569. Can you give us, generally, your view as to the economical result of this system to the colony in respect of the development of the mineral resources of the colony? There can be no question or doubt, so far as our experience goes, that mining development under Crown regulations is vastly more beneficial than if it were in private hands. That is our experience ; in fact, the feeling is so strong that I framed a bill before I left to take power to mine on private property, which I hope to be able to pass if I arrive back.

1570. Is that private property the property to which you have referred before? Yes, that property where it has been obtained without the reservation. We find that people who have obtained valuable mineral lands without the reservation are not ready to develop them.

1572. When the lease is once given as you have described it, does that constitute a property in the minerals to the person who has got the lease, or is it only for a limited term of years? For 15 years, with the right of renewal for 15 years more, and where it is worked according to the conditions the Crown never comes down upon the leaseholders in any way whatever, but will extend the time to an unlimited period as a matter of fact.

1575. Do you find that the party who applies for and gets the lease is usually the party who works the mine or not? I think not. Of course a man may be prospecting and may find a valuable coal deposit without having the capital to work it, and he necessarily sells the advantages he obtains from the Crown to those with capital who will work it.

1577. Do you know any cases in which parties rent these rights from others on condition of paying to them a royalty? No ; I think it generally leads to the formation of a company. A man obtains these rights, and then he places himself in communication with a number of gentlemen who form a company, giving him certain monetary conditions for the rights he has obtained.

1578. Paying him a lump sum, I presume? Just so.

1579. Would it be fair to say that the interest upon that lump sum would be a species of royalty paid to the person who obtains this right from the government? Of course the amount paid to him has to be estimated in making a calculation as to the cost of the coal taken out.

1582. Is the same course taken in the case of iron as in the case of coal? No. Iron comes under the other term, and there are no conditions of royalty charged upon it whatever.

1583. You charge nothing? No royalty whatever.

1584. Do you make any charge in the case of any other minerals, with the exception of gold? No. Coal is the only thing that carries the royalty.

1650. You appear to think that to have the minerals in the hands of the government is a better system than we have here? Undoubtedly ; I have no hesitation in saying that our experience proves it beyond a doubt.

1651. But supposing you had had the other system in operation, would you see any reason to change it by giving compensation to the owners of the minerals? Any private rights that were invaded should be properly compensated for.

1652. Do you mean surface rights? I am speaking not only of surface but of mineral rights. Any rights of that kind which would be invaded by any public interest should be.

as I say, properly compensated for. We are not communistic in New South Wales, and we believe if we invade people's rights we should pay for them.

1658. Do you think it is a fair principle to put all coal under the same royalty? What I have already stated answers that. I have said that in a bill I framed I fixed the large coal at 6d. and the small coal at 3d.

1659. But do not you think that the minerals of the country would be more readily developed in the hands of a private owner who had the power to charge much less royalty than 6d.? Our experience does not warrant me in saying that; I think that we have had one or two cases where private owners have opened up their paddocks for gold mining, and they have charged as much per week to each man as the Crown would charge per year.

1660. Yet, in every case it seems that when the mineral turns out more valuable than the charge made by the government, some private party gets the benefit and not the country at large, is that so? The country at large gets it indirectly, but the private people do not furnish the same facilities for working the mineral lands as the Crown.

1707. In the proposed legislation, where you propose to take authority to mine under the property of individuals who have acquired the mining rights, I understood you to say that provision was to be made for ample compensation both for the mining rights and for the surface rights? Ample compensation, and we give them three modes of obtaining it. That is, when the land is taken they send in to the Minister their estimate of its value; if the Minister does not accept that, they go to arbitration; if that is not accepted by the parties, we give them the right to go into the law courts and sustain their position there.

Barnard Platts Broomhead, barrister, and interested as landowner and shareholder in several mining companies:

1839. Have you had much practice as a solicitor in relation to leases of coal in South Yorkshire, Nottinghamshire, Derbyshire and the district around Sheffield? I have for a great number of years. I have many clients who hold very large mining royalties and very important leases.

1890. Could you tell us about how much the average of royalties in your district is? In our district the royalty up to within recent years was let or paid for at an acreage rate, so much per acre, say, for the Barnsley coal, so much per acre for the Silkstone coal, so much per acre for the Parkgate coal, and so on. Within my time, and certainly when I began practice, I never came across a case of footage rent. But now, in the majority of the cases, a rent of so much per foot per acre is paid, and not an acreage rent pure and simple. For instance, supposing you have got a four-foot seam to deal with, or what is supposed to be a four-foot seam, when you get to it the colliery lessee now instead of saying, I will give you £150 per acre or £120 per acre, as the case may be, would say, I will give you £30 per foot thick per acre, and then, as I find the coal free from dirt, I pay according to that footage rent. The ordinary rate in our district now is from £25 to £30 per foot thick per acre, and reckoning the yield of coal (I am not a mining engineer and I speak under correction) at something like £1,200 per foot per acre (I think that is about right), assuming that to be so, and I understand it to be so, then £30 would give a royalty of 6d. per ton, and £25, 5d. per ton, and so on. In my experience that is the average royalty.

1895. You, I believe, can explain to us the laws in force in the province of Biscay, in Spain, with regard to the working of minerals? I have had a memorandum prepared for me of the state of things with regard to the mining laws of the province of Biscay, in Spain, where my company has large interests. I will put it in for reference. In effect it is this: the mineral belongs to the state. Anyone, either a Spanish subject or a foreigner, I believe, may, what is called, "denounce" a mine, that is, bring to the notice of the state the fact that there is a mineral workable under certain property. He makes an application, and for a small payment he obtains the right to work this mineral just in the same way as an English landowner has the right to work his own minerals.

1896. What is the practical result of that? To show the practical result of that, I will give you our own case. In our case when I came into the company I found two sets of royalty owners. I found a set of royalty owners under the state, who were paying less than £100 a year to the state for the whole of the mines which we took over. I found that those royalty owners again had made an arrangement with some English people for a sort of sub-letting, and for the creation of an interest under them. I found that the English royalty owners had formed a company, which company I happened to take shares in, and became a director of. I found that we practically had two sets of royalties. First we had the English royalty owner; second, the royalty to the concessionaire from the state, who only paid less than £100 a year to the state. These royalties became so tremendously oppressive that we had to raise nearly £100.000 to get rid of the English royalty owner, who was sitting upon us like the old man of the sea. We got rid of him. We raised £100.000, and we cleared him off, and now we have the concessionaire, the royalty owner created by the state, in Spain, who is drawing £10,000 a year from the working of our mines, and I will undertake to say that that Spanish concessionaire has never spent £500 over the transaction. The state, which is the theoretical owner of the mine, is not getting at this moment £100 a year for which the concessionaire has got £10,000. That is the operation of the law there with regard to the state ownership of minerals.

1936. I think you said that you had had no experience of a sliding scale of royalties? I have not. We have often discussed it and we have felt that it would be a very desirable thing. I have had the experience of going to land owners within the last year or two and asking for concessions, and we have discussed from time to time the question of the sliding scale, and we, that is, the solicitors on both sides, have felt that we would not have had to be there if we had had a sliding scale.

1937. I understand you to agree with the principle that a sliding scale based upon the selling price would be very much more satisfactory, as it would render it unnecessary for a lessee to be making applications to his landlord in bad times, many of the applications possibly not being entertained? That is my opinion, given, however, without having had any actual practice. It is a matter of opinion in our district so far.

1938. Would that be necessary if the royalty was taken in low times? No; but then I would go further and say I do not see why a land owner should not have some little of the benefit of the high times. I think it is only fair all round.

1939. What some gentlemen would like would be to take it at the lowest and then get the benefit of the highest? I do not say that at all. I think you should find the proper stage. Let it go down as low as it may, it cannot go beyond a certain depth because when it has got to a certain point it is not profitable and the work must be stopped.

1940. Have you ever known any of the powers of the old Canal Acts exercised in your district? They have been exercised for navigation purposes, though not for other purposes within my knowledge; but I should say that I can only go back for 30 years or so myself. There has been nothing of that sort exercised in my time.

1954. You referred to Bilbao and the enterprises in which you are engaged there; that is ironstone mining, I presume? It is.

1955. Can you tell how much is paid as royalty; what is the total amount per ton on the ironstone in Bilbao? In our particular case I should think we pay at the present time something like £10,000 a year to the first concessionaire; as I tell you, we have got rid of the second royalty by the payment of something like £100,000.

1956. How much per ton would that be? My note here is that our mines pay the Government £56 a year, but that they were leased to our company under a royalty of 1s. 3d per ton and a dead rent of £5,000 a year.

2008. I think you said the rent you paid at Bilbao for Spanish ore was 1s. 3d. per ton? —Yes.

2009. Is that exclusive of the money with which the third man was bought out? Yes, we have to pay that independent of what the third man got.

2010. So that really your rent is a good deal more than the 1s. 3d. per ton? Yes, it would have been.

2063. With regard to the case of the Spanish mines, is it quite fair to say that what is the case in Spain is the necessary result of state ownership of royalties? Could you not imagine a case—perhaps there are cases—where the state would not give the concessionaire the power of subletting, and in such a case would not the state itself get the whole of the royalty? Your complaint was, I understand, that the state got less than £100 a year whereas you pay £10,000 a year for royalty; does not that arise, not from the state ownership of the royalty, but from a certain incident of the law in Spain which gives the first concessionaire power to sublet to a second royalty owner? No; there is very great difficulty in imposing a restriction on the first concessionaire. The first concessionaire, I think, must be left to make what he can of the property.

2064. That is just the point; why did you say "must be" left? I take it that the reason that the state in Spain has done this has been for the purpose of inducing foreign capital to come in and to work these mines as they have not capital enough in their own country.

2065. Would not the foreign capitalist be equally induced to come if the state confined the ownership of the mine to the actual worker of it; that is, if the state gave the concessionaire a right to the mine simply as long as he works, without giving him power to sublet to a third party? I only want to correct what I think is your too general statement that Spain proves the uselessness of the state reserving minerals? I have not considered all the results that would follow from a state-owned mineral property as against a privately owned mineral property. I merely wish to inform the committee about what happened as a matter of fact and practice in Spain where minerals did belong to the state.

2066. Would you not modify your evidence by saying that the evils of the Spanish system are owing to the existence of a power in Spain which enables the concessionaire to sublet? If that power did not exist, the state would get the £10,000 a year, and not merely the £100 a year, is not that obvious? Do you mean to say that if the state were to wait until the capitalists came forward to develop the minerals they might have got this money?

2067. That is how I put it? Then I say yes, if the state were disposed to wait as long as the state might have to wait till the capital came.

Alfred Barnes, M.P., member of the Commission, and chairman of the Derbyshire, Nottinghamshire and Leicestershire Colliery Owners' Association :

2134. I see from the answers that you do not have a sliding scale to any extent in your district? We have no sliding scales. I myself am not an advocate of the sliding scale. I think that we have got quite sufficient experience in the past to arrive at an average, and that both the lessor and lessee ought to know what the average has been, and that ought to be the basis for the future. I think it is merely a question of a small amount of capital. In the bad times it would not make a difference of 1d. per ton, and if anything so fine as 1d. per ton would stop a colliery I think it ought to be stopped. What has really been the means of bringing up this question of a sliding scale is the action of those people who have taken their royalties in high times. They naturally wish to come down to the low figure. They have taken their coal at perhaps twice as much minimum rent as it was worth and then in the bad times—of course things are better now—but in the last six or seven years they felt the shoe pinch very severely. That has been a great means of bringing about the outcry for a sliding scale.

2189. When you said that you did not coincide with those who argue in favor of variable royalty according to the selling price, that I think you said was because already the market had been so well established that there was no necessity for it? I think there is no necessity for it. I think as you have experience of from 30 to 40 years you can establish a fair average without having a sliding scale; in fact, it is practically the average result of a sliding scale you may say.

John Dixon Kendall, mining engineer and lessee of iron mines in Cumberland :

2484. You are interested in the hematite iron trade in Cumberland, I believe? Yes.

2485. What interest have you in it? I am acting as a mining engineer, and I am also a lessee of iron mines.

2488. You give us generally, I believe, what royalty is now paid upon ironstone? Yes, in the answer to question No. 7.

2489. What does it average per ton? It varies, of course, with the selling price. I have a number of instances here, no two of which are exactly alike. I have abstracted 16 leases, and have the figures with me which I will give you. Here is one dated 1886 with a minimum of 1s. 9d., it is never less than 1s. 9d., but up to 15s. the royalty is one-sixth of the selling price; from 15s. to 20s. the royalty is one-fifth of the selling price; from 20s. and upwards the royalty is one-fourth of the selling price. In the next one, granted in 1883, there is a minimum of 2s., but it is one-seventh of the selling price afterwards. In another, granted in 1875, there is a minimum of 2s., and the royalty is one-sixth of the selling price. Another, granted in 1873, but which has been determined, had a fixed royalty of 7s. Another, granted in 1862, had a fixed royalty of 1s. 3d.; that, of course, has expired. Another, granted in 1883, had a minimum of 2s. 6d.; that was when the selling price was 12s. and under; from 12s. to 20s., there was one-fourth of the additional selling price extra; and above 20s., one-third of the additional selling price extra. A lease granted in 1872 for 39 years has a fixed royalty of 1s. 6d.; another granted in 1875 for 1,000 years, has a fixed royalty of 2s., but the lessees paid a premium of £10,100 to the lessors. Another, granted in 1877, has a minimum of 2s. 7d. up to 13s.; above 13s., one-fifth of the additional selling price in addition. One granted in 1881 had a minimum of 3s., and the royalty was one-fifth of the selling price. Another granted in 1885 had a minimum of 2s. up to 12s., but the scale after that was a very complicated one. From 12s. to 12s. 6d. the royalty was 2s. 1d.; from 12s. 6d. to 13s., 2s. 2d.; from 13s. to 13s. 6d., 2s. 3d.; from 13s. 6d. to 14s., 2s. 4d.; from 14s. to 14s. 3d., 2s. 5d., and so on; it is an increasing fraction, and gets up to 6s. 4d. when the selling price is 24s.; then it goes on increasing 1d. per ton for every 2d. per ton increase in the selling price.

2492. If we were to take 2s. as the average royalty on the output, should we be far wrong? No, I do not think so, because the average price for the last ten years has only been about 11s. 9d.; that is for an average ore, so that the royalty on that would be about 2s., taking it all round.

2502. Cannot you give us the proportions in which it goes up? This is the way in which it is mentioned in the lease; there is no particular fraction. From 12s. to 15s. it is one-sixth of the selling price; from 15s. to 20s. it is one-fifth of the selling price; over 20s. it is one-fourth of the selling price. Another has a minimum of 1s., that is at 9s. and under; from 9s. to 12s. it is one-fourth of the extra selling price, in addition to the 1s.; from 12s. to 15s. it is one-sixth of the selling price; above 15s., one-fifth of the selling price. One made in 1887 has a minimum of 1s 9d.; that is at 12s. and under; from 12s. to 15s. it is one-sixth of the selling price; above 15s., one-fifth. Then there is one made in 1878 at a fixed royalty of 2s. 3d., which was determined on account of the royalty being too high.

2503. Is there always a fixed rent as well as royalty? Always a fixed rent, and that varies very considerably. I have known from 10s. 4d. per acre to £100 per acre.

2504. Is it the general opinion in the business that the sliding scale is the best arrangement to make? Yes, I think the lessees prefer it, unless, of course, they have a fixed royalty which would allow them to work in all conditions of the market. If you have got a fixed royalty which will allow you to work at any time, undoubtedly that is the best.

2505. I do not quite follow that; do you mean a very low fixed rent? A low tonnage rent. If your tonnage rent is low enough to allow you to work in depressed times, then undoubtedly that is the best so far as the lessees are concerned and so far as the district generally is concerned.

2506. That is, if the amount of royalty paid is small enough not to encumber the working of the mine? That is so. Of course if it is a high fixed royalty, then when times of depression come you simply have to surrender your lease, as has been done in some of these cases which I have given you. For instance, there was a case where a fixed royalty of 7s. was given in 1873, when iron ore was selling at 30s. to 36s.; when the iron ore came down to 13s. and 14s., and even lower than that, they were obliged to give up the lease. There was another case in the same district where, in 1873, they actually gave 15s. fixed tonnage. That lease had to be abandoned in the same way.

2510. Those very high rents were, I presume, given in the time of inflation, when people were speculating? Quite so, when nobody ever dreamt that iron ore was coming down below 18s. or 20s., but the older leases which were fixed at 1s. 6d. and 1s. 3d. and 1s. and so on, were never broken, so far as I know, on account of the royalty being too high; the lessees were always able to work under those leases, but probably that was because wages were less than they are now.

2554. Speaking generally, do you consider that the system of royalties prevailing in West Cumberland has an injurious economical effect upon working the hematite ore in that county? Below 12s. I think they have decidedly. Above 12s., as a rule, I have not much fault to find with them, but below 12s. they are not only injurious to the lessees but to the district at large, for the reason that if the royalties were lower we should be able to work many mines or parts of mines which now we cannot work on account of the high royalty.

2555. Have you had an opportunity of comparing the royalties that are paid in Cumberland with the charges in the nature of royalties which are paid at Bilbao? Yes, I have.

2556. What is the result of your comparison? They are much higher in Cumberland. If you get a concession there from the government you have no royalty to pay for it.

2557. It is not that that I was alluding to. Of course, as you know, the actual payment by the people working the ores there is not to the government but to the persons from whom they get the right; to the original concessionaires or the persons to whom the concessionaires have parted with their rights? Yes; but I think there are many cases, some of them very important cases, where the concessionaires are working the mines, and they in a great measure, holding as they do important mines, rule the prices, because they can work at a less price than the other people who have to pay royalties to the original concessionaires. I know that some of them are paying as much as 1s. per ton royalty, others 8d., but there are some parties working very extensively who do not pay anything.

2573. Can you tell us what proportion of the selling price, assuming it to be as you say, from 12s. to 16s., goes in labor? Yes; I have worked that out. Of course, it varies a great deal, 1st, according to the price at which the ore is sold, 2nd, according to the quantity raised, 3rd, according to the nature of the deposit, and 4th, according to the freight. But taking an average case of hard ore, which is difficult to get, and taking the selling price at 9s., I find that the wages would absorb about 50 per cent. of the selling price, and the royalty 22 per cent., and that the lessee would get nothing.

2574. What about the balance? The balance is made up of materials, rates, taxes, and so on. The wages and royalty only make 72 per cent., but the remainder is made up of a number of incidental expenses. If you take the same class of ore at 10s. 6d., you get 43 per cent. in wages, 19 per cent. in royalty, and 10 per cent. would go to the lessee. If you take 12s. as the selling price you have 40 per cent. in wages, nearly 17 per cent. in royalty, and 20 per cent. to the lessees. Take 18s., and you will have 30 per cent. in wages, 20 per cent. in royalty, and 30 per cent. to the lessees; that is to say, as the price goes up the proportion that is paid in wages becomes less, and the proportion to the lessee becomes greater, whilst the proportion paid to the lessor is practically the same all the way through. Now if you take a soft ore at the same prices, that is, 9s., 10s. 6d., 12s., and 18s.; at 9s. you have 30 per cent. in wages, 22 per cent. in royalty, and 28 per cent to the lessees; at 10s. 6d. you have 28 per cent. in wages, 20 per cent. in royalty and 63 per cent. to the lessees; at 12s. you have 27 per cent. in wages, 18 per cent. in royalty and 37 per cent. to the lessees; at 18s. you have 18 per cent. in wages, 20 per cent. in royalty and 48 per cent. to the lessees.

2575. That is, assuming the same royalty in every case? Yes, the same royalty for the same selling price in each case. It is a royalty with a 2s. minimum I have been working on.

2576. And the same wages, that is, you do not take account of any rise in wages? Yes.

2577. Then you do take account there of the rise in wages? I may say these are not estimates. they are actual figures.

2578. You think there, I suppose, that the wage-earner gets also some profit from the increased selling value, but not at once; it comes later? Yes, he gets a rise in wages as the ore rises. but he does not get the same percentage of the selling price; his percentage falls as the price rises.

2579. Do his wages rise at once? Almost always at once; they rise at once and fall at once with us.

Alfred Hewlett, mining engineer and colliery owner in Lancashire:

2724. Have you any opinion one way or the other as to the advantage or disadvantage of a sliding scale royalty as compared with an ordinary royalty? In my own opinion I would much rather have a fixed royalty. I might add to this that so far as my knowledge goes royalties were originally fixed by a sliding scale almost entirely. That was the origin of the royalty so far as my knowledge of the history of mining goes. Then great difficulties arise. It is always unpleasant to have all your books looked at and everything of that sort; but it is a necessity in the case of a sliding scale. Complications arose and hence the fixed royalty came, and for myself I very much prefer a fixed royalty.

William Barrow Turner, member of the Institution of Civil Engineers:

3000. How long experience have you had in the hematite mining? Over 30 years.

3001. Will you describe the nature of the mining generally; is the ore found in veins? It is found in veins, but mostly in irregular deposits. There is very great uncertainty about it. You can always say where ore may be found, but it does not at all follow that you will find it. I may say that there is more risk than there is almost in any other kind of mining I know; in fact I have searched for ore myself about twenty years before I found any at all.

3006. According to the sliding scale which you gave us the royalty upon a ton worth 10s. would be 1s. 8d., the minimum being 1s. 6d. when the price is not exceeding 9s., and there being an advance of a penny per 6d. up to 14s. Therefore, at 10s. the royalty will be 1s. 8d., will it not? Yes.

3007. Would you have to pay in addition to that royalty of 1s. 8d. any wayleaves, either underground or surface? Yes, you will frequently have to pay an underground wayleave, which in many cases is rather an excessive charge, and for this reason, that the royalties are so much mixed up. You may have a field of a few acres, say four or five acres, with the minerals belonging to two lessors. In a case of that sort you would have to pay a double wayleave.

3008. You mean you not only have to pay a royalty for the right of working the mineral, but you have to pay a wayleave for bringing the mineral worked on the property of somebody else through that part of the mine which is the property of another person, is that so? Yes; and that you have to do sometimes twice over; it would mean in certain cases 4d. per ton. That is really a tax upon the royalty.

3009. You would have then in regard to the royalty to add 4d. per ton in some cases for underground wayleaves? That is so.

3135. About how much per ton is the royalty rent as separate from the wayleave? It varies; there are so many schedules. There is one which is a sixth of the selling price, with a minimum of 2s. That is a scale of our own which we have been working under for a number of years. There is also a schedule with a minimum of 1s. 6d. at 9s. and it goes on increasing according to a scale which from 11s. 6d. to 12s. makes it 2s.; at 15s., 2s. 8d.; at 18s., 3s. 9d., and so on. There are several scales, but they are all more or less similar, except where you have the 2s. minimum.

3136. Have you found the sliding scale advantageous? I think it is an advantage. It is an advantage in this way. that it enables you to meet the consumer at the low prices.

William Kellett, mining engineer and manager of the Barrow Hematite Iron and Steel Company:

3212. Are the sliding scales of recent introduction into Cumberland? Those that I have handed in have been more than 10 years in existence.

3213. Were they introduced on account of any depression in the trade? They were.

3214. Would you say that the sliding scale system has now replaced the old system of fixed royalties? I should think it is gradually doing so.

3215. Gradually? Yes; I think when any new lease is made a sliding scale is adopted.

3216. Is it your opinion that the sliding scale system is a better system than the fixed system? Yes, I think it is a fair system. I think it is fair to both sides if it is a proper sliding scale, a just one.

3223. Do you consider that the high royalty at one end of the scale at a high price is not balanced by a correspondingly low royalty at the other end of the scale? I do not think it is.

3224. Now, you suggest that the same principle should be followed whatever may be the price, and that a certain proportion of that price should always go to the landlord—an eighth, I think, was the figure you gave? Whatever the price is, whether it be an eighth, a sixth, or a tenth, or whatever it may be, I would follow that through.

3225. You would admit, however, that one mine may be an eighth, another a sixth, and another a fifth? Certainly; I think you must fix your sliding scale according to the quality of the ore, the nature of the mine, the quantity of water that you have got to pump, and the distance from the surface that you have got to raise the ore.

3226. The result of that would be that the lessee of the mine and the miner would derive a greater benefit when prices are high than the royalty owner? I think the royalty owner would have had his fair share of it all through.

William Gill, general manager of the Orconera Iron Ore Company:

3373. Does the state in Spain levy any other tax on the minerals than the royalty? Yes.

3374. A special tax I mean; not a general tax? Yes, a tax of one per cent. on the value of the ore at the quarry's mouth. The ore at Bilbao is sold free on board ship; in fact, invariably free on board or sold on this side; so that the value at the quarry's mouth is a fictitious value, and has to be appraised and valued. It is settled at present at so much. We have meetings from time to time with the treasurer, with the assessor, and we arrange that the standard for the coming quarter shall be so much, and upon that we pay one per cent. It comes to a very small amount for the large quantity shipped by the Orconera Company for instance, which has nearly 900,000 tons per year of its own ore, but I think we only pay about £1,800.

3375. You said, I think, that the greater part of the hematite mines at Bilbao are not worked by the original concessionaires, but have been leased or parted with in some way to other parties? Yes, I should say two-thirds of them have.

3381. I understand it then as comparing the position of the concessionaire of the mineral rights in Spain with the proprietor of minerals in this country, that the concessionaire who works his own concession would stand in the same position as the proprietor of minerals in this country who works his own mines? Exactly.

3384. The sum paid by the lessee to the concessionaire would be a payment of the same class as the royalty paid by the lessee to the proprietor of minerals in this country, would it not? Yes.

3385. Then can you tell us what is the amount of royalty paid by the people who are working the mines in Bilbao, the actual workers of the mines, to the concessionaires? Yes; it varies very much according to the position of the mine and its facility for transport, and the quality of the ore; but it may be taken to range in the very old leases made about 10 or 15 years ago from 8d. to 10d. per ton up to 2s. and 2s. 6d. for brown ore, and up as high at present, but only just recently, as 3s. 6d. per ton for red hematite, which is getting very scarce, and of which there is only a very limited supply; but that can hardly be taken as a fair test of royalties over the whole district, because the red ore is in the hands of two or three people.

3386. What is the price of red ore free on board? Now it has gone back a little, but a short time ago it was 12s. a ton free on board.

3387. And was the royalty of 3s. 6d. paid on the 12s.? Yes.

3388. Do you make that calculation including any lump sums that have been paid for buying up royalties? They vary very much. Occasionally a lump sum is paid; occasionally a premium is paid in addition to the royalty—for instance a man will give £2,000 or £3,000, or whatever it may be, and a royalty of so much.

Septimus Alfred Stephen, member of the Legislative Council of New South Wales:

3477. Could you tell us generally what is the practice with regard to the concession of minerals in New South Wales? Originally, when all the grants were made under what we call the Orders in Council, that is, before 1861, the grants did not contain in every instance the same reservation. Some contained a reservation of timber for bridges; some contained a reservation of all minerals; and some would contain a reservation of roads in addition. But in 1854 (I am speaking entirely from memory, but I am sure I am right on this point), a proclamation was issued by the Governor cancelling the reservation of coal, which had the effect of making the grants prior to that date contain no reservation of coal. In the Act of 1861 there were two different conditions under which lands were granted, one simply where you took up the land, and had to reside upon it for a certain number of years, when you did not get the coal or minerals; and the other called a mineral conditional purchase, where you had no residence clause, but after expending £2 per acre in mining purposes other than gold, and paying £2 per acre, you got a grant of that and with no reservation of the minerals.

3478. Does a large extent of the land containing coal deposits in New South Wales belong to private owners, under the system of grants which you have described to us? As far as I know, I should say that until within the last few years all the coal mines worked in New South Wales were held by private owners, either purchased under the Orders in Council, or else bought as a mining conditional purchase. I should think perhaps very nearly the whole of the land worked for coal was worked by private owners till within the last few years.

3479. Are those coalfields which are held byprivate proprietors worked by the proprietors; or are they let? In many casee a company has been formed, and the property belongs to the company who have bought the land right out. In other cases the owners of the land have leased it on a royalty of so much per ton. The royalty varies from 6d. to 1s., which, I think, is the highest I know. They pay 6d. or 1s. per ton on all round coal, and on small coal I think 4d. is about the general price. That is the royalty paid to the owner of the land in fee.

3480. Is it customary to reserve what are called fixed rents also? Yes, nearly in every instance. The fixed rents vary. I know one case in which, I think, the fixed minimum rent is £2,000 a year. I know another where the fixed rent is £1,200 a year. I have known one as small as £450; but in that case I consider the fixed royalty was a very small one. I do not know any lease issued by a private person which does not contain a royalty.

3481. Could you give us the acreage in those cases? I could not tell you the exact acreage, but I think the royalty which I speak of as being £2,000 was for over 1,000 acres of land.

3482. It was about £2 an acre then? Yes. I have never known the principle fixed according to the acreage; it has generally been a matter of arrangement between the intending tenant and the landlord who has said, "I must have a fixed rent of so much, and I will not let it to you without."

3508. I think you said that it was not till 1884 that the Act was passed giving the Crown the possession and control of the minerals? In the 1884 Act there was a clause to say that for the future all minerals should be reserved in all grants: that was practically doing away with the M.C.P. clause, as it is known in the colony, which authorized persons to acquire the minerals by paying £2 per acre and expending £2 in mining other than gold.

3509. Can you say what led to the change from private ownership to state ownership? The colonists thought that, seeing that a large royalty was derived from these people who bought the land, they ought to have the right to reserve that for the state, that was the reason of it.

Richard Harris Williams, past president of the Mining Institute of Civil Engineers :

3833. What knowledge have you of mining in Cornwall? Very considerable; I have been engaged all my lifetime.

3864. . . I think the dues should be paid on the profits, and not on any given proportion of the mineral raised. Suppose that two mines are working side by side, or within the immediate district; one returns, we will say, 20 tons of tin per month, and leaves a profit of £500 per month; the other returns 20 tons of tin per month, and has to call upon the shareholders for £200 per month to keep it at work. Now, you see that the payment of dues there comes very hard on the parties who are paying more for the tin than it is worth. That arises from this fact that in the one mine, which is making a profit, the grade of ore is very high; in the other mine, which is making no profit, the grade of ore is very low, and it is only the hope of meeting with a higher grade of ore that this work is continued; the dues do come there with very great and severe pressure on the proprietors of the mine—unduly so, and help to crush them entirely, because it is the exhaustion of the shareholders' resources that shuts up the mine.

3889. Could you define what the profits are; do you think there would be any difficulty in defining them? No, I think not. I think that, if the books are fairly audited, there ought to be no difficulty whatever,

3890. The effect of it would be practically to make the lessor a partner? Yes, he would be a partner; but the lessor is the benefited party when often the adventurers lose all their money. First of all, there is the dead-rent. I have unfortunately worked mines that have returned so little mineral that the dues have not covered the dead-rent—the dead-rent being the full agricultural value of the lands occupied—besides paying £100 for what was damaged. Then, again, the people are employed, and the land and the houses become more valuable around the mine, and the markets in which the lords are generally interested more or less are better; whereas the shareholders lose the whole of their capital. Under conditions where the mine is, we will say, worthless, it would relieve the Cornish mines a great deal if the dues were paid on profits. If that relief was granted to mines or obtained by the mines a large number of mines which are now shut up would, perhaps, be re-worked, and it would revert to the lord's interests as much as to those of the shareholders.

3891. What proportion of the profits would you consider a reasonable rate of dues? I think that is a matter which should be well weighed over in all its relations, taking the average of the mines in the county which are paying profits. I think if there was a uniform rate laid down it would be only fair that that should apply to the whole of the mines, inasmuch as if the mine is paying an excessive profit over the outlay the parties associated in that mine are very often in a mine that is paying nothing. I look upon it on a broad principle, as if all the minerals belonged to one lord in the county.

3892. What should be the proportions? I think that ought to be well discussed and weighed over, but I should have thought that a fifth, or something like that—a fifth or a quarter part of the profits.

3893. Of course the lord would then be subject to good or bad management? That would be a very wholesome thing, because bad management would not be allowed; that would be good for the county, for the lord would come in to help to remedy the evils which ought never to be allowed to exist.

4102. Do you, therefore, think it would be fair for a landlord to be entirely at the mercy of his co-partners, as they would be in this matter; he holding, say, a fifth? No. I do not think so. I think the landlord should be fully protected in every way.

4103. In what way would you protect him? The landlord should be paid for the land at its freehold value, and 50 per cent. over, then he would have his dead-rent besides. Then you see the people are employed around him; his tenants are employed. Then, as far as the dues are concerned, the books would be audited, and the landlord would have full power to insert any clause relative to the management of the mine, or to the working of the mine.

William Rich, agent for the South Condurrow Mines, Cornwall:

4141. Did you hear the suggestion made by the last witness that it would be desirable that dues should be paid on profits? Yes.

4142. That is not a matter which this Commission can take into consideration, but at the same time we should like to hear what you have to say upon it? I do not think it is workable.

4143. Why? Because it would lead to an interference on the part of the lords, and it would be sure to create diversity of opinions, to say the least of it. I think it would be hardly fair to the landlord; I do not agree with it at all.

4179. Could you give me the reasons for which you think it would be unjust to the landlord to pay him a share of the profits? I should say that we have got trouble enough now with the landlord. I think the landlord would have a perfect right to interfere, and it would lead to further disputes about the profits, and how the mine should be worked.

4180. Would it not be to the interest of the shareholders to work the mine economically? Yes, certainly; but then there might be a difference of opinion with the lord upon that.

4181. If there was a difference of opinion, and if he had a quarter of the shares, would you not think it fair that the opinion of those who had the majority of the shares should prevail? Certainly; I should not like to give him a quarter part of the profits.

4182. Whatever it was, a quarter or a fifth? I do not believe in working with the landlord on the profits. I think the landlord should have certain fixed dues while the mine remains to be developed; let the shareholders take the profits, if any, and the losses.

4185. Do you think it is fair that the landlord should get a rent when there is no profit made? I should say so, a small rent, or a royalty which is the same thing, and then I would increase that royalty as the profits came up. You must look at both sides of it fairly. I do not think a low-letting royalty will hurt the mines in Cornwall. I do not think that, say, 2 per cent. on the gross produce until the mine pays would hurt them.

4186. Would you leave the fixing of the amount of royalty to arbitration? No, I should like the Legislature to step in there, and then let us get the best terms after.

4188. Supposing the parties differed as to what the amount of the royalty should be, would you let the court of arbitration fix the amount of royalty then? Yes, I have no objection to that.

4189. You do not think that that would be too great an interference with the right of the landlord? No; if the Legislature were to fix a low amount of royalty we should then know exactly where we were.

4190. But you approve of leaving it to the tribunal to fix the royalty? Yes, but not for any new ground, for mines that have been already worked. I do not go so far as to approve of it in the case of breaking up new ground. I speak of mines already worked, where the surface has been already opened and destroyed.

4191. Do you think that that would be quite fair to the landlord? I think so.

4192. Supposing the arbitrator said he is to get no royalty until a profit is made? I say I would limit it while the mine is developing, but he should have 2 per cent. at least.

4210. What standard would you take by which you would vary the dues as the mines improved? I should say that if we had to pay two per cent. during development, while our money is being expended, and then increase the dues to four per cent. when there are profits and dividends paid, and continue that four per cent. until all the capital is paid back, and then give the landlord five per cent. dues—I am speaking of the gross produce now—that would be about fair. I think we could stand that in Cornwall, and that it would be fair both to the landlord and to the mines. In no case should the dues exceed five per cent. of the gross produce.

4211. I am not altogether quite clear as to the exact meaning of the gross produce? That is everything sold out of the mine; the gross produce, regardless of cost; everything we return, whether it is sand, or tin, or stone, or ores or clay, everything we sell out of the mine, regardless of cost, is the gross produce of the mine.

Charles Fludyer, lessee of Violet Seton and Great North Seton Mines, Cornwall:

4342. You have said that you think the state should own the minerals of the country? Yes, I do.

4343. In answer to a question, you said you did not think it practicable to get the ownership conferred upon the state at present? I think not.

4344. Do you think it will be practicable at some time? Yes, I do.

4345. Have you any suggestion to make regarding how this notion of yours, to confer on the state the ownership of the minerals, could be made law? It depends upon the House of Commons a good deal, I think.

4346. In saying that you would give a fancy price to the surface owner for using his land to get that mineral, I presume yot do not mean us to understand by paying this fancy price you were recognizing his right to the minerals? I do not think he had any right to the minerals at all.

4347. Then you merely meant, by assenting to give this fancy price, that you would pay the price in order to compensate him for taking compulsory powers over his land? To compensate him for the compulsion; that is it.

4348. Then upon the state acquiring the minerals, I presume you would give no compensation to the present holders of the minerals? No.

4349. Would you give compensation in no case? Of course circumstances alter cases; there are cases, perhaps, of individual hardship which should be taken into consideration.

4350. Could you give me any idea of how you would deal with cases which the present holders have purchased during, say, the past hundred years? I should say that there should be some tribunal to settle that.

4351. Then your suggestion is, that an Act of Parliament should be passed, establishing a court for the purpose of deciding where compensation should be given and where it should not? Yes, in cases of individual hardship.

4352. I understand you to say, in answer to that question, that you would leave this court, instituted by an Act of Parliament, to decide what would be cases of hardship and what would not be cases of hardship? As Mr. Pendarves mentioned, there are men who have purchased a portion of the mineral rights, but have not any rights to the surface; such cases occurring within a certain stated period, say 100 years, should be considered.

4353. What about those who sold the surface, reserving the minerals under it? I would not give them any compensation—good gracious, no.

4354. You would not? Oh, dear no.

4355. You say that you would not compensate those whose families have held minerals for a number of centuries? No, I would not.

4356. Then you say they have no right to get compensation? I do not think that a landlord has a right to the minerals any more than he has to the rays of the sun or the fishes in the sea, or the air we breathe.

4357. If you say nobody has a right to the minerals, do you think anybody can sell a right in minerals? Well, they have done so, of course.

4358. If they had no right to sell, how could they sell it? It is the law of the land now that they should have these mineral rights, but I do not think it is a proper law.

4359. Then it is not as a matter of equity that you would compensate these people, but because they have taken the minerals from parties who have had no right to sell under the existing law; because they have made a purchase as they believe according to law? Yes, because they have made this purchase according to law within the last 100 years; the court should take into consideration the case of those who had made such purchases.

4360. Even though the parties from whom they made the purchase had no right to sell? Yes, even though they had no right to sell.

4405. Do you think the state, when it was owner, would treat its tenants as the generous landlords do theirs? It would do the same as Lord Robartes, I think.

4406. It would not try to get the best terms it could, but it would act charitably towards lessees? I do not know about acting charitably, but I think it would act fairly. I think it would be compelled to act fairly, because there would be a court, and that court would be answerable to the House of Commons.

4407. You do not think it would be its duty to make the best terms it could for the community, its *cestui qui* trust? I think it would be its duty to act fairly between the country and the man who lays out his money upon the development of the country, and lays out his money in the employment of the poorer class.

4408. Do you think it would be possible for the state not to think of commercial considerations, but to think simply of giving satisfaction to the lessees of its property? I do not go so far as to say giving satisfaction to the lessees, but I go so far as to say that it would do what is actually fair and right between those who invest their capital in developing their country and those who own the country, which, in that case, would be the people of the country

4409. Do you think you can arrive at what is a satisfactory term between the lessor and the lessee in any other way than by the bargain of the market? Yes, I believe that in those cases a court would settle the matter more fairly between the parties.

Josiah Thomas, member of the Commission, and manager of the Dolcoath mine, Cornwall:

4417. Can you tell us the history of the Dolcoath mine; how long has it been working? It commenced working in 1799 and has been working continuously ever since; it was formerly a very rich copper mine, but in the last 40 years it has been worked principally for tin. The lode in the upper workings produced copper, but with the depth the ore changed from copper to tin, and during the last 30 years we have not been raising any copper at all; it has been entirely tin.

4418. When would your last lease have expired? The last lease for 21 years would have expired in August, 1887.

4419. I believe the shareholders of Dolcoath have some complaint to make, or think that they have some complaint to make, in connection with the negotiations for the renewal of the lease, is that so? Yes; the complaint was this, that they received different treatment from that previously received by any set of shareholders in Cornwall.

4420. Will you explain the circumstances and the grounds of their complaint? About 4½ years before the expiration of the lease the shareholders applied to the lord to ask on what terms he would give a fresh lease for 21 years, and as the mine was so deep (being nearly half a mile deep, or over 400 fathoms) and the price of tin for some years had varied considerably, the shareholders thought that one-fifteenth, which they were then paying, was a very high rate of dues, and asked the lord to grant them a new lease for 21 years at one-eighteenth; that is one-eighteenth of the gross produce. After a few days a reply was received from the steward. This was the first written communication the shareholders had from him. The first thing he said was, and this is a quotation from his letter, "You must bear in mind that at the end of about 4½ years Mr. Basset will have this valuable property to deal with in any way he chooses, and that he is not bound to renew the lease at all. Mr. Basset will accept a surrender of the existing lease as from January 8th, 1883," that is 4½ years before the termination, "and grant a new lease for 21 years," which would virtually be 16½ years, "reserving one-fifteenth dues together with a quarter part of the future profits to be paid every 12 weeks until, exclusive of dues, he has received £40,000. You must consider these terms as final. If they are accepted Mr Basset will require a notification to that effect not later than the 1st day of April; if they are not accepted the negotiation must be considered as at an end and the lease must then run out." That, as I have said, was the first communication we had from the steward on an application for a new lease. He wanted us to resign a lease then, which had 4½ years more to run, to take a new one for 21 years from that date, pay one-fifteenth dues, which is what we were then paying and £40,000 in addition. When those terms were announced to the shareholders and afterwards to the public there was a great commotion throughout the country. Such terms had never been heard of before. Many of the shareholders in Dolcoath had also large interests in several other mines upon the same lord's lands which were making heavy losses, and they naturally thought the lord would have taken that fact into consideration in granting a new lease for Dolcoath. Dolcoath was a prosperous mine, as you may see by the returns which I have sent in.

4421. Do the returns show the profits? Yes.

4422. What were they? From the beginning of 1799 to the end of 1889 they were £806,217, and we had paid to the lord during that time £259,579.

4423. Do you refer to the profits divided? Yes; the profits divided amongst the shareholders,

4424. Will you pursue the history of the transaction? There was a great stir in all the neighborhood. Then there was a great deal of negotiation. A committee was appointed by the shareholders, consisting of some gentlemen outside the executive, some very influential gentlemen in the county, Mr. Thomas Bolitho and some others, and they had several meetings with the lord and with the stewards. After about two months' negotiations the best terms that could be obtained were a new lease for 21 years after the termination of the then existing lease (that was 4½ years more than the first offer), a royalty of one-fifteenth as before, and a payment in cash of £25,000. Those were the best terms that we could obtain, and we had to pay that money.

4425. Did the transaction have any effect upon mining enterprise in Cornwall? Very much so.

4426. Why? The outside shareholders appeared to have lost their confidence in the lords. I have known some instances of shareholders residing outside Cornwall selling out their interest in Cornish mines; some of them have gone so far as to say they would never take a share in a Cornish mine again if they were to be so treated by a lord.

4427. The reason being, as you explained before, that previously leases had been renewed as a matter of course? Certainly.

4428. And, as I understand, without a fine? Without a fine. This was the first fine; they did not call it a fine, they called it a premium. Fine or premium, call it what you like, we had to pay £25,000, and that was the first instance in Cornwall, that ever I heard of, of a fine or premium having been enforced.

4429. Do you mean, as a matter of fact, that leases in Cornish mines have been invariably renewed upon the same terms as before? No, I would not say always upon the same terms. That would depend somewhat upon the value of the mine at the time. I mean that they have always been renewed as a matter of course, without any question.

4430. And without a premium? Without a premium. This is the first and only premium, so far as I know, that has ever been paid in Cornwall.

4435. Then, as I understand it, the practice has been that although the royalty was subject to revision on the renewal of the lease, yet no premium had ever been asked for before? Never before; it was the first instance that I ever heard of. The way in which the steward put it irritated the shareholders very much; it shook their confidence, because he stated plainly, Mr. Basset "is not bound to renew the lease at all;" almost intimating that he might take it into his own hands.

4436. And the words created the greatest uncertainty and doubt? Yes; they shook the people's confidence, because there never had been any question before about the leases being renewed, and they had never thought it possible that a lord would take a mine into his own hands and work it.

4437. As a matter of fact, according to the legal construction of the lease, was the agent of the lord correct in saying that he was not bound to renew the lease? Yes; as the law now stands, undoubtedly, the lord can say at the conclusion of the lease, "Will you please leave the mine, I am going to work it myself." There is no law to prevent that.

4438. That is to say the adventurers or the shareholders, when the lease was made originally, did not request that a provision should be made that the lease should be renewed at the expiration of 21 years, upon terms equitable or otherwise? No; because it was always the custom of the country for leases to be renewed whenever desired.

4524. Will you tell us again what was the capital expended by the company in developing the Dolcoath mine? In the printed return I gave it as £45,252.

4525. What had the lord done towards the development of the mine, what service, what outlay, or what anything had he done for this amount of money received from the company? Nothing beyond this: in the period that I spoke of between about 1846 and 1853, when the mine was changing from copper into tin, the lord gave up some dues which he might have lawfully demanded. He did not contribute any money, but he did not take some dues which he might legally have taken.

4526. That would reduce the sum which he would receive? The sum which he was legally entitled to receive.

4527. Did he spend any money? No.

4528. Did he help the company to develop the mine in any way? Not at all.

4529. Still he got this amount of money? £259,579.

4530. If Mr. Basset had taken the mine and laid down a precedent in that way would that have prevented capital coming into Cornwall? Of course it would. Who would think of speculating a lot of money on a mine with only a 21 years' lease and with a prospect of being turned out whenever the lord chooses to do so? Nobody would speculate any more on such terms as those. It would stop all speculation in the county. As you may probably know, having visited Cornwall, metalliferous mining is very different from coal mining. We may work a mine for 15 years out of the 21 before we meet with anything of value.

4555. Do the lords in Cornwall, to any extent, conduct mining operations themselves? Not at all.

4556. Therefore mining in Cornwall has been developed altogether by capital found by other persons than the lords? Entirely.

4557. Excepting so far, the lords may be shareholders? The lords may be shareholders, but there is not very much of that now.

4558. Speaking generally, the capital sunk in mining enterprise in Cornwall is found by those who are not lords as well? Yes.

James Barnes, member of the South Wales and North Wales Colliery Owners' Associations :

5210. During the past five years in the Monmouthshire and South Wales coal trade, what proportion of the selling price have you paid to the landlord? That is a very fair question. The landlord has had from me on an average over 14 per cent. of the selling price. I will undertake to say that since we have had the Nantyglo leases it has been 14 per cent. on the value of the coal.

John Bell Simpson, member of the Institute of Civil Engineers, and past president of the North of England Institute of Mining Engineers:

10,203. Have you worked cut from that return any estimate of the royalty for the whole of the coal mines of England and Wales? Yes I have applied the whole output of the country to this return; the whole gross estimated rental of the whole of the coal mines is put down in this return as £3,601,386, and if we take the output as given by the Government inspectors at 153,596,360 tons for the same area, we arrive at the average rental of 5.63d. per ton, but as this is said to include in many instances fixed machinery and other things not chargeable with royalty———.

10,204. On the assumption that it is charged with royalty, but not properly termed royalty? Royalty, but not properly termed royalty; it may be taken as exceeding the average royalty rent of the country, and we should probably find that if we had accurate statistics that even with all the easements hereafter referred to, the total rate throughout the country does not exceed 5d. per ton. That is based upon those figures.

10,176. You have collected information showing what the royalty rate per ton upon coal was between the years 1705 and 1804? Yes, I had the means of getting the terms of 53 leases between those periods, and I find that the royalty rate was about 4d. per ton on the output.

10,177. And from that time till now what is it? There does not seem to have been much variation that I can make out.

Stanislaus John Lynch, Senior Land Purchase Commissioner under the Act of 1885 (Ashbourne Act) :

11,768. The law in Ireland is the same as the law in England in respect to giving the property in the minerals to the freeholder of the surface? Yes, but in Ireland we have a very considerable number of estates, especially in the north, and in portions of Kerry too, which are held by the present landlords under fee farm grants and leases for ever, sometimes there being two or three superior leases or grants between the owner and the fee simple one above the other, and in these the mines are usually reserved, that is royalties are reserved. In such cases of course we would only convey what was the immediate grantee's interest excepting the mines.

11,780. Can you give us any idea as to what number of sales have taken place under the Ashbourne Act in those districts which you consider to have mineral capabilities? Have there been a large number of sales already? Very large sales. Now, in the Queen's county we have very large sales adjacent to those coalfields.

11,781. Have you seen any probable difficulty in these sales having taken place in the event of the minerals becoming more worked? In my opinion the minute subdivision of land and the vesting of the royalties in small proprietors would effectually stop any development, or certainly impede any development of the mineral resources of the country. I think the difficulty would be this: In the first place the majority of the small tenants have not the intelligence to see the advantages to them of such development. Then, again, when they become proprietors they become naturally conservative about the rights which they had purchased and which are really their agricultural holdings, and they would perhaps think that it would interfere with the working of their farms.

11,795. Have you considered how the difficulty which you have pointed out in respect to the small patches of land which have already been bought could be met by legislation? In my opinion any future legislation which would vest in the state or in any department of the state the mines and royalties would have to be to a certain extent compulsory so far as when there was an agreement for the sale of the entire estate; the landlord would be bound to deal with the Government or the state authority for the royalties. Then again, I think the power could be taken to acquire from the existing tenants at whatever was the value any mineral royalties that exist. You must first ascertain that they are there; they can suffer no damage; they must get compensation.

11,796. What do you mean by tenants? I mean, of course, tenant proprietors.

Charles Stewart Parnell, M.P. for the city of Cork :

12,667. Can you give us any idea of the probable development of the mineral resources of Ireland generally, or of your own county in particular? The mineral resources of Ireland, generally speaking, are extremely limited, but there are places where mines could be started and developed with every prospect of success. These places would require to be carefully selected and worked with judgment owing to the nature of the case and the fact that the mineral resources of Ireland are so limited and, comparatively speaking, poor. In some cases the mining industries of Ireland have been kept back by the action of the owners of land in refusing royalties and refusing to let their royalties on any terms whatever. In other cases the mining industries have been kept back by excessive royalties being demanded. I myself know of one case in Wicklow where I wished to open a mine in the Wicklow mountains far away from any cultivated land, and where no surface damage could have been by any possibility done. It was an iron mine. I applied for the royalty and the owner, a gentleman of considerable landed property in the county, a neighbor of my own, declined to allow any mines to be opened on his estate on any condition whatever. In another case where I had leased the royalty, the royalty amounts to more than the profit and renders it impossible to open or develop the mines.

12,680. You are thoroughly acquainted with all the Acts relating to the purchase of land in Ireland? Yes.

12,681. And you are aware of what has occurred under Lord Ashbourne's Act and the extension of Lord Ashbourne's Act? Yes.

12,682. Have you any view as to the possible effect upon the development of the mineral resources of Ireland by the sub-division of land that may be created to a very large extent under the operation of these Acts? I do not think the multiplication of owners contemplated by these Acts will render the development of the mineral resources more difficult; on the contrary I think these Acts will facilitate its development because I think the small owners will be more easy to deal with than the larger ones; at all events probably the majority will be more easy to deal with and the result so far will be beneficial. But undoubtedly there will be many cases where it will be impossible to approach the new owners or to obtain from them fair terms as regards the development of the minerals; and I think the principle is certainly a false one of allowing the mineral rights to be owned by the surface owner, and especially in the cases to which you referred. It is scarcely within the intention of the Legislature to give the mineral rights to the owner of the surface. I think it is only the intention that the agricultural and surface rights should pass. I think it would be very desirable if the Legislature were to take powers to put these royalties in the hands of some local authority instead of transferring them to the future owners. If we had county boards in Ireland that would be the authority that would be indicated to my mind as being the most suitable to look after such a question and to own the royalties which they might let and which they then would be able to let and deal with on a systematic plan, and that the proceeds of these royalties should go to the reduction of the county and other rates, and they might be used for educational purposes.

12,683. Therefore your view would be that the ownership should be in the state, but the public generally should have the mineral rights when those purposes that you mention are met? Yes, I think the local authority in every case would be the best fitted to deal with the mineral rights when acquired.

12,684. When you say acquired them, your view I take it to be is that in the settlement of this purchase under the Ashbourne Act, neither the landlord nor the occupier should have anything more than the surface value of the land—the mineral value does not come in? Quite so.

12,685. Therefore there would be no hardship to either side if the mineral right was reserved to the public. Would that be expressing your view? I think it ought to be clearly reserved to the public. I think that would be the most advantageous while it would be more easy to deal with the new owners than the old owners.

Andrew Sharp, secretary and agent for the Coal Miners' Association in Cumberland:

13,379. Have you ever considered the question whether the royalties ought to belong to the state and not to private individuals; did you ever think of that? Yes.

13,380. What is the opinion generally upon that, do you think? There are a great many who have purchased them and who have legal claims, and I do not think we could hinder that by taking a sweeping view and taking things from people without proper compensat on.

13,381. You would give proper compensation? Yes, I think they ought to be compensated to some extent.

13,382. Have you ever thought whether you would wish the whole business to be managed by the Government or not? I think that the royalties ought to be managed by the counties. I believe the county council as now appointed would be the best authority to have the dealing with the royalties similarly as they deal with the assessment of rates. They know the local circumstances of every county.

T. F. Brown, mining engineer, chief mineral inspector for Her Majesty's Commissioners of Woods and Forests, and Deputy Gaveller of the Forest of Dean:

13,950. What governs the royalty? Is it the quality of the coal or the distance from the port, or what? There are a great many circumstances. One element is the time at which the royalty is taken. For example, if it is an entirely undeveloped district, without railways and so on, a lessee would perhaps obtain a royalty on exceptional terms; but apart from that, where the district is developed the royalty depends on a variety of circumstances: whether the coal has to pay wayleave, if it is very deep or not, whether the quality is good or the roofs are good or bad and so on. In fact, practically all the circumstances that go to make a colliery more or less profitable operate in fixing the royalty. The element of competition also enters into the calculation.

14.019. Have you many arrangements for a sliding scale in Wales? Wherever we can we introduce the sliding scale, but we find the lessees object to it.

14,020. Why? For this reason, that the present system really operates in their interest as a sliding scale which does not slide upwards. When a new coalfield is acquired, it is acquired on a fixed royalty. Then the lessees work out the best seams and then they go to the lessor and say: "Now, we cannot continue to compete with our neighbors, we have worked out the best coal and we must have a reduction," and the lessor has to give a reduction; so that practically there is a lessee's sliding scale in operation in South Wales which only slides in favor of the lessee.

14.979. I think you said that you were now mineral advisor to the office of Woods and Forests? I am.

14,080. That is to say, in respect to those mineral properties which are in the hands of the Government and are managed for the Government? That is so. I also act specially and have done for 25 years for the Crown in the Forest of Dean.

14,081. I believe the customs of the Forest of Dean are totally different to any other customs almost in the world? They are very peculiar; the tenure is an exceedingly peculiar one.

14,082. Is it not in the nature of a privilege, giving mineral rights to persons born within a certain area? Yes; workingmen born within a certain hundred have power if they have worked a year and a day in a mine to come to me to be registered, and then they become what are called free miners and they are entitled to apply for a grant of an area or a royalty of coal or iron, the first applicant being entitled to a grant. The area of the grant is within the control of the gaveller and deputy gaveller, but the royalties in case of dispute can be settled by arbitration. The royalties only remain in existence for 21 years, when they can be readjusted either on the application of the Crown or on the application of the galee; and in case of dispute it may be referred to arbitration.

14,083. What is the principle on which the royalty is assessed? The basis of the maximum of the royalty is the right which the Crown has to put in a fifth man to work after the mineral has been won. The effect of that is that as regards a shallow mine or a shallow colliery the free miner secures a considerable interest; but as regards a deep mine, where the capital outlay, is great he has to give up or will have to give up the whole of his interest to compensate the person who sinks.

14,048. What happens with regard to those rights which the free miners obtain; do they work them themselves? No.

14,085. What do they do? Immediately a free miner acquires a right over an area he goes into the market and endeavors to sell on the best terms he can get to a man who may be either a speculator or a man of capital who is going to open; if he is a speculator he holds it with the hope of being able to sell to some one else at an improved price; if he is a person who puts his own money in and is going to work the mine of course he proceeds at once to work.

14,086. In point of fact he is in very much the same position as a concessionaire would be in Spain or in any of those countries in which the minerals belong to the Crown and are given to concessionaires on application? Yes, that is the simple operation; the result has been most fatal to the development of the Forest of Dean.

14,087. Will you explain how it has been so injurious to the development of the Forest of Dean? To begin with, the minerals were sold to speculators; the speculators went to the banks for loans on the security of these properties; the banks I suppose had not appreciated the unsoundness of the properties, but the time came when those minerals had to be opened under the rules and regulations or they had to continue to pay rents without any result. As time went on the banks became aware of the unsound nature of the property, and they of course brought pressure to bear and the result was a general collapse of the whole thing.

Rossiter Worthington Raymond, Ph. D., secretary of the American Institute of Mining Engineers:

14,278. For how long have you been secretary of the American Institute of Mining Engineers? I have been secretary of the American Institute of Mining Engineers since 1884, and I was formerly president of that society.

14,279. I believe you are a mining engineer? I have been a mining engineer in active practice for twenty-eight years.

14,280. You have also been a government inspector of mines for many years? Yes, I was for some eight years the government Commissioner of Mines and Mining in the states and territories in and west of the Rocky Mountains.

14,281. You are editor, I believe, of the *Engineering and Mining Journal* of New York? I was editor of the *Engineering and Mining Journal* of New York from 1866 until some time last year.

14,282. And you are largely interested in mining undertakings? Yes, I am the consulting engineer of the house of Cooper, Hewitt and Company of New York, which is largely connected with the mining of iron and coal, and with the manufacture of iron and with the manufactured forms of iron.

14,316. . . The system of mining—that is to say as to whether the miner, the actual operator of a mine, owns the land or not, is, I should say, something like this: Most of the important mines on the public domain, the gold, silver, copper and lead mines on the public domain, are operated by persons who have bought them from the original patentee, or who have bought the original possessory title and have got it patented. Generally if you wait until the mine is developed so that you know it is worth putting money into it you pay something for it, and what you pay for it is a sort of capitalised royalty, but you do not pay it to the government; you pay it to the man who was lucky enough to have got that thing from the government at five dollars an acre. He raises the price from five dollars an acre probably to $50,000 if he happens to have the luck to find the thing, and if you pay him $50,000 for it apart from the money you put in then to the mine with machinery and so on, you are paying what you are willing to give in a lump sum instead of undertaking to take it from him for fifty or ninety years, and pay him so much a ton on the ores you get out. There are, however, a great many cases of the public lands in which a regular tonnage or percentage royalty is paid. Those are generally cases in which the first adventurers have lost money; they have made a mistake or have had bad luck; or, after having made dividends for a while, they have got into a poorer part of the mine and stopped paying, and not wishing to put up any more money they call a halt. That is the case with a great many of the English companies which are operating in our country. One company, of which I am now president, and which was originally the purchaser of patents from the patentees——

14,317. I presume you use the term patentees in the sense of grantees? Yes, grantees under the patent. We call them patentees. Those grantees sold to us for a large sum of money, and that was our amortization or a lump sum for a future royalty. Well, we had got a great deal of money out of the mine I am thinking of now——

14,318. What class of mine was it? It was a silver and lead mine. We had taken out something like $5,000,000, that is £1,000,000, out of the mine, and paid a good many hundred thousand dollars in dividends. We had exhausted the particular beds of ore that we knew anything about, and we are now exploring to some extent on our own account, but to a still greater extent we are allowing other people to explore upon lease. They come along and say they would like to spend their money. I feel that we have not got enough to waste and I let them. Now, these things are arranged with no other authority to settle the terms than a free contract between the parties. The terms will vary very widely according to the risks and costs of the operation. A man comes along and offers to mine in a place where I do not think he will ever find anything in this world, but I am willing to have it explored, only I hate to do it with my company's money. I say to him, If you will mine there you need not give me but ten per cent. of what you get; you may have the other 90 per cent. The next man comes along and he wants to mine in a place where we both of us know there is ore, and I simply let him have it on lease rather than go to the expense of keeping up my organisation to work that particular part of that mine myself, and I make him give me 25 per cent., 50 per cent. or 75 per cent. of the gross proceeds.

14,319. What lease do you give? We generally give a lease ranging from six months to two years; nothing much longer than two years. That, however, is simply owing to the peculiar state of this particular class of cases, namely, companies owning a property who do not wish to surrender the control of it, who merely for the present, until something can be found, are willing to let somebody else spend the money and to make it an object to find the mineral.

14,320. That is a sort of search note then; it is only a lease for searching? That is what it is; but we are obliged to make it long enough so that if something is found the adventurer who takes a lease will have time to recoup himself. We say: Here, if you can find a good thing you can make enough of it in a year. In such a case as I am describing the owners would not give more than a year unless crowded to it by inability to find lessees who would take the adventure on such terms. I mention such cases only as examples apart from the offer of a lump sum in lieu of royalties, which may be perhaps held to be in the nature of the first payment of a purchaser of a mine. Apart from that I say royalties are only paid as such in the west, generally for what we call "chloriders," because they go round picking out the rich chloride of silver ore from a mine after it is otherwise exhausted, and they generally get hold of the companies who have seen better days and are in trouble, and who temporarily go into that system to keep things going. In the east on the other hand our iron lands and our coal lands are almost universally worked upon a regular system of mining leases under royalty. Such a lease is usually for twenty years at least.

14,321. The grantor being the person who owns the surface and the minerals? The grantor is the person who owns the surface and the minerals with it. On the regular English common law the boundaries so let are the vertical boundaries.

14,322. That system is exactly akin to the English system, is it not? So far as I know, barring a great many long words in an English lease. I think we manage to get at it in shorter language, but it is precisely the same condition. We have what you call short workings; we have a different name for it, but it is the same thing: that is to say a dead rent or mine rent is fixed as a minimum. The way in which we usually express it is: That the lessee (we will suppose now that we are dealing with an ironstone mine) agrees to pay quarterly or semi-annually at the rate of so much a ton of iron ore removed from that property; and he also further agrees to take away every year or pay for so many tons. If he does not take them away he pays for them. Then it is further provided that if in any year he does not take as many tons as he has paid for, he may make up that deficit at any period during the term of the lease. There is a little difference here, I think, as compared with the general practice in England. You have what are called "breaks" in the lease; a deficit must be made up within three years or four years, or five years possibly; we give the whole term of the lease; but this clause provides that the minimum mine rent shall be paid. I cannot make up my short workings at the cost of the mine rent. In any one year I must always pay the minimum rent, and that being done I am entitled, if I choose to do so during the period of the lease, to carry away as much ore from the property as I have paid for.

14,323. I think you were going to tell us what rents are usual? The average royalty in the United States is about 2s. per ton on magnetic iron ore and somewhat less than that on hematite ore because our hematite ores, which are mainly the brown hematites, are not so high in iron as our magnetic ores. Our magnetic ores average over 50 per cent. up to 66 per cent., and our brown hematites run from 28 or 30 to 40 or 45 at the most.

14,324. As regards coal, what are the rents? There are three classes of coal mines in our country which really have to be distinguished in this matter. The first is the anthracite coal, which has its own system both of mining and of wages and royalty. The next is bituminous coking coal which will make coke; and then the third would be all the other coals, including the non-coking bituminous coals and the lignites, which are merely steam fuels and domestic fuels. With regard to the third class, the lignites, which lie mostly in the Rocky Mountains in the west, they are not mined under royalty; they are mined by parties who have taken up the land because the government sells the land very cheaply; and if there is any royalty paid there it is in the form of a lump sum by practically a sub-purchaser, who purchases from the original locator. With regard to bituminous coals, I think the royalty ranges from about 5 cents (that is 2½d.) to 10 cents a ton. I know that I am mining—at least our house is interested in mining—large amounts of bituminous coal at a royalty of five cents, but I believe they are considered to have a very favorable lease. They took hold of a property which was neglected and producing no income, and this low royalty, coupled with an option to purchase, was given to them as an inducement. I judge therefore that that may be a low figure. With regard to the anthracite, the royalty is based upon the class of coal which, as you know, is very carefully crushed, cleaned and sized before going to the market, and the royalty is calculated upon the amount which is actually sent to market, not upon the amount in the ground and not upon the amount at the pit's mouth, and not upon any coal which is consumed in the mining operation itself. The latter is, however, usually waste coal; because they want to sell all that they can and they burn the refuse. Now, my impression is that these classes range from 5 cents, that is 2½d., which would be on the smallest sizes up to perhaps 40 cents a ton on the best quality and the finest and most expensive sizes of coal in the best collieries. With us the royalty always settles itself according to special advantages. The lowest royalty is the royalty that must be paid or else the landowner himself would not care to let the mine be worked. On the top of that you have all these higher royalties coming in to represent special natural advantages.

14,340. . . We cannot write down the rule which will fix the rate of royalty, nor can we safely interfere, under our conditions, with the free contract of the owner of the soil to hold on to or to segregate his mineral rights, and the only remedy for a possible inconvenience hereafter, such as has not yet been encountered, would of course be that the state (in that case the state of Pennsylvania) should assert a right over these minerals. Well, gentlemen, I do not know what conditions that would involve. With us it would mean confiscation and anarchy. If there is anything that the state has done, it has been to recognize the right of property in the coal as well as in the land, and it might as well go the whole figure with Mr. George, and assert ownership in the land and wipe out all private property, as to begin in that way. I suppose the safety of the people is the highest law, and that there might be a condition in which the state ought to do that or anything else most terrible, but with our conditions we have got to get a great many hundred years further on towards ruin before it will be necessary for the state of Pennsylvania or the United States to confiscate private property.

14,341. I did not like to interrupt you, but I should like to ask you a question in reference to your statement that the royalty was 5 cents, on an average, up to 40 cents. I should like to know what proportion of the selling price that was, if you could give it? I suppose you would say the selling price at the pit's mouth?

14,342. No, the selling price on which the royalty was calculated? The royalty is rarely based on the selling price. I have heard of a few cases in which anthracite royalties varied with the selling price at Mauch Chunk or New York. But in these cases, as in all others, the royalty is calculated on the weight—on the tonnage.

14,343. I thought you said that it was on the coal that is sold in the market? I said on the amount of the coal sold in the market. For instance, we have got underground so many thousands of tons of coal. Now, our anthracite mines are terribly wasteful by reason of the necessary preparation of the coal for the market. To us poor fellows who mine the coal, it sometimes seems as if the public were altogether too fastidious; they want it sized carefully and done up in tissue paper. We have to separate it into different sizes, clean it of dust and slate, and so on. Then, our system of mining in these very thick pieces is necessarily wasteful. We are improving it all the time, but we cannot work long-wall, and we have to leave pillars, and we often lose them by a crush. From first to last, as a general proposition, up to five years ago, at least (I hope we have made great improvements in the last five years), the general history has been that, out of 1,000 tons of coal in the ground in the anthracite thick seams in Pennsylvania, one-third stayed in as pillars and never came out; another third was wasted in the breaker, and got into the culm heaps with the slate waste; and the third was all that got to market. Now, no royalty has been paid on anything but that last third. If a smaller royalty could have been charged, and based upon all the coal hoisted to the surface, or even upon the measurement of all the coal underground, there would have been a pressure upon the lessees of our anthracite collieries to be more economical about the coal. But the coal they were wasting was not their coal. It was the coal of the landowner, and they were not charged any royalty upon it, and it was easier to waste it, and let it go; therefore we got no hold upon that thing to reform it, until these great companies, like the Philadelphia and Reading, and the Lehigh, and the other great companies mostly connected with railroads, began to acquire these lands for themselves either by the fee simple or by long leases, which made it worth their while to economise the coal. Since then we have begun to improve in economy, and we have made very great improvements within the last few years. That is what has saved the anthracite country from a tremendous waste and ruin. Up to the time when these great companies got the proprietorship and the colliery operators began to be at the same time practically owners, either by such long leases or else by fee simple, up to that time the anthracite region was exactly what Mr. Henry George would call paradise, but others might describe by a different name. The whole pressure of taxation and business interest was towards immediate product, and the land lay there wholly in the hands of occupants who gutted it and ruined it. It seems to me that that system is thoroughly illustrated as applied to mining land by the experience of the anthracite country.

14,344. Then as to this 2½d., what was it charged on—was it charged on the ton? On the ton. But that is the royalty I named on bituminous coal, not on anthracite.

14,345. On the saleable ton? Yes, on the ton sold.

14,346. What did the ton fetch? The trouble is to answer what it brought at the pit's mouth, and that, I suppose, is the place where you want it priced?

14,347. Yes? The difficulty is, that the price at the pit's mouth is determined by the price at tide water, minus the cost of transportation to tide water, and varies for every colliery according to the distance it is from the point where these prices are fixed. I would say, therefore, for our colliery, that it was an average colliery in the anthracite country, and that the average price obtained by us at the mine of all classes of coal——

14,348. On which the royalty was paid? On which the royalty was charged. They are ranged up and down, but it was about 1 dollar and 30 cents a ton, and the average royalty on that would have been about 25 cents.

14,349. I do not quite understand what that is? One dollar and thirty cents is a little over 5s.; 5s. 6d. we will say was the price for the average of our coal. Taking all the money I get at the pit's mouth for the coal, taking the weight and not minding the different classes, I think the average came out at 1 dollar and 30 cents, or 5s. 6d. Then the average royalty on that, if I had been paying royalty in that form on all the coal, and I was not, because my company had the fee simple (I am now thinking about the royalties actually paid around there), the average royalty on that would probably range about 25 cents, that is about 1s. out of 5s. 6d. One of our largest operators, Mr. Eckley B. Coxe, who mines something like 2,000,000 tons a year, I think, pays on the average about 1s. 3d. royalty on his coal, going as high in some cases, I am told, as 2s. or even 2s. 6d. per ton, where the mines leased have improvements. He has very fine coal, and he has splendid collieries and beautiful veins.

14,350. You are speaking simply of anthracite, I presume? This is all anthracite: with regard to the bituminous coal, I think, as I said before that probably 2½d. is a low average royalty. Much more might be charged, according to the location of the mine.* Upon limestone, used as a blast furnace plug, we pay, in the east, 2½d. per ton, or more, if the quality or the advantages of the quarry call for it.

14,358. Do your royalties ever vary by sliding scale? I do not know how that is in the bituminous coal country, but in the anthracite country I have never known of it, and with respect to iron mines I have known it in a few cases only. It is purely a matter of habit and custom, you know. They could be varied that way, and I have taken one lease myself in which they were varied that way.

14,359. Could you give us the terms of the sliding scale in that case? I cannot remember them, but I can tell you practically what they amounted to. In that case it was a magnetic iron mine in the state of New Jersey: the royalty was so fixed on a sliding scale that when iron was about the average range of prices with us the royalty would be about the average royalty of 2s., but as we have had some bad years in iron this lease provided that the royalty should drop with the selling price of pig iron. It was not based on the price of the ore, because there is no regular market quotation for ore in our country at all. There is a market quotation for pig iron, which can be ascertained. This was a rough calculation, by which we assumed that so many tons of the ore would be required to make a ton of pig iron, and that every fall of so much in the ton of pig iron would affect the value of the ores so much, and the royalty went down. I think, in a rough way, we divided it evenly with the lessor. If any fall took place in the price of a ton of iron we split the difference with him.

14,360. What did you assume to be the price of pig iron when the royalty was 2s. a ton on iron ore? The price of pig iron, for what we call grey forge pig iron, which is not the foundry iron, nor the white iron, was about 20 dollars; 18 dollars, I think, more nearly.

14,396. Then in the large coalfields within the states I take it that there must be a large amount of coal worked by those who are the proprietors of the mines, and who do not pay any royalty, and that other fields are worked by those who pay a substantial royalty? Undoubtedly the two classes exist, and, as I said, on the whole, I think the tendency is to work under royalty. I think, in other words, that coal operators do not care to own the land and be burdened with the management of the land.

14,397. In the market, if the coal from two mines is of the same quality and same kind, and the same distance from the port of shipment, will not the coal from those two mines sell at the same price? Certainly. Nobody knows with regard to any given coal whether it is mined on royalty or without royalty, by the proprietor or by a lessee; and what is more, all our great coal-mining companies are mining in both ways at the same time, and they are mixing the coal in the cars.

14,398. They do not ask and take a less price for the coal that they raise out of a mine for which they pay no royalty as compared with the coal they take out of a mine and for which they pay a royalty? No; on the contrary, permit me to say, that most companies, and notably in the case of the Philadelphia and Reading Coal Company, which you Englishmen ought to know something about, because you have got a lot of money in it, the coal on which they pay no royalty has cost them so much that it ruined them, because in avoiding the payment of a royalty they went and bought the land, and they paid a lump price down in lieu of the royalty. Any man who owns the land is dragging along in some form or other the interest on the money which it cost him to buy the land. The Philadelphia and Reading Company borrowed $50 000.000 to buy 100,000 acres, and paid that money and gave bonds for it, and the Reading Railroad Company guaranteed the bonds. The whole thing went down in ruin together, because they were trying to mine the coal without paying royalty, having paid in lieu of royalty $50,000.000.

14,452. Am I right in concluding that, with your great and varied experience, you are of opinion that notwithstanding the royalties you have mentioned as being paid amounting to as much as 20 per cent. of the value of the product, the payment of royalties has not in any way retarded the development of the minerals in the United States? I think it has assisted the development of the minerals of the United States. My reason for saying that is, that I have had a chance of observing in the western United States for a period of nearly 20 years the operation of a system without royalty, namely the system of free license to mine on the public lands, and I have found there that an element of stability

*In an appended supplementary note Dr. Raymond explains that his statement of royalty on bituminous coal in his evidence was based on a single district, where royalties are exceptionally low. He finds, on comparing rates elsehwere, that they vary from 5 cents to 28 cents per ton. A common royalty is 14 cents. Where the operators own the land, having bought it cheaply, the royalty is of course lower, or not reckoned at all. On anthracite coal it ranges up to 60 cents per ton, and the average may be between 30 and 40 cents. He is of opinion that 25 cents would be a fair royalty for coal land not already developed or improved.

and progress and of real regulated industry was introduced when these public lands were made private property, which is only to say in other words, when they were made subject to private royalties. It seems to me that in our country, so far as we have got with the question, waiving all difficulties, which you may have encountered in your more advanced position of development, in our country it is perfectly well illustrated that private property and the enlightened self interest of private owners is a far better atmosphere for the development of a regulated and a prosperous industry than any amount of free gift on the part of the state. We went and made every mine on the Pacific coast from the Rocky Mountains to the Pacific Ocean free of royalty, and we just had chaos, anarchy, and no progress, no stable order, no clear and definite title. Then we went laboriously to work, and have at last got it round so that the principal mines are in private hands, and they charge whatever royalty they can, and we have got more industry and more safety and security and profit by introducing the principle of private responsibility and private interest. Until anybody can show me a case where the opposite has taken place, I must confess that I feel as if that was for my country in its present condition a conclusive answer to the whole subject. I have been accustomed to say at home over and over again, that it would be better for the United States to-morrow to give up all its mineral land and deliberately convey it to individuals for nothing, in order to have somebody own it instead of the government.

Mr. John Bramston, Assistant Under Secretary of State for the Colonies:

15,196. You are Assistant Under Secretary of State for the Colonies, I believe? I am.

15,197. And you have been kind enough to look through some "Notes on Mining and the Law as to 'Ownership of Minerals in India and the Colonies,'" which we have had printed? Yes.

15,198. You have looked through them, I believe, with a view of telling us whether, so far as your information goes, these notes are correct, or of supplementing them if you are able to do so? Quite so.

15,199. I think the most convenient thing to do would be to take this memorandum, and go through the colonies which appear upon it. First, what information have you about Ceylon? The Act which is quoted in the notes—the Ceylon Ordinance, No. 7 of 1882—has been repealed by a subsequent ordinance, No. 20 of 1890, but the note is substantially correct, for mining for gold, silver, gems, or precious stones is prohibited except by the holders of licenses. The fee for a license is 5 rupees, and there is also a fee of 75 cents for the permission to employ any person in or about a mine. I find that on plumbago there was a royalty on export of 25 cents per cwt.

15,200. Do you mean by royalty on export a duty on export? Yes, but I think they call it a royalty; it is really a tax or a duty upon the export of plumbago.

15,204. Then Labuan? In Labuan, leases after 1849 are subject to a royalty to be fixed by the Governor in Council, and that royalty is to be levied upon all coals and other minerals.

15,205. There is a considerable amount of coal in Labuan now, is there not? I believe there is; it certainly has been worked for a long time, but I think not profitably. There is a later ordinance which reserves to the Crown all coals and other minerals within lands to be disposed of under that ordinance.

15,208. Then Perak? There are leases granted by the state; that is, the native government, which receives the rent of a dollar per acre, and a royalty as agreed on granting the lease, or as may be notified from time to time in the Government Gazette. There are also regulations for the alluvial mining of tin, but I have not obtained any particulars of those, for I understood they would not be required.

15,213. Natal? In Natal there is a later ordinance than the one mentioned in the notes, namely, No. 34 of 1888. The right of mining for all minerals is vested in the Crown. Mineral leases are granted for working base minerals in Crown lands, and the Commissioner of Mines may enter and bore for coal upon private lands, but the owner may grant mineral leases upon the same land, so that in that case there appears to be a double right between the Crown and the owner.

15,214. Zululand? The same as in Natal.

15,216. Then we will take Prince Edward's Island? In Prince Edward's Island there appears to be nothing, but in British Columbia on Crown lands there is a royalty of five cents per ton upon coal raised. The coal is the property of the surface owner, subject to a royalty.

15,217. Subject to royalties payable to the Crown do you mean? Yes, in regard to minerals other than coal the free miners may search for and take up claims. The claims may extend to 1,500 feet by 600 feet, and within those limits all veins and lodes belong to the miner holding the license. He has some right of following the veins outside his boundaries. He may also obtain a Crown grant covering all those minerals within the boundaries of the grant, and may run drains through unoccupied mining lands, paying compensation to the owner.

15,228. Then go to Queensland? First of all the Government has power to create mining districts; within those districts licenses are granted for mining over the Crown lands, and those licenses carry all minerals other than gold. Then licenses are also granted by the Crown over any Crown lands for 21 years, with a rent of 10s. per acre. All Crown grants reserve gold but not the other minerals. The law contains provisions preventing unauthorised mining upon private lands, and the taking of minerals upon private lands. Then there is a specific Coal Mining Law, No. 20 of 1886, under which a license is granted to occupy for one year a specified portion of Crown land up to 640 acres. Within those areas the holder of a license may search for coal. The rate is 6d. per acre. The license is renewable at the same rate of 6d. per acre for another year. A licensee, if he discovers coal, may obtain a lease for 320 acres at a rent of 6d. per acre, and a royalty, as stated in the note, of 3d. per ton of coal raised during the first ten years, and then 6d. per ton of coal raised during the remainder of the lease.

15,230. What have you to say about the note upon Victoria? In Victoria there is a very elaborate Mining Act of 1890 which is a consolidation of all their previous law. That law is later than the Act quoted in the note. There is, as in the other colonies I have mentioned, a license to search for minerals other than gold upon Crown lands. A license may also be obtained to cut races and make dams, and reservoirs, and divert waters on Crown lands, and apparently on lands leased to private persons on paying compensation. Then there are also mineral leases on Crown lands for 30 years up to an area of 640 acres with a right to cut races and make dams and reservoirs. The Governor may make regulations as to rent and royalties, I have not got the regulations, and I have not been able to trace the amount of the present royalty. There were mining leases on private property; but those appear to be only for gold, a natural distinction, as other minerals belong to the surface owner, and therefore no mining leases for them would be granted by the Government.

15,232. Now take Western Australia? Up to the present time all their regulations are approved by the Secretary of State at Home, so that they are not under a local Act as yet. Permits are granted to search for minerals. Then leases for seven years are granted of not less than 20 or more than 200 acres, and upon these Crown grants may follow for not less than 20 acres, provided plant and other machinery and improvements are erected to the value of £3 per acre. Then by the new regulation of 1890 the owners of land where minerals are reserved to the Crown may obtain a permit to mine on payment of a royalty of 6d. per ton on coal, 2s. per ounce on gold, and on other minerals 2½ per cent. on the value at the pit's mouth.

15,233. Now take New Zealand? They, again, have a very elaborate system of mining law. They have a separate law for coal mines. Leases may be granted on Crown lands, for 30 years, upon 640 acres, at a dead-rent from 1s. to 5s. per acre, and with a royalty of from 3d. to 1s. per ton, and the term may be extended from 30 years to 99 years. . . . . Then there is another law, No. 51 of 1886, in reference to other minerals. Here, as in South Australia, land which has been alienated by the Crown may be resumed for mining purposes, including land which may be required for races, dams, watercourses, and so forth. Then, of course, the owner receives full compensation, but not for the auriferous or argentiferous value of the land, and the money received by the Government is not handed over to him as in South Australia. There is a license to search within mining districts, or to search outside mining districts, and mining leases are for 21 years at 10s. per acre.

15,234. What are the regulations in Tasmania? In Tasmania mineral leases are granted for 21 years of not less than 20 acres, and for coal, shale, limestone, slate, or freestone of not more than 320 acres; of other minerals not more than 80 acres. The rent of the coal and limestone is not less than 2s. 6d. an acre, and for other minerals not less than 5s. per acre.

15,237. It seems that in three colonies in Australasia the Governments, although they have in the first instance conceded the full mineral rights to the person to whom they allotted Crown lands, have taken powers to resume those rights on certain conditions? Yes, that is the case in South Australia, New South Wales and New Zealand.

William Pritchard Morgan, M.P. for Merthyr Tydvil:

15,751. You are a member of Parliament? I am.

15,752. You have had some correspondence with the Chancellor of the Exchequer on the subject of royalties which the Crown demand upon gold mines in Wales, I believe? Yes.

15,753. The Chancellor of the Exchequer desired your letter of the 22nd May, 1890, to be sent to this Commission with a suggestion that we should examine you upon it In that letter you pointed out to the Chancellor of the Exchequer that, in your belief, the demand of a royalty by the Crown, that is to say, practically speaking, the public of England, upon gold puts the enterprise of mining for gold in this country at a disadvantage as compared with the gold mining enterprise in foreign countries? I did.

15,755. Perhaps you would explain to the Commission what are the grounds for your view that the royalty as charged in England by the Crown, the facts of which are not disputed, I presume, namely, that the terms are, at present, that if the Crown is the owner of the land the royalty is one-fifteenth of the gross produce, and if the Crown is not the owner of the land, one-thirtieth of the gross produce? Those are about the figures that they adopt now, but the figures have been varied from time to time.

15,756. What we should like to know is, what is your ground for supposing that that charge is too high as compared with similar charges in the colonies? Similar charges do not exist in the colonies. I have had interviews this week with most of the Agents General for the colonies. I find that in Tasmania no royalty is charged upon gold or any other metal; there is simply a nominal charge for what is called a miner's right. Leases of mineral lands are granted there upon the easiest possible terms. The Tasmanian Gold Mining Company, which company has paid £400,000 in dividends, had their lease renewed lately without any fine whatever, and not 1d. royalty has ever been paid by that or any other company. In that same colony the Mount Bischoff Tin Mine has paid £1,200,000 in dividends, but they have never paid a 1d. royalty to the Crown or anybody else.

15,757. Is the property in tin in Tasmania in the Crown or in the surface owner? In the Crown.

15,758. Are you certain of that? In this particular case of the Mount Bischoff it was originally a mining lease from the Crown.

15,759. A lease of tin? A mineral lease of tin. I am informed by the Agent-General that the only instance of a royalty ever having been imposed in Tasmania was upon coal, and in that case 10,000 acres were leased for five years at a peppercorn rent.

15,760. Are you aware whether the coal in general is the property of the Crown in Tasmania or the property of the surface owner? This was on Crown lands.

15,761. Then you are not speaking of private lands? No, I am speaking now of a lease having been given for coal in Tasmania for 10,000 acres for five years at a peppercorn rental. After the first five years, for 25 years at 2d. per ton for large coal and 1d. for small coal, and 1½d. for fireclay, brick-earth, lime and shale. For a further period of 30 years after the termination of the first 30 years the Government could double those royalties if they liked. In new Zealand there is no royalty whatever on gold, or any mineral or metal. The gold and silver in New Zealand are always reserved in the grants of land issued by the Crown.

15,762. Do you mean that in New Zealand anyone may work for gold or silver without paying any tax of any kind? Except the mere license fees or small rentals. In New Zealand there is now an export duty of 2s. per ounce on gold, but it is only on gold exported from New Zeland. That is by the Customs Duties Act of 1882. They have produced over £46,000,000 worth of gold in New Zealand, and they now produce about £700,000 or £800,000 per annum, and not 1d. is paid by way of royalty. In the colony of Victoria there is no royalty on gold or silver; on the contrary, they pay bonuses and rewards for new discoveries of gold and silver. Twenty years ago there was an export duty on gold of 2s. 6d. per ounce. Previously to that they used to charge them for their licenses, I think about 30s. per month; that was abolished, and this 2s. 6d. per ounce substituted for it. That, however, was found injurious to the mining interests, and that royalty was reduced to 1s. 6d.; then it was further reduced, and ultimately abolished altogether. Victoria produces between 500,000 and 600,000 ounces of gold annually. In New South Wales there is no royalty upon gold or silver, and their production is enormous. I have the Gold Fields Regulations here of all the colonies, and practically they have copied each other from time to time. The fees charged to miners for mining vary from 5s. to 10s. per annum. Then a miner's right is issued, or a consolidated miner's right may be issued to two, or four, or eight men, and those men are entitled to peg out claims upon Crown lands wherever they like as long as they do not interfere with any existing interests, and they are entitled to search for gold, and have possession of it, the law says, without any interference whatever from the Crown. In the Colony of Queensland the law is the same. There they not only allow men to work for gold and silver for nothing, but they give rewards for new discoveries. For the discovery of a gold field in Queensland, distant more than 20 miles from any place where payable gold has previously been obtained, on which there shall be employed four months after the report of the discovery not less than 200 miners, they give £500. For the discovery of gold distant more than 20 miles, and on which there shall be employed six months after the report of the discovery has been made not less than 500 miners, they give £1,000. In some of the colonies if miners have not been successful in obtaining payable gold down to a certain depth, they are given bonuses by the various Governments to assist them in sinking their shafts deeper. In England and Wales the difficulty arises particularly in this way: that the gold is invariably associated with base metals. This sample (*producing same*) is an exceedingly rich sample such as we seldom get. There you will see the gold is associated with zinc blende.

15,765. And your argument as addressed to the Chancellor of the Exchequer would be this: namely that the royalty which the public require for the working of gold in this country places the producer of gold here at a disadvantage as compared with the producer of gold in the Australian colonies and thereby tends to check the enterprise? It has practically stifled the enterprise because 447 licenses have been already granted by the Crown to persons desirous of working for gold in Wales and only one has taken advantage of it. and we have been obliged to take advantage of it because we had expended so large a sum of money.

15,770. Do you propose that the public should charge no royalty on the gold worked in this country? No, on the contrary I am strongly in favor of the Crown insisting on a royalty and maintaining control of the industry.

15,771. Then what royalty would you consider to be a fair royalty from your point of view as compared with the licenses and so on given in the Australian colonies? The licenses in the Australian colonies are so nominal that I could not make any comparison. but I do not think that the gold mining industry of Wales can carry more than a handicap of 2 per cent. on the gross product.

15,772. Would you propose a royalty of 2 per cent. on the gross product? I do not think that that would kill the industry ; it would sufficiently handicap it, and it would be in my opinion a source of immense revenue to the Crown.

Gold and silver are the only minerals reserved for the Crown on freehold lands, and mines containing ores of these metals may be worked under a royalty. But there are no valuable mines of these ores in the United Kingdom ; the most productive are in Wales, where the amount of royalty received for gold in the fifty-five years 1836-91 was only £6,364.

The Ecclesiastical Commissioners in England have the control over minerals in the lands of the state church. They are probably the largest owners of minerals in England, and their total income from royalties, way-leaves and other profits is £300,000 a year. Minerals in the Crown forests are also worked under leases, subject to royalties payable to the state treasury, and the total revenue derived by the Crown in the year ended 31st March, 1891, was £51,599. This included royalties on coal, iron, lead, zinc blende, slates stone, gold, silver, copper, tin, salt, etc.

But on all private lands the minerals go with the freehold, saving that on a sale of land "any earth, coal, stone or mineral may be excepted, and any rights or privileges may be reserved."

The general practice, as will be seen in the evidence taken by the Commissioners, is for the owner of the freehold to lease a mining privilege upon his property subject to payment of a fixed rent and a royalty, and usually to such terms of working as he may see fit to exact.

It is obvious that there are many grievances under this system, and among representatives of labor bodies the opinion prevails that private property in ores and minerals ought to be confiscated by the state. But the representatives of other classes, almost without exception, hesitate to approve a policy for the nationalization of minerals, or if they do it is on the condition of compensation.

It is certain that dissatisfaction with the system is widespread, and it is quite likely that were British mining companies and miners to begin in a new country they would favor some alterations, if not an entirely new policy. Hon. Mr. Abigail testifies very confidently in favor of government control of mineral lands as against the levying of royalty by private owners in New South Wales. Dr. Raymond, on the other hand, has confidence in the policy of private ownership ; but he does not make it clear that reservation of minerals and provision for a light royalty payable to the public treasury would not have given as great results in the United States. What he does make clear is, that the coal and iron mines pay enormous tribute to private owners ; and that, as in the case of the Reading Railway Company, the payment of vast sums to private owners for mineral rights is a boon to a few at the risk of disaster to many.

The sliding scale, intended to raise or lower the royalty dues according to the market prices of minerals, is regarded in England with favor, and in a number of instances it has been adopted ; but it is opposed by some because it might necessitate an examination of the books of mining companies. In practice, however, this objection does not appear to arise, as by the terms of lease the royalty bears a fixed proportion to the selling price of the product.

In the Ontario Act this principle of a sliding scale is provided for in two ways, first by the clause which makes royalty a percentage of the value of the mineral at the pit's mouth, the amount of it thus rising or falling with that value, and secondly by the clause which enables the Government to make the rate by Order in Council up to a fixed maximum.

The rates of royalties in Great Britain differ very greatly, being dependent upon the situation of a mine, its shipping facilities, and the character of the mineral; but the range is from one-fifth to one-eighteenth of the market value.

There can be no question that in most cases the system of paying royalties to private owners is an advantageous one to these parties. They have no risks, and whether the mines are worked or not, or whether mining companies make a profit or not, the owners are sure of their rent and almost invariably of a minimum fixed sum for royalty besides. Naturally enough they would prefer activity in mining operations and substantial profit for the companies, since their own revenue is in a large degree dependent thereon; but one will look in vain through the evidence for an indication that the owner of a mineral property would willingly surrender any of the advantages he possesses as lord of the land.

The total amount paid in rents and royalties to private owners of mineral lands in Great Britain upon the production of 1890 is estimated to be not less than £6,500,000, or say $32,500,000, a sum larger than the yearly revenue of the Dominion of Canada from customs and excise taxes.

The Royalties a Question of Public Interest.

The question of Crown royalties has clearly another side, and I feel bound to say that I am not now as confident as when I wrote the Section which treats of this subject in the Report of the Commission on the Mineral Resources of Ontario.

No one who reads the Reports of the British Commission on Mining Royalties will pretend to say that the system of private royalties is free from grave objections, and where the minerals go with the surface to the owner of the fee it is almost inevitable that private royalties will be levied. It is so in Great Britain and the United States, as has been shown. In Ontario we are hardly old enough to have an experience; but the system is being introduced here also.

If therefore the minerals can bear a royalty payable to the owner of private land, there is no obvious reason why they cannot bear it if payable to the public treasury, and more especially when the lands are held by the miner or mining company in fee or leasehold direct from the Crown at the low rates fixed by the Mining Act.

The objection to mining royalties certainly loses much of its force when we come to look upon them in the light expressed by Hon. Mr. Abigail, in his evidence before the British Commission, as simply "a small equivalent to the Crown for great benefits granted to private people." And furthermore there is the point of view from which so cautious a man as Sir Isaac Lowthian Bell regards the royalties when in speaking of the mining policy of Spain he says: "If I were at the head of the Spanish government and I saw foreigners coming in and reaping very large sums of money from mining enterprises there, I should begin to enquire whether a reasonable portion of it should not go into the national exchequer." If to "foreigners" we add "speculators" or "private people," is the sentiment less reasonable or just in the public eye?

Is it in the public interest, or in the interest of the mining industry, that foreigners, citizens, or private people of any class should be encouraged to secure blocks of mineral land from the Crown and hold them until they can be sold at a great advance on the cost price, or lease them at a fixed rental and upon a royalty, or perhaps sell at a good figure and retain a royalty interest besides? Or is it not more desirable that the miner should deal directly with the Government and purchase or lease the land at a low fixed rate, subject to a moderate royalty ? *

It will be said that under the latter system the speculator can still operate, since he may take up the land as before and dispose of it on the best terms he can get. This no doubt will happen ; but mining companies are not disposed to pay double royalties when by dealing directly with the Crown they can obtain lands on more liberal terms, without any middleman to levy tribute upon them.

In so far as prospectors are concerned, they have done a valuable work in the country, as without their service many ranges and deposits of minerals would have remained undiscovered. There is still a large area to be explored in the northern districts, and as it is now well established that this is a mineral-bearing country it is not unreasonable to expect that capitalists and mining companies will employ prospectors to explore it in their interest. Or possibly some satisfactory way of compensating them might be found such as obtains in the Australian colonies, where rewards are offered by the Government for the discovery of ore or mineral in new districts.

The Government has a right to look to the public lands as a source of revenue, but it cannot afford to make the mistake of putting on such prices, or rents, or royalties as would be a burden upon industry. The interests of the Government and the mining companies must be interdependent, and in the two new features of the amended Act which provide for the leasing of mineral lands and the levying of a royalty a bond of connection is maintained. When the lands are sold outright the interest of the Government ceases ; but where they continue to be a source of public revenue the occupiers have a reasonable claim for aid in the construction of roads and railways, so necessary to successful mining enterprise in our rough northern woodlands.

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* These and other features of the mining question are dealt with very forcibly in the following letter from Mr. C. S. Morris, of Toronto, written to me under date of December 21, 1891: "Referring to the subject of the development of the mineral resources of Ontario, I beg to express the opinion, based on a considerable knowledge and experience, that as to the commercial minerals the want of markets is a sufficient and constant reason for non-development, while as to the precious metals the backward condition is very largely owing to the disinclination or inability of owners of mining claims to test and prove the value of their properties before offering them for negotiation. It may as well be thoroughly understood and realised—and the sooner and more widely the better—that foreign investors and speculators, both in the States and in the old country, have no use for untested and undeveloped mining properties, and will not invest in such, saving in very exceptional cases, at any price whatever. The foreign speculative centres are constantly overstocked with mining properties of all kinds, in all stages of development, and it is only those which are well proven and vouched for that stand much chance of attracting the favorable consideration of investors, and so obtaining the capital necessary for their full development and operation as mines. A second cause, I may suggest, is the non-existence in this country of a class of practical mining investors, —men who know enough of mining to invest their own capital in the industry and make it a permanent pursuit and look for their profits out of the actual operation of the mines, and in so doing also prove the value and create confidence abroad in the wealth of our mineral deposits. We go abroad and assert that the country possesses this wealth, but we do not sufficiently demonstrate it by showing the actual output. It is a matter of too much bragging and too little work. Our "alleged " mining men are, with few exceptions, simply speculators in wild lands. It may be said that there is no home capital available for actual mining investment, but I am quite sure that there is in this country, in the aggregate, a large amount of speculative capital which is frequently employed in quite as risky ventures as mining, and which might be attracted thereto if properly approached and its confidence gained. But too many holders of mining claims pursue an unintelligent and somewhat dog-in-the-manger policy, and will not work and develop the properties themselves nor permit others to do so on any reasonable terms. And this leads me to mention another evil, and that is the ridiculously exaggerated notions of *price*, so entirely disproportioned to *value*, entertained by the large majority of owners, especially those residing at the different mining localities, whose ideas and knowledge are purely local and therefore narrow. But this matter of exaggeration seems to be incidental to new mining regions everywhere and generally cures itself in time, when the first set of owners are either dead or starved out. I regard the growth of a home interest in actual mining and the adoption of it as a legitimate business as an object to be especially aimed at in any efforts to better the situation, and perhaps this may be considerably aided by the amending of the Ontario Joint Stock Act so as to permit of the formation of mining companies in a much more simple, inexpensive and expeditious manner than can be done at present. Actual and extensive mining operations are generally too heavy for a single individual, so that a combination becomes necessary, and to effect this a limited liability company must be formed. To do this the present Act is too slow, cumbrous and expensive. It should be as easy to form and incorporate a mining company in Ontario as in England or in many of the United States, as for instance, Minnesota, Illinois, New Jersey, West Virginia, etc., where a single day's time and a few dollars of expense are all that is involved in obtaining a charter for a company. The English Companies Act is stringent in its provisions, and at the same time simple, easy and expeditious to form and operate under, and such facilities would be no more liable to abuse in Ontario than in England."

ARTESIAN WELLS.

In nothing is the untiring activity of nature better shown than in the never-ending round of processes which go to maintain and distribute the water supply of the globe. Moisture descends upon the surface of the earth in the form of rain and snow. Part falling upon mountain sides and untimbered spaces may run at once into streams and rivers, part descending upon forest lands may be detained upon its return journey by a slower process of percolation, part falling upon pervious soils may sink out of sight to re-appear as springs or to form those underground supplies of water which are the sources of artesian wells, and part may remain for long years locked up in arctic and antarctic regions in the shape of glaciers and vast fields of snow; but, speaking broadly, the moment water is deposited from the clouds it at once begins a voyage to the ocean. There, and on subsidiary sheets of water, evaporation is continually setting it free again and giving it to the clouds, which re-deposit it on the land, once more by direct or tedious route to seek its way to the sea. By this beneficent circle of operations the equilibrium of water on the earth's surface is maintained. The sea is never full, and the earth is never dry.

But although this is the case viewing the earth as a whole, there are nevertheless parts of its surface where rain either never falls at all or falls in such scanty volume as to be inadequate to the needs of man.

Fortunately for the people of Ontario, there are no portions of this extensive province which are rendered useless by the lack of rain. Over by far the greater part of its occupied area the labors of the farmer in the tilling of his soil are rendered effective by the falling of the rain in due season, and in most localities he is, in ordinary years, at no loss to procure ample supplies of good water. Where a spring is not found issuing from the ground in a convenient spot, a well sunk a few feet in the upper stratum of the soil generally secures an adequate supply.

There are sections of the province however where it is difficult to obtain from the surface good water in large enough quantities to answer all the purposes of farm and domestic use, as where the drift is composed of impermeable clay. There are other sections, as in the eastern counties, where the rock lies near the surface and acts like a system of natural underdrainage, so that the water absorbed by the earth from precipitation is quickly carried away by springs or in streams.

In towns and cities, again, the conditions of life are altered. Even if an abundance of water may be had by sinking wells, it is apt to be polluted by sewage and surface drainage, and its use is attended with danger to health and life. An abundant supply of water is required for protection against fire, and even if a river may be taken advantage of for this purpose its waters are frequently found to be contaminated by the drainage of the country through which it passes to such an extent as to be unfit for domestic use.

Even those cities which are situated on the shores of the great lakes, and therefore on the brink of an inexhaustible supply of pure water, find that within the area affected by the city sewage the pollution is so great as to cause them to consider very seriously the question of obtaining their supplies from some other source.

In such circumstances as these the question of artesian wells becomes of great importance.

In countries where the rainfall is insufficient for the requirements of agriculture artesian waters are resorted to for purposes of irrigation, often with extraordinary results, In some parts of the desert of Sahara, for instance, whose very name is a synonym of aridity, the enterprise of French engineers has of late years wrought a remarkable transformation. Many artesian wells have been put down which supply the requisite moisture for the cultivation of the date-palm and other forms of vegetation, and which have become the centres of fertile oases whose freshness and verdure afford welcome relief from the dry and sandy monotony of the surrounding desert. It is stated that upwards of 600 borings have been made within the limits of the great desert, and the transforming effects of artesian water among the sandhills of Algeria are said to be equally great.

The whole question of irrigation is receiving great attention in the United States, where large areas in the western states, otherwise fertile and capable of sustaining a large population, are made useless by the want of sufficient water. Artesian wells are found of great advantage in remedying this defect, and an investigation recently undertaken by the Department of Agriculture shows that thousands of such wells have been sunk and many districts of considerable extent have already been reclaimed. The work of reclamation is actively going on, and many sections hitherto uninhabitable are being opened to the fruit-grower and the farmer.

In the pastoral districts of Australia the question of obtaining a supply of drinking water for stock during the dry season is often a very serious one, and it is also necessary to have watering-places at intervals along the routes over which stock is driven to market, and which are almost impassable in a drought. Resort has been had to artesian borings for the purpose of providing such watering-places, with considerable success. The government of New South Wales is now engaged in putting down artesian wells on an extensive and systematic scale, with the double object of watering certain arid stock routes and of testing the geological formation of a large area of hitherto unexploited country.

No necessity however has as yet been felt in Ontario for the irrigation of crops or for public watering-places for stock, and the climatic and agricultural conditions of the province are such as to make it unlikely that we shall ever require to attempt the utilization of artesian waters for either of these objects.

It is for the purpose of supplying water for farm and domestic use, and for meeting the demands of cities, towns and villages for private, manufacturing and fire protection purposes, that artesian wells are of importance in this province, and their importance in these respects is likely to increase rather than diminish in the future.

It is no doubt true that a source of supply of public water for towns and villages, not inferior in importance to that afforded by artesian wells, is to be found in springs which abound in many parts of the province.

The towns of Owen Sound and Milton and the cities of Guelph and London find in neighboring springs an abundant supply for all purposes, and where perennial springs of sufficient size are found conveniently situated it is doubtless the part of wisdom to utilize these in preference to taking the risks inseparable from the sinking of wells in search of artesian waters. The quality of the water supplied by springs is usually good, and the expense of providing a system of waterworks is not necessarily any greater in one case than in the other.

Apart however from the fact that springs are frequently natural artesian wells, their presence is always sufficiently obvious, and a little experiment and calculation is all that is required to ascertain whether or not they are likely to prove equal to the demand proposed to be made upon them.

It is not therefore the purpose here to treat largely of springs, but to seek to convey what information is available regarding those more hidden reservoirs of water whose underground existence may often be unsuspected in circumstances which would render a knowledge of them in the highest degree beneficial.

CONDITIONS OF ARTESIAN SUPPLY.

The conditions necessary to the presence of underground water which may be brought to the surface by means of artesian wells are now sufficiently well understood. It is a matter of much greater difficulty however to say whether or not a flowing well is likely to be found at any particular spot.

The requisite conditions are that the edge of an inclined stratum should be exposed to the surface at a level higher than that of the proposed well, and that this water-bearing bed should be confined both above and below by impervious strata. It is of course essential that the water in this stratum should have no means of escape at a lower level, otherwise, no matter how elevated the fountain-head or how copious the rainfall may be, no considerable pressure can be exerted in an upward direction at any point in the descending stream.

The typical requirements are met if the water-bearing and associated strata come to or approach the surface in such a way as to form a basin or depression in the region of the proposed well.* It is not however absolutely necessary that such a basin should exist. A similar effect will be produced if by a change in the composition of a descending water-carrying stratum the passage of the water be rendered difficult or impossible, as for instance when a coarse, open sandstone passes into a fine-grained compact rock. In such a case it is evident that the water will descend until its progress is checked by the impermeable part of the bed and will there remain under as great pressure as if the stratum occupied a basin shaped depression.

Strata of sand, sandstone and gravel, which afford free passage to water, are usually those in which the desired supply is found, though occasionally even limestone rocks, much broken and fissured, are found available as sources of artesian wells. In the latter case however the irregular and tortuous courses which the underground waters must pursue as they flow along the joints and fissures of the rock and through the channels worn in its soluble portions make the task of locating a well entirely a matter of chance. The confining beds are usually of clay, and in most cases, if of sufficient thickness, they act as almost perfect barriers to the passage of the water.

It is as important that the bed above the water-bearing stratum should be impervious as the one below. The tendency of water is of course to obey the law of gravitation and sink deeper and deeper into the earth, and were its downward course unobstructed it would probably descend until that great depth is reached at which the tension of superheated steam is equal to the hydrostatic pressure. On the other hand, if the stratum superimposed upon the water-bearing bed be of a permeable character the water will rise in it up to the permanent water level, and make its escape as springs where erosion has brought the surface down to this level.

It is obvious that the quantity of water to be found in a given permeable stratum will depend upon (1) the rainfall, and (2) the area of such stratum laid bare at the surface.

The quantity of rainfall varies in Ontario from year to year, but this variation is within moderate limits, and the average is probably not far from thirty inches a year. At this rate the annual precipitation upon an acre would be about 680,000 imperial gallons. If one-half of this quantity sank into the ground, for every acre comprised in the gathering-area the water-bearing stratum would receive 340,000 gallons a year, or rather less than 1,000 gallons a day.

Of course such figures are only approximate, and the whole quantity of water contained in the stratum would not be tributary to any one well, but if the area of the district forming the collecting-ground for artesian water in any particular case were once ascertained, it would not be difficult to arrive at an estimate of the quantity of water contained in the stratum, though the actually available supply would in all cases be considerably less.

The limit of the yield must necessarily be much within the limit of the receipt of water, and this fact should not be lost sight of in any calculations as to the number of wells which may profitably be sunk within a given area, or the quantity of water which they may be expected to produce.

Experience in some parts of the United States has shown that the supply of artesian water is no more unlimited in any given field than a supply of petroleum or natural gas, and though not productive of utter exhaustion as in the case of the latter, a multiplication of wells beyond the resources of the underground supplies has the effect of diminishing the flow of water at each well and correspondingly lessening its value and usefulness.

It has also been observed that the great number of wells sunk in and around London, England, has reduced the flow to such an extent that wells which were flowing a few years ago have now to be pumped.

The area of the gathering ground will be determined by the thickness of the stratum and the angle of its dip at the place of exposure. If the angle of the outcrop be high and the bed thin, the area exposed will be small and the supply of water probably insufficient for large and important wells. If the angle be low and the bed thick, a more extensive area will be laid bare and the quantity of rainfall received will be correspondingly increased.

The height to which the water will rise in the well, or above the surface of the ground, will theoretically be the height of the collecting area above the site of the well, or, speaking more accurately, the height of the permanent water level in that area. In practice however it will not rise so high.

The pressure under which the water travels from source of supply to point of delivery is diminished by several causes. Chief among them are the leakage which takes place when the confining beds are not entirely water-proof and so permit a portion of the water to be absorbed and transmitted through them, and the friction to which the water is subjected in its underground passage, varying according to the composition of the stratum through which it flows. Sand and gravel offer the minimum amount of opposition to the flow of water, while in close-textured rock the friction reaches a maximum.

The conditions in which artesian wells may occur are so varied that any definite rule as to the amount of loss by friction may be misleading when applied to particular cases, but in general it has been found that a deduction of one foot should be made from the height for every mile between the collecting area and the site of the well.

SURFACE GEOLOGY OF ONTARIO.

The geological conditions of a country have of course a very important bearing upon its water supply, and a brief sketch of the superficial geology of Ontario may help to a better elucidation of the subject in hand.

The palæozoic rocks which underlie the southern and western portions of Ontario are separated from the post-tertiary formations resting upon them by long ages of geologic time. The newest member of the palæozoic series is the Devonian, which in other parts of the world is followed by the Carboniferous, Permian, Triassic, Cretaceous and Tertiary systems. Whether the corresponding rocks were deposited upon the surface of the older groups and afterwards ground off by slow erosion or swept away by denuding agencies, or whether, as some conjecture, the surface of what is now Ontario may have been dry land affording no opportunity for the deposition of higher strata, it is impossible now to tell. Certain it is that if these missing members in the geological scale ever existed, they were effectually planed away before the era set in which finally left the surface of this part of the continent in the shape in which it now is.

It is to the operations of the glacial age that the existing contour and physical conditions of Ontario are due. The vast masses of ice which flowed in rigid, irresistible streams from the cold northern regions towards the south-east and south-west plowed up the surface of the older rocks, softened and decomposed as it is supposed to have been, and ground the fragments into the clays, sands and gravels which were deposited in the beds of the glaciers or in the lakes formed by the melting of the ice under the heat of a succeeding warmer era.

A submergence of the land probably followed the glacial period, in which the material accumulated during the ice age was to some extent worked over, and the present arrangement of the superficial deposits effected.

The lowest deposit is the boulder-clay or till, which is followed by various strata of clay, sand and gravel. Of these strata the Erie and Saugeen clays, the Algoma sand and the Artemesia gravel are sufficiently continuous and recognisable to be granted definite places in the scale.

The Erie clay, which is of a blue color, with thin gray bands, underlies the whole of the south-western part of the province, and is found as far as Brockville on the east. Resting unconformably upon this in many places is a thinly bedded, brown, calcareous clay, known as the Saugeen clay, so called from an extensive exposure in the valley of the Saugeen river.

The Erie clay has nowhere a depth of more than two hundred feet, though it occurs at levels showing an extreme difference of about five hundred feet.

The Saugeen clay is probably rather less in thickness than the Erie clay, but is found overlying that formation in its higher as well as in its lower levels.

Beds of sand and gravel in many places separate the Erie and Saugeen clays, and are of frequent occurrence in the latter. Under otherwise favorable conditions these beds may often be found acting as reservoirs for the supply of artesian waters.

In the district lying north of lake Huron and between the Georgian bay and the Ottawa river, where the rock is not protruded at the surface it is generally covered by a yellowish sand resting in broken areas immediately upon the Saugeen clay. This sandy formation, which supports—or rather did in the past support, for the lumberman's axe and the forest fires have done their work too well—great groves of noble pine, is called the Algoma sand.

The Artemesia gravel is a belt of loose gravel extending parallel to the Niagara escarpment from Owen Sound to Brantford, following the highest ground of the peninsula. The Oak Ridge may be considered a spur of this remarkable belt, running in a north-easterly direction and rising at a point north of Toronto to a height of 720 feet above lake Ontario.

In addition to the strata thus briefly enumerated are many deposits of sand and clay overlying them which are too irregular and local in their character to admit of classification. Crossing these strata in almost every direction are streams emptying their waters into one or other of the great lakes or the St. Lawrence or Ottawa river, which have worn their way down to their present beds, in some instances through many feet of sand, gravel and rock.

It is evident that although we have not here those foldings and upliftings of tertiary and secondary formations which go to form artesian basins on the grandest scale, the conditions are nevertheless eminently favorable for the existence of smaller depressions, local in their character, but capable of yielding large supplies of water.

It is accordingly found that in almost every part of the southern and western portions of the province, in other words, in those districts where the superficial deposits, generally speaking, are deepest and most varied in their nature and order, artesian water is obtainable at no great depth.

Large supplies of water are also frequently found in the underlying rock, as in the case of wells bored for salt and petroleum, the southerly dip which characterises the older formations as well as the chief members of the post-glacial group being sufficient to afford the necessary pressure upon the contained water.

The water found in the rock is usually more or less mineralized. Sulphur and magnesia are frequently present, and nearly all the deep wells of south-western Ontario yield salt in greater or less quantity. Many of them also give traces of oil.

The valleys of the rivers and streams doubtless expose permeable strata which must receive a portion of the rainfall, and where they are of a sandy or gravelly nature and confined above and below by beds of clay they present the conditions which require only the existence of sufficient pressure to constitute them the sources of artesian wells.

Where a dip occurs in the strata followed by an upward inclination the requisite pressure is provided, and a boring down to the water-bearing bed is certain to be rewarded by a supply of water. The gathering grounds provided in the immediate valleys of rivers must of necessity however be of limited area, as the outcropping of the permeable strata will in all ordinary cases present too high an angle to permit of a large section being laid bare.

In the uplands lying between lakes Huron and Erie and Ontario, and north of the last mentioned lake, are areas extensive enough to collect rainfall for the supply of large reservoirs of artesian water.

A synclinal basin extending from London westward to the river St. Clair is composed of beds of sand and gravel confined between impermeable clay strata, and readily yields artesian water at depths varying according to the dip of the strata and the undulations of the surface.

Similar basins occur in various parts of the province. An interesting example is afforded at Sundridge, in the district of Parry Sound, where a depression apparently exists on the surface of the Laurentian rocks filled in by post-glacial deposits. Here several wells have been sunk from 80 to 100 feet deep, and water obtained rising three or four feet above the level of the ground.

QUALITY OF ARTESIAN WATERS.

Artesian waters vary greatly in quality, even in wells comparatively short distances apart. In some wells the water will be of great clearness and purity, while in others, perhaps at no great distance, it will be charged with mineral substances of various kinds to such a degree as to be unsuitable for domestic or manufacturing purposes.

The reasons for such variations are obvious.

When water descends from the clouds it is usually of a high degree of purity, containing merely such foreign ingredients as it may come in contact with while on its downward way through the air. Should it fall upon the upturned edge of an open sandy stratum of low inclination, which maintains a uniform texture throughout, the water will meet with little or nothing in the way of mineral substances which it can dissolve and carry away, and hence if brought directly to the surface by means of an artesian well it may be found to be quite soft and pure. On the other hand, if the receiving bed be of a calcareous nature, or if the water in its underground passage force its way through the pores of strata retaining a large proportion of their original salts, it will inevitably become hard and more or less mineralized.

The degree of mineralization depends also to some extent upon the depth to which the water penetrates and the length of time it remains beneath the surface.

The temperature of the earth increasing by one degree for every 50 or 60 feet in depth, the water will become warmer in like proportion, and its capacity to dissolve and hold in solution minerals with which it comes in contact will be correspondingly heightened. The longer it is retained in the underlying strata the greater will be its opportunity for exercising these solvent powers. Consequently if raised at once from a considerable depth, as in an artesian well, the chances are that such water will be both warmer and more highly mineralized than if drawn from a stratum nearer the surface.

This general rule is borne out by the results of artesian borings in various sections of Ontario, the water from shallow wells being more frequently fresh and potable, while that obtained from the rock or at great depths is often unfit for use on account of the minerals held in solution.

There are however many exceptions to the rule. It does not follow because a flowing well is obtained at no great depth that the water has travelled but a short distance from its source, or that the stratum through which it has passed may not at some point lie much deeper. If such is the case, the water from a shallow well may be mineralized to a greater or less degree.

On the other hand good water may be procured at great depth if the bed in which it is found has a high inclination, or if it is composed of insoluble sand or other material closely confined by impermeable strata.

The irregularity of the surface deposits of Ontario, as already pointed out, and the variety of ways in which they overlap each other, increase the chances of striking water at an easy depth, but cause as well abrupt and great variations in the depth at which water is present.

NATURAL SPRINGS AS SOURCES OF SUPPLY.

When a town has advanced to that stage of progress at which ordinary wells are felt to be no longer safe and convenient, and when the need of fire protection presses itself upon the minds of the inhabitants, it is to springs that attention is first directed as being one of the most apparent and directly available sources of water supply. Many of our villages and towns are fortunate enough to be so situated as to be able to take advantage of springs, and some of them have already done so. Before giving particulars regarding artesian wells in various parts of the province, it may not be out of place to cite a few cases in which springs are made use of with excellent results.

CITY OF LONDON.

The city of London is abundantly supplied with water of first-class quality from springs situated along the bank of the river Thames, some three miles below the city. These springs issue from the hillside on the surface of a stratum of "hard-pan," and the quantity of water available has been very largely increased by running a gallery along this stratum for about half a mile. The water is then conducted to the pumping basin, from which it is distributed through the city mains.

The sources of the springs are on the higher grounds to the south, which rise to a height of nearly 200 feet and are formed largely of pervious sands and gravels.

TOWN OF MILTON.

From the "mountain" or isolated elevation of limestone rock which rises at the distance of about a mile from the town of Milton flow three natural springs at a height of 300 feet above the level of the town. These springs unitedly supply about 35 gallons a minute, the water being collected first in large cisterns and thence conveyed through a four-inch pipe to the reservoir a distance of about 300 yards.

The water is of good quality, not hard, and is extensively used for domestic and other purposes, no new wells being now sunk in the town.

The waterworks system also affords efficient protection from fire, and Mr. T. G. Matheson, county crown attorney, who furnishes these particulars, states that the insurance rating of Milton has in consequence been raised from class "E" to class "D."

TOWN OF OWEN SOUND.

Mr. James C. Kennedy, town engineer, furnishes the following facts respecting the water supply of Owen Sound.

The town is supplied from springs which rise from the hillside at a height of about 200 feet above the level of Georgian bay, or say 180 feet above the level of the main street in the centre of the town. Their volume is about 400 or 500 imperial gallons per minute in dry seasons of the year, and from 900 to 1,000 gallons during wet or freshet seasons. The average flow throughout the year is perhaps 600 gallons a minute; but by taking in other springs in the vicinity the supply might be largely increased.

At the minimum flow of 400 gallons per minute the daily capacity of the springs is 576,000 gallons, and at the maximum of 1,000 gallons per minute it is 1,440,000 gallons.

The daily consumption of the town in winter is 200,000 gallons, and in summer probably 300,000 gallons. The water is of good quality and is largely used for domestic and fire protection purposes.

The reservoir, which is three miles distant from the springs, has a capacity of 500,000 gallons and is situated 180 feet above the level of the lake.

ARTESIAN WELLS FOR TOWN SUPPLY.

Where springs are not available on account of their absence or insufficiency of volume the choice in the case of towns removed from the banks of the great lakes may sometimes lie between utilizing the waters of a stream or river and boring for artesian wells. In few cases will river water be found to possess the requisite purity, and if the topographical conditions are such as to lead to a belief in the existence of artesian water the money spent in an endeavor to reach it will generally prove a profitable investment. The towns of Goderich, Essex (formerly Essex Centre), Chatham, Newmarket and Barrie, among others, afford good examples of the utilization of artesian wells in supplying water for public use.

TOWN OF GODERICH.

The inhabitants of the town of Goderich were in the position of being able to make choice of two sources of public water supply, either of which in countries less abundantly supplied with good water than Ontario would be considered an inestimable boon. At their feet lay lake Huron, whose waters cannot yet be appreciably lessened in purity by the population on its borders, while beneath them borings in the salt formation had proven the existence in the upper limestone layers of artesian waters of great volume and excellence.

It was decided to make use of the latter, and six wells were sunk on the edge of the lake about ten feet above the water level, two being put down to a depth of 263 feet and four to a depth of 240 feet.

The water rises about twelve feet above the surface of the ground or about twenty-two feet above the level of the lake, and the supply appears to be inexhaustible. The consumption of the town rises as high as 450,000 gallons a day.

The Holly or force-pump system of water-works is in use and ten miles of mains have been laid, the total cost of system and mains having been about $75,000.

An analysis of the water shows it to be soft and of great organic purity and excellent quality. It is almost entirely free from chlorine, showing that it has no connection with the salt beds below which are of much greater depth.

TOWN OF ESSEX.

At Essex the want of a sufficient supply of good water was long felt to be a serious disadvantage. In the fall of 1890 a by-law was passed appropriating the sum of $26,500 for the purpose of sinking artesian wells.

In the summer of 1891 borings were made which proved the existence of good water at a depth of about 125 feet. Three wells were sunk in proximity, the strata penetrated being given by Mr. John Milne, mayor, as follows: Clay, with occasional sand veins, 100 feet, hard-pan one or two feet, then a bed of gravel where there was a good supply of water, after which the rock was struck and penetrated about 18 feet. Here a good flow of water was found which rose to within 27 feet of the surface. Around these three wells a reservoir 25 feet wide and 50 feet deep was excavated into which the water flowed. This was built up with brick and cement and cemented thoroughly at the bottom.

From the reservoir the water is pumped to an elevated tank which furnishes sufficient pressure to destribute it through the mains and to throw a stream over any building in case of fire.

The quality of the water is excellent, and the supply is estimated to be sufficient for the wants of the town.

The cost of sinking the wells and constructing the whole system of water-works did not exceed the sum voted for the purpose.

Town of Chatham.

Greater difficulties had to be overcome at Chatham. A company undertook the contract of supplying the town with artesian water and made a number of borings within the limits of the town itself. At a depth of 64 feet they struck the rock, lying immediately upon which was a layer of coarse gravel about three inches in thickness. Above this lay 2½ feet of very fine sand. In these strata a good supply of water was obtained, but on putting a steam pump at work on one of the wells the fine sand or silt was soon found to fill the pipe and stop the flow of water. None of the devices which were resorted to had the effect of checking this inflow of silt and the wells had to be abandoned.

It was then proposed to secure a supply of water from the river Thames on which Chatham is situated. The agreement between the town and the company prevented resort to a source so questionable in point of purity, and a new field of operations was found in the township of Raleigh, some four miles south of Chatham, where artesian wells bringing the water just to the surface had been known to exist for years.

A number of borings revealed the fact that a large supply of good water could be obtained at a depth very little exceeding that at which water was found at Chatham, and in a sand bed much coarser in character than that encountered at the town.

On the farm of Mr. Laurie a well four feet in diameter was dug to a depth of 32 feet, and bricked up to a height of two feet above the surface. From the bottom of the well an iron casing 13 inches in diameter was sunk to the rock, 40 feet further down. A bed of sand between two and three feet thick lay between the rock and an overlying stratum of clay, and supplied a column of water rising to the surface, which on pumpng is not reduced to a lower level than 17 feet from the ground.

At a short distance away a reservoir 36 feet deep was sunk and connected with the supplying well by a pipe 30 feet below the surface. A pumping station was built, mains laid to the town and a system of water-works successfully inaugurated early this year (1892). The daily consumption of water does not as yet exceed 150,000 gallons, wells being plentiful in the town. The works are capable of supplying 1,000,000 gallons daily at least.

That the water-bearing stratum in Raleigh thins out in places has been shown by the fact that in several borings made close to productive wells the clay bed was found to extend to the rock. Such cases of course constituted "dry holes" where no water was found.

Following is the average of several analyses made of the water :

Free Ammonia, per million parts	.3600
Albuminoid Ammonia	.0900
Chlorine	202.0000
Oxygen absorbed in 4 hours	.6457
Oxygen absorbed in 15 minutes	.5430
Nitrogen	.1130
Hardness	6.5000

Town of Leamington.

At Leamington in the county of Essex, near the lake shore, an artesian well for the supply of public water discharges a stream five feet above the surface of about 50 gallons per minute. The depth of the well is 55 feet. The following analysis of the water from this well may be compared with that of the Chatham water :

Chlorine, per million parts	1.500
Free ammonia	.130
Albuminoid ammonia	.040
Nitrates	Traces.
Oxygen absorbed in 15 minutes	.156
Oxygen absorbed in 4 hours	.300
Total solids	322.000
Phosphates	None.
Hardness	10.360

Town of Newmarket.

At Newmarket, which is situated on the northern slope of the Oak Ridge, the wells which furnish the town supply are four in number, all sunk within a few feet of each other. Their dimensions and depths are as follows: 4½ inches diameter, 145 feet; 3½ inches diameter, 160 feet; 6 inches diameter, 147 feet; 6 inches diameter, 250 feet. They are all flowing wells and discharge their contents into a cement reservoir from which the water is pumped into the mains and an upper reservoir.

The natural flow is greatly augmented by pumping. The water is pure, clear and cold, and is largely used.

The stratum in which the water supply is found is composed of gravel, and is reached after passing through a bed of blue clay 100 feet in thickness. Water is also found at a depth of 40 feet, but in smaller quantity, and is utilized in a few wells by private families.

Town of Barrie.

Good supplies of artesian water are found and made use of for public purposes at Barrie, in the county of Simcoe. Mr. Henry Bird, town clerk, furnishes the following particulars:

The number of borings is 16 or 17, of which 13 or 14 have been successful and are still flowing, although the flow has diminished in some of them.

Beds of sand and clay of about equal thickness are penetrated, the clay varying in color and consistency, some of it composed largely of minute shells.

The wells vary in depth from 100 to 140 feet, the average being about 120 feet, and are from 2½ to 4 inches in diameter. The capacity of the 4-inch wells is about 150 gallons per minute, the public supply being drawn from two wells of this class. The water is good and moderately soft.

All are flowing wells, some rising to a height of ten feet above the surface.

Town of Midland.

At Midland, on the Georgian bay, borings were made by a hotel proprietor which R. McGee, M.D., states are of a depth of 35 feet and penetrate the following strata:

Soft sandy soil 20 feet, hard pan 3 inches, sandy soil 15 feet. A hard gravel bed is then reached in which an abundant supply of flowing water is found.

Each of the wells yields at the rate of 24 gallons per minute, and the quantity appears to be gradually increasing. The water is suitable for use and is utilized in the hotel.

Town of Kincardine.

At Kincardine, on the shore of lake Huron, a boring in the drift reaches a stratum carrying water in small quantity at a depth of 126 feet, while at a depth of 480 feet a very large supply is obtained in the rock under sufficient pressure to raise it to a height of 25 or 30 feet above the surface of the ground, which at the well is only eight feet above the level of the lake. This water is of good quality, but is not utilized, the town obtaining its supply from the lake.

In Eastern Ontario.

In the eastern part of the province necessary supplies of water have generally been found on the surface, and hence artesian waters have not been largely sought after. In the town of Lindsay several borings have been made at a level of from 40 to 60 feet above that of the Scugog river, varying in depth from 75 to 125 feet according to the fluctuations of the surface of the ground. One well 4 inches in diameter and 100 feet deep yields under a steam pump at the rate of 25,000 gallons per day. The water in these wells comes from the rock and is of good quality.

An artesian well sunk in the limestone underlying the town of Smith's Falls, county of Lanark, supplies water for public use.

Borings Elsewhere.

Borings made at Forest, Courtright and other places in Lambton county strike water at a depth of about 75 feet, which rises to within 20 feet of the surface.

In the vicinity of Windsor no good water is obtainable by means of artesian wells, but brackish water is found at depths varying from 60 to 200 feet, which does not come to the surface.

Mr. Hiram Walker of Walkerville has two artesian wells at Marshfield, in South Essex, intended to flood his 200-acre cranberry farm there. They are each about 130 feet deep, and the water rises in full volume to the surface through a pipe of 4½ inches diameter. It is mildly sulphurous. About 10 miles farther east numerous borings from 50 to 250 feet deep have failed to develop water.

East of Essex about ten miles good water is found at a depth of 120 feet, and is also readily obtainable between that town and lake Erie.

A well was bored last year at Ransome's schoolhouse on the Communication road south of Blenheim, township of Harwich, Kent county, to a depth of 135 feet, of which one foot is in slate below the drift. Water was struck at the bottom of the drift, and it rises through an inch pipe three feet above ground. The flow is strong, but noticeably intermittent, owing no doubt to gas pressure. The water has a slight mineral taste, yet it is pleasant and potable. This well is about 100 feet below the level of the gravel ridge at Blenheim.

Numerous flowing wells exist at St. Marys, where they are found in the limestone rock.

Artesian wells have been made use of for years at Waterloo to supply water for private purposes.

West of Port Colborne is a deep well which has for many years been flowing a sulphurous water of good quality, but is now of less volume than formerly. When the water was first struck it was thrown to a height of 40 or 50 feet above the surface.

Artesian water of good quality is also found at Orillia and Bradford in the county of Simcoe, Collingwood in the county of Grey, and Holland Landing in the county of York.

Ebb and Flow of Artesian Waters.

A peculiarity of many of the artesian wells in the country bordering on lakes Huron, St. Clair and Erie is the fact that the water in them rises and falls according to the direction from which the wind is blowing on the lakes. If the wind is strong and continuous off-shore the water lowers appreciably in the wells, while a contrary effect is produced by a wind from the opposite direction. A gale has also the effect of rendering the water in them turbid. These circumstances clearly point to a direct communication with the waters of these lakes, and the fact no doubt is that the water-bearing beds of sand and gravel overlying the rock, as well as the rock itself, are continued out into the lakes and are cut into by the waters of the latter. A wind which drives the water towards the American shore lessens the pressure upon the strata at the Canadian side and consequently permits the water in the wells which penetrate them to fall, while a wind from the American side bringing the water back of course reverses the operation.

MINERALIZED ARTESIAN WATERS.

At various points in Ontario borings have been made which yield mineral waters of varying qualities, some of which have been utilized for their curative properties; but the large majority have either been allowed to run waste or have been choked to gratify the curiosity of the small boy.

VILLAGE OF KINGSVILLE.

Drillings for gas about 2½ miles north-east of Kingsville, Essex county, encountered a flow of water at a depth of 300 feet, strongly impregnated with sulphur and sulphate of magnesia. Two or three miles west of that place a strong flow of fresh water is found before reaching the rock, at a depth of about 30 or 40 feet. At the town itself the rock has been penetrated for 1,000 feet without finding water.

CITY OF ST. THOMAS.

Two wells have been sunk within the city limits of St. Thomas in the hope of finding water suitable for public use. The log of the one sunk at the court house by authority of the county council is given by Mr. James Bell, county engineer, as follows:

20 feet clay, 190 feet hard clay, 30 feet fine putty mixture containing a very fine sand and water, 10 feet hard pan, 33 feet gravel with considerable water, after which the limestone rock was reached and penetrated 7 feet.

The water rose to within 37 feet of the surface, and with a steam pump yielded at the rate of 30,000 gallons per day of 24 hours, the water standing in the well while the pump was working at a depth of 60 feet from the surface. An analysis of the water by Prof. Ellis gave the following result:

Solids	26.040
Chlorine	7.420
Free ammonia	.047
Albuminoid ammonia	.005
Oxygen absorbed in 4 hours	.090

The water is classed as of medium purity.

Encouraged by this result the city council ordered a test to be made in the flats of Kettle creek, about 100 feet lower than the site of the court house, in the expectation of striking a flowing well in the same stratum. Here however the bed of gravel found overlying the rock in the other case was wanting, and the boring was continued into the rock, a black shale being first penetrated, which yielded water, but so strongly impregnated with sulphur as to be unfit for use. Boring was then abandoned, but was afterwards continued by private individuals for about 100 feet farther, the rock proving to be limestone after the first 10 feet.

The well is now flowing at the rate of 8,000 gallons per day, but no use is made of the water, which is so strongly sulphurous as to leave a yellow streak along the sides of the ditch in which it runs.

CITY OF LONDON.

On the left bank of the river Thames at the foot of Dundas street, London, a well was sunk about 30 years ago to a depth of 765 feet, the particulars regarding which were given by Dr. Sterry Hunt in the report of the Geological Survey for 1866.

The strata encountered were clay 70 feet, soft gray shale with a band of hard bituminous shale 20, limestone 600, soft magnesian marl 75. The limestone at 300 feet from the summit was a true dolomite and the marl at the base was also dolomitic, scarcely attacked by cold acids, but effervescing freely by heat. At about 114 feet from the surface two crevices of a few inches each were met with in the limestone, and from this point there is an abundant flow of bright, limpid, somewhat sulphurous water, estimated at 1,000 barrels per hour. This water deposits pure, yellow pulverulent sulphur around its outlet. Its analysis by Prof. Croft gave about two parts in 1,000 of solid matters, consisting of nearly equal portions of sulphates of lime and magnesia, with a little carbonate and traces of chloride of sodium, besides sulphuretted hydrogen. It is worthy of note that the slight sulphurous impregnation previously common to many of the ordinary well-waters of London disappeared on the opening of this great subterranean sulphurous fountain.

The waters of this well have been used for medicinal purposes to a greater or less extent both in the bath and as a beverage for a number of years, and recently a company has been formed under the name of the White Sulphur Springs Company with the view of utilizing them on a more extended scale. The well throws a stream to a height of 40 feet. In a prospectus issued by the Company the statement is made that the well yields at the rate of about 100,000 gallons a day. If this estimate is even approximately correct, there has been a considerable diminution in the flow since the examination made by Sterry Hunt twenty-six years ago.

A number of years ago a well was sunk on the grounds of the Asylum for the Insane to a depth of 2,000 feet. Water was obtained and rose to within 100 feet of the surface, but it was brackish and not fit for use. No record of the strata passed through seems to have been preserved.

TOWN OF CHATHAM.

A well sunk in the eastern end of the town of Chatham about the year 1864 to a depth of 1,000 feet in the hope of finding salt struck a vein of salt water with some oil in hard limestone at 422 feet. Still lower, at about 600 feet from the surface, a copious source of sulphurous water was encountered. Attempts were made to pump the oil, but the volume of water was so great as to prevent successful operations. The water continued to flow for some months, filling a pipe three and a half inches in diameter, and discharging into a neighboring creek, but so strongly was it impregnated with sulphur that the well was voted a nuisance and the owners were obliged to plug it, which they did with some difficulty.

PARKHILL AND VICINITY.

Mr. R. S. Macalpine of Parkhill states that between that town and lake Huron, a distance of 13 miles, there are 50 or 60 artesian wells, varying in depth from 80 to 180 feet, and within a radius of 3 miles from 80 to 156 feet. In a well sunk within the corporation of Parkhill the following strata were presented :

Clay 145 feet, soapstone (so-called) 5 feet, shale 1 foot, hard-pan 1 foot, shale 2 or 3 feet, in which water was found. The water in this well stands at a level of 60 feet from the surface.

Nearly all these wells furnish water in abundance, of varying quality, but generally containing iron, sulphur, etc., in sufficient quantity to unfit it for human use, though cattle drink it readily.

TOWN OF PRESTON.

Artesian borings at Preston are noteworthy from the fact that they have developed a highly mineralized water which is held in repute for its curative powers. Three wells have been sunk there to a depth respectively of 224, 280 and 1,252 feet.

In the first of these, known as the Del Monte springs, the water flows at the rate of 17,280 gallons a day and rises to a height of 12 feet above the level of the river. The water of this well, as well as that of the second, is used in the mineral baths for which the town enjoys a reputation.

The deep well also yields a mineral water which flows at the rate of 11,520 gallons a day, but is used only in flooding a curling and skating rink.

TILSONBURG AND VICINITY.

Mr. Wm. S. Law gives particulars of wells at Tilsonburg, in the county of Oxford, where numerous borings have been made for oil, and latterly for salt, the drill in one case having been put down a depth of 1,947 feet in the hope of striking workable deposits of the latter article.

All the wells bored are flowing, but the water is so highly charged with sulphur or sulphuretted hydrogen and various other mineral substances as to be unsuitable for household use. The water from one well however is in constant use as a beverage, and is also in demand for medicinal purposes.

The water was analyzed by Prof. Croft, and pronounced equal to some other noted waters. All record of the strata passed through has been lost.

Mr. E. D. Tillson adds that nearly all the wells put down some thirty years ago during the oil fever were in the valley of the Big Otter creek, where the blue clay lies in a bed 30 or 40 feet thick, resting upon the limestone rock.

At a depth of about 60 feet in the rock a heavy flow of water was struck, mixed with a little oil. Many of the wells would flow from 30 to 50 gallons per minute, and generally when piped would rise from 40 to 60 feet above the level of the ground; but the water, being mixed with oil and very strongly impregnated with sulphur, was not fit for drinking or domestic purposes, although the product of a few of the wells containing less oil and sulphur was and is yet made use of for drinking. Some people are fond of it and think it conducive to health.

After hopes of getting oil were abandoned some of the wells were sunk to considerable depths in search of salt, a few thin deposits of which were passed through. In most of the deep wells several veins of water were met with, and the deeper the well the more highly charged was the water with mineral substances, in all cases being unfit for use.

About three years ago the quest for oil was renewed, and five wells, varying in depth from 100 to 200 feet, were put down with the same result as formerly, viz: large flows of water and comparatively little oil.

One boring was made on Mr. Tilson's own farm about a mile north of the town, at a point 175 feet higher than the bed of the Otter creek. Here a surface bed of clay 8 feet thick was succeeded by a stratum of coarse sand or fine gravel, as clean and bright as lake gravel, in which at a depth of 18 feet a strong flow of water was obtained, which rose to the height of 10 feet above the ground. The water was clear and of fine quality, with a slight mineral taste, and flowed at the rate of 60 or 80 gallons a minute. Mr. Tillson has connected a three-inch pipe with the well and brings a portion of the water to his farm-house and barn. It is worthy of remark that this flow of good water is found in the superficial beds, while wells sunk in the rock in the valley of the Otter creek below this level produce only water of a decidedly mineral character, unfit for use.

Eight or ten miles north-west of Tilsonburg, in the township of Dereham, a large number of artesian wells have within the past six or eight years been sunk by farmers. In some cases water is reached in the surface deposits, in others the rock must be penetrated, but as a rule good water is obtainable.

Mineral Wells in various Localities.

In the township of Walpole, in the county of Haldimand, numerous artesian wells are put down in the rock a distance of from 25 to 90 feet. An abundant supply of water is obtained, but in very many of the wells it is so impregnated with sulphur as to be unavailable.

At Dunnville in the same county three wells have been sunk, 82½, 80 and 65 feet deep respectively. The water contains sulphates of lime and magnesia, and is unusable. On the opposite side of the Grand river the rock crops out at the surface, and the wells there are not over 10 feet in depth. A peculiarity of the water of these wells is that at certain times it becomes very muddy, apparently as an effect of storms on the lake.

Near Ancaster an artesian well produces a supply of water of a sulphurous character.

No artesian water has been found at Toronto, but along the lake shore a few miles west of the city borings made on the Asylum grounds encountered gas at three distinct levels and a light flow of bitter water in a thickness of over 1,000 feet. A boring made within the last few weeks about a mile to the north-east also struck gas, but reached the Laurentian rocks at a depth of 1,300 feet without revealing the presence of water in appreciable quantity. A bitter saline water was however struck near the bottom of this well.

T. W. G.

THE LAURENTIAN AND HURONIAN SYSTEMS NORTH OF LAKE HURON.

By Dr. Robert Bell, Assistant Director of the Geological Survey of Canada.

This paper is intended to give a brief account of the geology of the country represented on the accompanying map extending from lake Huron northward to lake Temiscaming and from lake Nipissing westward to the Spanish river. It will aim at giving a summary of the various reports of the Geological Survey referring to that region in the light of the most recent views in regard to the rocks of the district, and will cover ground already described by the writer in the annual reports of the Survey for 1865 and 1866, 1875 to 1877 and from 1887 to 1890, by the late Mr. Alexander Murray of the same service in the reports of 1847 to 1857, and by reports made at various times by officers of the Department of Crown Lands.

The geological coloring of the map is compiled by the Director of Surveys in the Department of Crown Lands from the maps and descriptions of Mr Murray, the geological map of the Basin of Moose River, 1883, and that of the Sudbury Mining District, 1890, by the writer, and also the maps accompanying Sir William Logan's Geology of Canada, 1863, as well as from the descriptions contained in the various reports above referred to. As these reports and maps are not very accessible to the public, and some of them are out of print, it is felt that a short summary of their contents, with suitable explanations, arranged in convenient form for reference and illustrated with a geological map, would be found useful at the present time. The colors used are made to harmonize with those at present adopted by the Geological Survey. The topography is compiled from the surveys of the Department of Crown Lands and of the Geological Survey.

With the exception of the larger islands on lake Huron, and possibly a tract in the Sudbury district, the area represented on this map is occupied almost exclusively by rocks of the Laurentian and Huronian systems. Descriptions of these rocks in general and of their relations to each other by the writer are contained in the Section devoted to Geology in the Report of the Royal Commission on the Mineral Resources of Ontario, 1890. But it is now proposed to give a more detailed and local account of the rocks belonging to these systems which are met with in the area represented on the map.

THE LAURENTIAN SYSTEM.

The Laurentian system may be divided into an upper and a lower formation. The latter consists almost entirely of primitive or fundamental gneiss, which is supposed by many geologists to have been originally of an igneous nature, but to have undergone alteration which has produced its more or less foliated character. The upper Laurentian appears to consist of metamorphosed sedimentary strata to some extent at least, while the Huronian rocks are undoubtedly largely sedimentary, but mingled with a varying proportion of igneous rocks, both of which have undergone more or less metamorphism.

Metamorphism.

By this term is meant those changes in rocks which have been produced by pressure and heat, and possibly electricity, acting slowly or through a very long time, and producing molecular or chemical interchanges in their constituents, and causing them to become in a greater or less degree crystalline. The original composition of some rocks is more favorable to metamorpism than that of others.

With a change of conditions, rocks may undergo a second or further metamorphism. The element of time being very important in bringing about metamorphism, it follows that the older rocks are the more subject they have been to have undergone this process. The more ancient rocks have necessarily been those most liable to disturbance from the changes which have always been going on in the crust of the earth, so that they have been moved from their original positions and have been tilted, crushed and contorted more than the newer ones, almost in direct proportion to their age. The very fact of strata standing at high angles to the horizon appears to be connected with the metamorphic processes, and rocks which are locally disturbed, as in certain mountain chains, are found to be metamorphosed, while the same strata in continuation are not changed where they are found nearly horizontal. Great outflows of igneous matter have also in many instances had the effect of altering rocks locally.

A crushing and disturbing force due to the constant shrinking of the earth and acting horizontally at the surface has been going on in its crust from the earliest times. The effect of this force may be seen, not only on the large scale, in the tilting, folding up and faulting of the older rocks, but also in their microscopic structure, thin sections of them very often affording the clearest evidence of their having been subjected to intense pressure, forcing asunder solid grains, grinding them against each other or crushing them to small particles. Another effect of the intense lateral pressure referred to has been to produce in rocks a schistose or a slaty cleavage at right angles to the direction of the force. In the crystalline schists this has been effected by the crushing force, aided often by a shearing movement, causing the component particles to move slowly around till their greater diameters assumed positions at right angles to the direction of this force. In the schistose rocks the cleavage planes of such minerals as possess cleavage have been made to correspond with the directions of the mechanical arrangement of the other particles, so that in cross section the whole texture has a parallelism of its grains, giving it a laminated appearance. Dioritic schists have probably been originally massive diorites, and have had their cleavage structure developed in the manner just indicated. Many geologists believe that some kinds of gneiss have been formed out of massive granite in the same way.

These processes involve an enormous lapse of time, so that a crystalline and schistose condition is *prima facie* evidence of antiquity. Indeed if we exclude those cases of local metamorphism which have been referred to, it may be said, in a general way, the more crystalline and altered rocks have become the more ancient they may be presumed to be.

Notwithstanding the apparent stability of the rocks in this part of the world, far removed as they are from volcanic activity, there exists nevertheless within them a state of perpetual unrest. Unceasing changes are going on in the arrangement of their constituents as illustrated by crystal enlargement, pseudomorphism and decomposition in a petrological sense.

Besides the constant internal changes taking place in the rocks, there is restless action or movement on a large scale throughout the whole body of the earth. One of the primary causes of this movement is the constant shifting of the matter on the surface by the action of air and water or ice. The earth is not a rigid solid, but obeys hydrostatic laws. When a certain weight of matter has been transferred from one part to another its effect is to sink down the part to which it has been transported, while there will be a tendency to rise to a corresponding degree at the point which has been relieved of this burden. These oscillations were probably more frequent and rapid in the earlier geological ages than they are now, but they will continue to go on to a greater or less extent as long as air and water exist to transport matter and disturb the equilibrium of the earth.

Divisions of the System.

The lower division of the Laurentian system is characterized by a monotonous uniformity in the nature of its rocks, which consist of gray and red gneiss, usually much bent or disturbed, and having generally only a rudely foliated structure and a solid or massive character. Its felspar is almost entirely orthoclase, whereas the other species are abundant in the upper division. There is a general absence of economic minerals, and the number of mineral species is small as compared with the latter. The upper division is of a more complex or differentiated character, or comprises a greater variety of rocks and minerals. It possesses more regularity in its stratification and includes great banded masses of crystalline limestones, vitreous quartzites, mica and hornblende schists, massive pyroxene, and both massive and foliated labradorite rocks. Considerable areas of granite and syenite occur in the formation. These, as well as the pyroxene rocks, and perhaps also the hornblendic bands, are evidence of igneous action. The dykes of greenstone and porphyry which cut the upper Laurentian may belong to a later geological period.

Upwards of sixty different mineral species have been found among the upper Laurentian rocks in Canada. They also contain a variety of economic minerals, among which may be mentioned graphite, apatite, mica, serpentine and limestone marbles, limestones suitable for calcining, felspar for porcelain, porphyries and other ornamental stones, pyrite, sulphates of barium and strontium, asbestos, crysotile, building stones, and ores of iron and other metals.

It is not impossible that gneiss may have been formed in more than one way. While some varieties, from their microscopical characters and other circumstances, appear to be of clastic origin, it seems to be equally certain that others owe their foliation to pressure and internal changes which may have taken place in rocks of igneous origin. Dr. Sterry Hunt is of the opinion that we have not yet discovered any rocks which can be regarded as having formed part of the original crust of the earth, that is, if we suppose the crust to have been first formed by the mere superficial cooling of a molten mass, since the earliest rocks of which we have any knowledge all contain water and free silica.

The lower Laurentian gneisses are the oldest rocks with which we are acquainted. Their thickness is entirely unknown, and it may ever be found impossible to arrive at even an approximation to their volume. It must however be enormous. The upper Laurentian, of which some kind of measurement is possible, may be roughly estimated in the Ottawa valley, where it has been more studied than elsewhere, at from 50,000 to 100,000 feet, or nearly 20 miles in thickness, and even much more.

Although the older Laurentian rocks may afford no mechanical proof of the permanent existence of a sea upon the earth, unless their foliated or stratiform character be taken as such evidence, water appears to have been present, perhaps as only temporary precipitations upon the surface, at every stage of their formation. But in the upper Laurentian the great deposits of nearly pure carbonate of lime and of tolerably pure silica in distinct bands afford strong support to the aqueous theory of their deposition, while it negatives that of their igneous origin. An important feature in the general character of the Laurentian system is that its rocks, as a whole, are of an acid nature, or contain a preponderance of silica in their ultimate chemical composition. We shall see further on that in this respect they contrast with a considerable proportion of those of the Huronian system, which are largely of a basic character.

Whether we regard the bulk of the Laurentian rocks as having had a clastic or an igneous origin, the general condition of the surface of the earth does not appear to have undergone any great change while they were being formed, or while the cooling process was going on to the extent of their thickness. Even in the upper Laurentian we have found no proof of the pre-existence of solid rock or dry land such as might be afforded by conglomerates.

A Period of Change.

But with the beginning of the Huronian period came a new order of things. Great volcanic activity took place, and at the same time we have distinct evidence of the permanent abode of water on the surface of the earth and of the wear and tear of the sea on the solid rocks. Immense quantities of volcanic ashes, cinders or tufa, broken rock and other ejectamenta were thrown out, in some cases with explosive violence. Molten matter was poured forth in great quantities from vents and rents in the crust, forming thick sheets and large masses that became incorporated among the marine sediments which were probably accumulating rapidly. The surface of the earth would be almost entirely covered by the sea, which would likely be shallow, hot and full of dissolved mineral matters, the greater part of which have since been eliminated. It would be unfit to support animal or plant life, and it is therefore improbable that we shall ever find any organic remains in this system. Some of the erupted rocks remain massive and unchanged to the present day, except by the internal or molecular action among the constituents themselves, but the bulk of them had become broken up under the strong weathering influences of the period, or by contact with water, and spread out on the bottom of the sea to form the various stratified rocks of the system. The general character of the Huronian rocks may therefore be said to be pyroclastic, this term signifying that although fragmental they have nevertheless had an igneous origin. The Huronian rocks of lake Superior, and the country north and west of it, consist largely of greenish schists which are, chemically speaking, basic as distinguished from the gneiss of the Laurentian, which, as already stated, is of an acid or silicious character. A considerable proportion of the great Huronian belt is made up of greenstones and allied rocks that are also basic.

Rocks south of the Huronian Belt.

In the country represented upon the map, the rocks lying between the great Huronian belt and the shore of Georgian bay appear to belong to the upper Laurentian formation. In the French river region the gneisses are generally characterized by much regularity in their dips and strikes, which often maintain the same course and about the same angle of inclination for long distances. The dips vary from a horizontal to a vertical attitude, but in the majority of cases they are about intermediate between these.

This region is noted for its peculiarly straight and almost parallel rocky channels, many miles in length, having a general course nearly east and west, which are intersected at large angles by other channels almost equally straight, the whole forming a sort of network quite unique in its character. Some of these channels belonging to both sets run with the strike of the gneiss, which when mapped has a sort of zig-zag arrangement on a large scale, while the others follow the lines of the principal set of joints. It sometimes happens that between two leading joint-planes other and parallel joints occur, unusually close together, breaking the rock up into blocks which have been removed by glacial denudation, thus producing these channels. The angles of dip being only moderately steep, those channels which follow the strike occupy ditch-like notches formed along the outcrops of particular sets of beds which have been more easily excavated by eroding agencies than those on either side of them.

It will be observed that the French river flows in two principal east-and-west channels between lake Nipissing and its rocky delta, and that about half way down they both jog to the southward at right angles. This interruption in their course is perhaps originally due as much to some north-and-south break or disturbance in the rocks as to changes in the strike. The long east-and-west channels, whether parallel with or transverse to the stratification, are also probably situated upon lines of crushing, and possibly of some dislocation, along which the strata have been broken up so as to permit of the deeper penetration of the surface waters and the consequent decay of the rock prior to the glacial period, during which these channels have been excavated below the general level of the country. They are really only long and very narrow lakes, with slight falls or rapids between them, and they persist in their courses uninfluenced by the changes in the strike of the rocks they pass through. Besides the channels shown upon the older maps, there are many others in the French river country, all of which belong to the reticulating system of waters which forms so remarkable a feature in this whole district.

The curious rocky delta of the French river has a breadth across its mouths of fifteen miles. The channels, which are very numerous as we leave the coast, form three groups, the east, middle and west, each of which unites by cross channels into one at a short distance up. They are all nearly parallel and have a general northeast and north-northeast course as we enter from Georgian bay. The gneiss in the whole interval covered by these channels runs parallel with them and has a uniform dip to the south-east and east-southeast, with an average inclination of from 40° to 60°. This general strike extends for twenty miles inland from Georgian bay, when it becomes disturbed, and a little further on is cut off by a northwesterly strike in similar gneisses which prevail on the upper part of the French river and the country to the northward of it.

In the central part of the course of the river the strike in different intervals runs about north and south, east and west, northwest and northeast, while between these groups of tolerably straight bands it is often more or less bent or distorted. In some parts of the French river region, even where the strikes are regular, Mr. Murray considered the structure to indicate a series of anticlinal and synclinal folds, in which some of the strata are repeated, and that the thickness of the gneisses is in consequence made to appear much greater than it really is. But after making allowance for this partial repetition, the actual thickness must be very great.

Southeastward of the mouths of French river, along the shore of Georgian bay, the rocks are everywhere well exposed, and the structure of the gneiss and associated strata or their local configuration is well brought out by the erosion to which they have been subjected. This fact is graphically illustrated by the recent charts of Captain Boulton.

Locally the run of the stratification is often indicated by the form or direction of the points and bays, the larger islands and the chains of smaller ones. The curving outlines of the islands, channels and inlets opposite to Penetanguishene, the twisted appearance of Parry island and of the channel on its southeast side, as well as the singular straightness of Partridge bay, the Long inlet, the points on the west side of Parry island and about Shibaishkong island, all correspond with the local strike of the rocks and are due to the effects of denudation, which has formed channels along the courses of the more yielding strata, and left ridges or higher ground where the rocks resisted decay and erosion. Along this shore there is however a class of channels and inlets due to another cause, namely, the existence of dykes of trap and breccia and of granite veins, and also of parallel joints or cracks along which the rocks have been rendered more decomposable; or these latter may have acted merely as starting points or guiding lines for the action of glaciers or other denuding agencies which constantly enlarged and deepened the depressions, once they had been commenced. The channels and inlets of this class usually run nearly east and west and have steep sides, while those which follow the stratification have usually some other course and are not so abrupt.*

These lines of rock-crushing and subsequent erosion have doubtless had a great effect in producing the river and lake features in most of the regions occupied by our upper Laurentian rocks, as well as in some other metamorphic districts of Canada. Dykes of greenstone and breccia have also played an important part in this connection, generally giving rise to river-channels and long lake-basins, but occasionally, where hard or resisting, having the opposite effect, producing ridges, or causing falls and rapids where they happen to cross streams.

Near the head of Byng inlet, a short distance southeast of the mouths of French river, a brecciated rock is exposed near the edge of the water which apparently forms part of an east-and-west dyke, along the course of which the channel of the inlet and of Maganetawan river have been excavated. Parallel to this dyke are joints stained red by oxide of iron, giving a dry and crumbling character to the gneiss along their course, which is east and west, while the gneiss they cut runs in various directions transverse to the joints.

On the lower or western north channel of French river Mr. Murray noticed a friable brick-red quartz-syenite at the Grand Recollet falls and for some miles below it. This probably belongs to an eruptive dyke-like mass, following a line of weakness in the course of the channel.

In the French river country the gneisses are most commonly of dark reddish-grey shades, and they comprise both the mica and the hornblende varieties. Their texture is usually from medium to coarse grained. As a rule the latter are gray and darkly colored, while the finer grained varieties are generally reddish. Silicious belts, in some cases amounting to vitreous quartzites, bands of mica schist with garnets and of hornblende schist occur among the gneisses, and in some localities they are largely developed.

* Dr. Robert Bell in the Report of the Geological Survey for 1876, page 195.

Veins of coarse reddish and nearly white granite running in different directions cut the hornblende and mica schists and schistose gneisses about the mouths of French river, and similar veins are also met with occasionally in the interior. A few greenstone dykes were noticed along the river, but they do not appear to be very common in this region.

Quartz veins running in various directions are of frequent occurrence in the French river region, but they are all of a "hungry" character, and none of them have been observed to carry economic minerals in promising quantities.

The dividing line between the Huronian and Laurentian systems runs northeastward from the head of Shibaonaning or Killarney bay. Between this locality and the middle of Philip Edward island, including the township of Rutherford and most of Carlyle, the rock is a massive red quartz-syenite or hornblende-granite, which occasionally shows patches of an indistinctly foliated character; but this rock does not appear to extend far inland, although it occupies about twelve miles along the coast. Mr. Murray mentions the occurrence of a similar rock, which seems to have a breadth of about two miles and a length of about four miles, in a northeasterly direction between the western and middle groups of mouths of the French river.

In the region covered by the map certain differences may easily be observed in the general characters of the Laurentian rocks on the southeast side of the great Huronian belt as compared with the rocks on its northwest side, which we have for the present classified for convenience with the same series, because we have not yet found it practicable to separate them by a definite line from the undoubted Laurentian still further northwest, with which they are continuous. Between the shore of Georgian bay and the Huronian belt, and about as far north as the line of the Canadian Pacific Railway, the gneisses are of the typical Laurentian varieties, all evenly stratified and regularly arranged in anticlinal and synclinal forms, according to the structural laws governing stratified rocks. The angles of dip are on an average not far from 45°, although in some cases they are nearly horizontal and in others almost vertical. Except in a few localities the bedding is not contorted, but runs straight and evenly for considerable distances, and these gneisses have every appearance of being altered sedimentary rocks. Red and grey varieties are represented in about equal proportions, and they alternate with each other in both thick and thin sheets. They are mostly mica-gneisses, although the mica is present in rather small proportions, but in some cases hornblende replaces the mica in whole or in part.

No beds of crystalline limestone have been found among these rocks west of the longtitude of Iron island in lake Nipissing, where this rock has been noted by Mr. Alexander Murray. These limestones are also associated with them on some of the islands in the eastern part of this lake and at lake Talon on the Mattawa. Further east, in the Parry Sound district, the writer in 1876 traced five distinct brands of Laurentian limestones running for considerable distances in a northerly direction from the shore of Georgian bay.

The Laurentian rocks between Georgian bay and the great Huronian belt, from the characters which have just been described, would therefore be classified along with those of the counties of Ottawa and Argenteuil, which belong to the upper portion of the system.

Rocks northwest of the Huronian Belt.

On the northwest side of the great belt the conditions are different. At some distance to the northward of this belt the heavy contorted gneisses of the lower Laurentian cover an immense area, but there is an intermediate region in which red hornblende granites prevail, but they are mingled in some parts with gneiss. The granites are largely developed along the northwest border of the Huronian belt all the way from the west side of lake Wahnapitae southwestward to the Sable river, and probably still further. From this geological boundary they extend northwestward out into the midst of the lower Laurentian gneisses to a variable distance, their greatest extension being unknown. Along the main line of the Canadian Pacific Railway they are found all the way from the junction of the Huronian at Onaping station to Spanish Forks and westward from the railway to the Spanish river, but beyond these limits the country has not been carefully explored.

Similar red hornblende granite, occasionally showing gneissoid texture, forms an elongated area in the middle of the Huronian belt in the Sudbury district, extending from near the South bay of lake Wahnapitae southwestward to the township of Drury. The southern boundary of the main granitic area crosses the Spanish river midway between the northern and southern lines of township 111, whence passing westward it sweeps round to the south and forms a promontory in the townships of Gough and May. From the northern part of the latter township the boundary between the granite on the north and the Huronian quartzites, greywackes and schists on the south runs westward parallel to the shore of lake Huron, as far as the township of Proctor, were it turns northwestward and the Huronian rocks occupy a large area lying to the northward of Algoma Mills.

Although the granites which have just been described are provisionally classed with the Laurentian, it is uncertain that they are all really of this age. In some localities they are so intimately associated with gneisses of the ordinary Laurentian types that it would be impossible to draw a line between them. In such cases they may have been formed out of portions of the gneiss softened by heat and re-crystallized after having lost their stratiform character. In other places it is quite possible they may be due to the alteration of arkose or greywacke similar to that which is so common in the adjacent Huronian series. Or it may be that these granites are mainly eruptive in their origin. The writer has pointed out in various reports on the Archæan rocks of northern Canada that the commonest situation of the granitic areas among these rocks is at and near the junction of the Laurentian and Huronian series, and there is perhaps no good reason yet known why they should be assigned to the one more than the other.

In the region at present under consideration, along the line of contact between these granites and the Huronian quartzites, schists, etc., the rocks are often much broken up and intermingled with one another, both in great masses and smaller fragments. This effect has probably been produced when the granite was in a soft condition and subject to intense pressure, coupled with more or less movement. Referring to the last mentioned consideration, it is not improbable that faults of considerable extent have taken place along the lines of junction between these two classes of rocks, not only in this region but in other localities where the Laurentian and Huronian rocks come into contact. This is only what we might expect to occur along the lines dividing rocks having unequal powers of resisting the great strains to which the crust of the earth must have been subject in all ages. These faults may be looked for more especially at those parts of the junction of the two sets of rocks which have been most exposed to lateral pressure, and along those portions of the lines of contact which are tolerably straight for considerable distances. The bed-planes of the Huronian and Laurentian rocks on the opposite sides of a contact thus faulted might show some want of parallelism, and from this accident a general unconformity of the two series might be erroneously inferred. The few instances of apparent local want of conformity which have been observed seem to be capable of explanation in this way. One of these instances may be seen at the Wahnapitae river where it is crossed by the Canadian Pacific Railway.

Within the area represented on the map, besides the gneissic and granitic rocks flanking the great Huronian belt, there remain to be noticed a few inliers of these rocks. One of them, consisting of gneiss, lies between the north and northeast arms of Temagami lake. Another, also of gneiss, which has been described by the writer in the report of the Geological Survey for 1875, surrounds Paul's lake on the upper part of Sturgeon river, and appears to extend for some distance to the south of it. A short distance east of the angle formed by the junction of Proudfoot's east-and-west and north-and-south lines an area of red hornblende granite was discovered, which may extend to the northward, but its limits have not been traced out. Two belts of gneiss projecting from the northward cross Montreal river, one at Elk lake and the other at the sharp turn in the river about midway between this lake and the junction of the east branch. Both of these belts appear to terminate at no great distance to the south of Montreal river.

THE GREAT HURONIAN BELT.

Sir William Logan and his assistant, Mr. Alexander Murray, after examining the crystalline rocks of lakes Superior and Huron, gave the name Huronian (at the suggestion of Dr. Sterry Hunt) to all those of both regions which lie above the granitic series which they called Laurentian. These terms were not restricted to any particular area, but were meant to designate the two great divisions of the Archæan rocks and to be of general application in Canadian geology. Both sets of rocks extend into the United States and the Canadian names, having priority, were adopted there. But of late years efforts have been made to abolish the convenient and well established designation Huronian, except for one small area of these rocks lying on the north side of lake Huron and forming only a part of the great belt which is continuous from lake Superior to lake Mistassini, a distance of 700 miles following its axis, on the asserted ground that the selected part alone forms what some geologists call the "typical Huronian." I cannot however understand why one particular portion of one belt of rocks of the Huronian system should now be selected for this distinction to the exclusion of the remainder of the belt which is continuous with it, and also of other areas of rocks which are most naturally placed with them and which were expressly included by Logan when he classified them and gave them this name.

The rocks of the Huronian system as defined by Logan consist of crystalline schists in great variety, quartzites, conglomerates and agglomerates, clay-slates, greenstones, dolomites, etc. At the time referred to, more than forty years ago, the science of petrology was in a crude state compared with its present position, and the microscope was but little used in determining the nature of rocks. Hence Logan did not recognize the volcanic or rather pyroclastic character of a large proportion of the Huronian rocks. Some of the rocks of the system, such as the quartzites and clay-slates, although they do not themselves show a direct igneous origin, may have been derived from the products of volcanic activity through the intervention of water.

Owing to the pyroclastic origin of the majority of these rocks the various members in any region are not usually persistent for any great distance, but diminish in volume and are replaced by other beds which increase in thickness as the first diminish. As these rocks are usually tilted to high angles, the sections afforded by the surface of the earth are generally nearly at right angles to the bedding, and when mapped often show the interlocking character of the different bands as they terminate in both directions. This want of persistence is exhibited on both a small and large scale, so that the general characters of wide belts of Huronian rocks differ much in different regions.

In other parts of the world, such as Scandinavia and Scotland, where Archæan rocks are largely developed, series corresponding with our Laurentian and Huronian are met with. Nowhere have rocks of a different character been found to intervene between them. We might therefore infer that in a general way the two systems are conformable to one another. This inference is borne out by our observations over the enormous area of Archæan rocks which we have in the Dominion. It might be expected that in some parts of this great area a local want of conformity might be detected at the same time that the two systems were conformable on the grand scale. But in the few instances where there appears to be a want of parallelism in the stratification on the opposite sides of the contact, this is more probably due to faulting.

On the other hand, we have observed numerous instances where there is a gradual and conformable transition from the lower into the upper series. The beds of passage as a general rule consist of hornblende and mica schists alternating with fine-grained gneisses, and these are followed by other crystalline schists. In the Huronian areas of lake Superior crystalline schists predominate, although representatives of all the other varieties of the rocks of the system are not wanting, while in the lake Huron region and to the northeastward of it greywackes and quartzites with clay slates are the most conspicuous rocks, but the various crystalline schists similar to those of the lake Superior region are likewise to be found.

An impression has got abroad in some quarters that one of the distinguishing features of the Huronian rocks on the north side of lake Huron is that they usually dip at very moderate angles. Even if this were true, it would be a matter of no consequence in chronological geology. It is however only an incorrect assumption, and on the contrary as a rule the rocks of that region are highly inclined, as shown in a section by Mr. Murray in the report of the Geological Survey for 1856, and in my own section across the Sudbury district published in 1891. They do however dip at low angles in certain limited areas, such as the tract lying northward from St. Joseph's island and in that situated to the east of lake Wahnapitae, and again between lake Temagami and the Montreal river. But instances of equally low dips are to be seen among the upper Laurentian gneisses, as for example in a large region to the northward of Montreal.

Although in the lake Superior region and thence westward to Lake of the Woods the Huronian rocks consist so largely of crystalline schists, still there are silicious rocks among them, which may be the equivalents in diminished volume of the quartzites of lake Huron; also conglomerates, clay-slates, serpentines, dolomites, etc., and on the other hand there is an abundance of crystalline schists among the Huronian rocks of the lake Huron region. Conglomerates occur at various horizons among these rocks in both regions, but any single conglomerate bed is probably only of local occurrence and cannot be held to be the equivalent of any particular conglomerate in another region. As these conglomerates cannot be connected with one another in different Huronian areas it can scarcely be said that they represent a general break in the chronological continuity of one part of the system with another, much less a time break between this system and any other.

From what has been said of the nature of the Huronian system we should not expect even contemporaneous parts of it to be everywhere represented by the same kind of rocks. On the contrary, great local differences might be looked for at the same horizon. In a given region one variety may be largely developed, and yet in another this may be entirely replaced by a different rock without there being any difference in the age of the two. Rocks like those of the Lake of the Woods may be the equivalents in time of those of the north side of lake Huron, or of some other part of the system where the lithological difference is equally great. Still we have always admitted that perhaps the prevailing schistose series of the lake Superior region may belong to an older part of the system than the quartzite, clay slate and greywacke series of lake Huron, which apparently forms the newest portion of the great belt. Thus the area characterized by the great development of quartzites in the region extending from lake Huron to lake Abittibi may be somewhat newer as a whole than those portions of the series where the quartzites are in small amount or entirely absent. At the same time it is not to be forgotten that the quartzites of the region mentioned are associated with a variety of crystalline schists, such as may be seen on Spanish river, around Temagami lake, on Montreal river and in the region to the northward of it. The stratigraphical sequence of the various kinds of rocks found in the Huronian belt within our region has not yet been ascertained with sufficient certainty. The following descriptions of these rocks are therefore not given in the supposed order of their superposition.

Quartzites.

It is an interesting fact in connection with the origin of these rocks that the quartzites and clay slates are so often found together. The decomposition of the arkose or greywacke and the separation of the silicious grains and the clayey portion would give rise to these two kinds of rock. Or they might result from the decomposition of the binary granite, from which the greywacke itself is probably derived, by the separation of the quartz grains from the argillaceous matter that would be produced from the felspar. Nearly all the quartzites contain more or less felspar, and sometimes it is present in large proportions, giving the rock the general outward appearance of granite. In some instances observed by the writer this mixture had become so far metamorphosed back into granite that it required to be examined in thin slices under the microscope before it could be decided that it had ever been a clastic rock at all.

These highly felspathic quartzites are abundant along the North river canoe-route from lake Mattagamashing (just east of lake Wahnapitae) to the upper part of Sturgeon river, and again west of Lady Evelyn lake, which lies north of Temagami lake. In other regions however the proportion of felspar in these rocks is generally small, and the texture of the nearly pure quartzites varies from compact with conchoidal fracture and composed of microscopic grains up to coarsely granular, made up of small pebbles closely crowded together. Some beds in almost every large outcrop of these rocks are of a distinct conglomerate character, the pebbles being well rounded and almost all of white quartz.

In the country just north of Bruce Mines, and again on the north side of Goulais bay, lake Superior, some beds and groups of beds of these conglomerates contain pebbles of red and dark jasper and light-colored chalcedony, thickly scattered among others of white quartz, all in a matrix of white quartzite. This beautiful rock has long been known as jasper conglomerate, and forms a fine ornamental stone, but owing to its hardness it is expensive to cut and polish. A few scattered pebbles of jasper are found here and there in the quartzites all the way from the above localities to Montreal river.

Light grey and nearly white quartzites form the north shore of lake Huron from the mouth of Spanish river eastward to Killarney bay. They constitute the LaCloche mountains, which run as two and sometimes three parallel ridges close to the shore, and nearly due east and west with the strike. The height of the front ridge varies from 400 to 755 feet above lake Huron, but the altitude increases in the continuation of these hills to the eastward, and it rises at one point to an elevation of 1,180 feet. The dip is everywhere nearly vertical. Similar quartzites, also standing nearly on edge, form the long and high points jutting out into lake Huron in a southwesterly direction between McGregor and Killarney bays. The strata forming these points are probably repetitions of those of the La-Cloche mountains, on the opposite side of a synclinal ot nearly vertical strata, one extremity of which would be in the vicinity of the east end of lake Panache. The quartzite of the points and islands south of Frazer bay continues southwestward, and appears on Heywood island, and further on upon Grand Manitoulin island, at the head of Sheguiandah bay, and thence past the northern sides of Bass and Pike lakes. Quartzites, mostly of light colors, constitute the prevailing rock around lake Panache and the great bend of Spanish river, and northeastward to the township of Broder, but beyond this, for some distance on the general strike, they diminish in volume, and a considerable proportion of what remain merge into greywackes in passing through the contracted part of the belt in the Sudbury district. Still further on in the northeastward strike, or in the country to the eastward of lake Wahnapitae, the greywackes have passed into or have been replaced by clay-slates and argillites, dipping at much lower angles.

Northward of lake Wahnapitae the quartzites are again met with in great abundance Along the upper Wahnapitae river they strike north-northwestward parallel to the Laurentian boundary in that direction, and dip at high angles. On the North river chain of lakes the general strike is east of north, turning more easterly in approaching Sturgeon river, beyond which the quartzites run northeasterly towards Lady Evelyn lake and Maple mountain to the west of it. These rocks are exposed in numerous places along the main Montreal river, and both its branches south of the great bend. Still further north they are largely developed in the country along the height of land westward from its intersection with the north and south inter-provincial boundary line.

In the region northeast of the St. Mary river the quartzites show considerable differences of color, and on this ground Mr. Alexander Murray separated them into different bands. In the southern part of the district shown on our map they are nearly all of light shades, but near its northern border there are red, pink and purple varieties. These are however of local occurrence. Greenish and yellowish tinges are common in all parts of the distribution of the lighter varieties.

Clay-slates and Argillites.

The term slate should be given only to rocks formed principally from clay, in which parallel cleavage planes have been developed independent of the bedding. It is not properly applied to those crystalline schists in which the cleavage is more or less imperfect and the planes are not parallel to one another. Argillites are claystones in which the slaty cleavage has not been developed.

Confining our remarks always to the area represented on the map, rocks of these two kinds are met with most largely in the country between lake Wahnapitae and Sturgeon river, along that stream between the Maskinougé and Round lake branches, about the north end of Temagami lake, and thence by Lady Evelyn lake to Montreal river, and on the latter; likewise along the Matabechawan river, which discharges into the foot of lake Temiscaming. These slates are mostly of olive or bluish green, purplish, drab and gray colors, and are often barred across the cleavage with narrow parallel bands of different shades. At the northern outlet of Temagami lake a greenish compact variety is marked by thin interrupted black bars. This rock, when cut, takes a smooth surface, and was much prized by the ancient Indians for ornaments and ceremonial stones.

These principal accumulations of slates and argillites appear to be in a general way about contemporaneous with the quartzites, that is to say, they were being deposited in the above localities at the same time that the quartzites were forming in others. Where they occur in smaller volumes they are sometimes found in proximity or interstratified with one another. As already stated, they may both be derived from the greywackes, which form so large a proportion of the rocks of the great Huronian belt in this region; and the greywackes in their turn are evidently made up of the *debris* of a quartz-felspar rock or binary granite. Or they may have been formed directly from the decomposition of this rock and its rearrangement by water, the silica and the undecomposed felspar, when any of the latter remained, going to make the quartzites, while the fine mud resulting from the decay of the felspar was carried elsewhere, and now constitutes the slates and argillites. As far as our present knowledge goes, the quartzites therefore cannot be said to be either older or newer than the slates of this part of the Huronian series.

The roofing slates found among the metamorphic rocks of the Eastern Townships in the province of Quebec are probably of somewhat newer geological age than those just described, which in some places may be found suitable for roofing purposes. Among the localities where the argillites or non-cleavable varieties occur may be mentioned the southern part of Mattagamashing lake, Koo-ka-gaming and Lady Evelyn lakes. Good cleavable slates occur on the Canadian Pacific Railway a short distance east of Algoma Mills. Felsites are sometimes found associated with the slates and quartzites, but they are more abundant among the greywackes.

Dark gray or drab and almost black clay slates are found along the Spanish river, in the northern part of Baldwin, and at the falls on lot 1, fifth concession of Nairn. Similar slates are met with on the Canadian Pacific Railway in the southwestern part of Graham, and again just south of Geneva lake. They are also said to occur in the township of Drury and a short distance east of Bannerman lake.

Greywacke or Arkose.

In some parts of our region a rock which may be described under either of the above names is met with in great abundance. It has some resemblance to sandstone, but does not usually occur in distinct beds with parallel faces, and is generally either massive or divided by joints or a rough sort of cleavage. Under the hammer it breaks readily, and may be easily bruised or scratched, thus showing the presence of a considerable proportion of ingredients softer than quartz. It has an ashy appearance, and its color is usually some shade of ash-gray. On closer examination it is found to consist of comminuted granitic *debris*, and generally holds quantities of pebbles and angular fragments of all sizes of the granite itself. The latter are mostly of the same character in all parts of the district, and consist of a binary granite or quartz-felspar rock of either a red or gray color. Fragments of gneiss and other crystalline rocks are occasionally mingled in small proportions with those just described. Under the microscope the matrix or finer portion of this rock is seen to consist of somewhat rounded grains of quartz, and more angular ones of felspar, with a filling of fine serecite or of some dark amorphous mineral.

Rocks of this kind occur here and there in almost all parts of the Huronian belt within our region, but they are particularly abundant in the narrowed portion in the

Sudbury district and around Temagami lake and Rabbit lake to the east of it. They are also common in the Onaping and Straight lake outliers and all along the Spanish river, below the granite area, and thence westward as far as Mississaga river.

Sometimes, as on the Montreal river, the included fragments of granite attain the size of boulders, and these, as well as the smaller inclusions, may occasionally be found so closely packed together that only the interstices are filled by the finer material. The fragments are most common in the greywackes where the latter occur in large volume, and in these cases there is little evidence of stratification. The more uniformly-grained varieties, without angular fragments, are often found interstratifying quartzites, as in the Sudbury and Whitefish lake regions, and they may be seen containing every proportion of quartz grains till they themselves become quartzites.

There was no doubt great volcanic activity on the earth at the time these greywackes and their associated rocks were being formed. The thick unstratified and brecciated masses of greywackes may represent volcanic ashes or mud with stones thrown out upon the land or in shallow water, while the stratified varieties may have been similar ejectamenta thrown into deeper water and modified by the currents or waves of the sea. Some of these rocks, whether stratified or otherwise, may represent volcanic products which were originally poured into the sea in a molten condition and became broken up and disintegrated. The glass breccia already referred to as forming such a thick belt in the Sudbury district is direct proof of volcanic activity with explosive violence on a scale probably grander than any such action in modern times. Even without this and many other proofs which might be cited from the earliest records of the rocks themselves, it would only be in accordance with the general geological history of the globe to believe that volcanic or igneous action was going on upon the surface more generally and on a greater scale in the earlier than in the later geological times.

From a study of the greywackes and the rocks associated with them there would appear to be little doubt that the former constituted the crude material from which the quartzites and clay-slates were derived by the modifying action of water. Again by the action of time, pressure, heat, electricity, and perhaps other metamorphosing agents upon different varieties of greywacke, some of our granites, syenites, gneisses, felsites and possibly other rocks were formed. Many instances were noted in the Sudbury district where the more massive greywackes exhibited a proneness to revert to granite again, while some of the stratified varieties showed different stages of their passage into gneiss, and again certain of the finer-grained and more homogeneous kinds had been altered into felsites.

Slate-Conglomerate.

Some of the argillaceous varieties of the greywacke containing pebbles of granite, and occasionally some of quartz, jasper, etc., and having more or less slaty cleavage, were called slate-conglomerates by Mr. Alexander Murray, and he even extended this term so as to include massive brecciated forms of greywacke, which show no cleavage at all. This name was also given to certain Huronian schists containing rounded pebbles and boulders, and likewise to dioritic schists full of lens-shaped inclusions parallel to the cleavage or bedding, and which in cross-section look like elongated pebbles but which may be of a concretionary character in the majority of cases. They are often inconspicuous or difficult to distinguish on dry surfaces of the rock, but when wet are quite distinct, having a lighter color than the matrix. But they do not appear to differ much in composition from the rest of the rock. These rocks, which have sometimes been called dioritic schist-conglomerates, are very common in the lake Superior region, but they appear to be scarce in our present district.

Imperfect Gneisses.

Imperfect gneisses are met with in most of the Huronian areas in both the lake Superior and lake Huron regions, but they always occur in limited quantities. They differ from the Laurentian gneisses in being usually finer grained and less perfectly crystalline. Under the microscope they sometimes show traces of clastic origin. In all of the numerous cases tried by the writer it was found that they invariably contained carbonate of lime, whereas the Laurentian gneisses are seldom calcareous. Where their crystallization has been coarse enough to observe their felspars easily these have sometimes proved to be of triclinic species, while the felspars of the Laurentian gneisses are chiefly orthoclase.

GREENSTONES.

Within that portion of the great Huronian belt which traverses our district are numerous areas of greenstone, varying in dimensions from masses too small to define on the map up to others many miles in length. The word greenstone is used in this paper to include a variety of trappean rocks which cannot always be distinguished from one another in the field. These crystalline masses have often undergone metamorphism as well as the sedimentary rocks, and it sometimes happens that even a microscopic and chemical study of them in the laboratory fails to prove what their original condition has been. The term greenstone, which includes them all, is therefore a very convenient field-name. In the Sudbury district they consist of diabases, diorites and gabbros. The last named constitute some of the dykes, while the others shade into each other, and as a class may be divided geologically into three groups.

The first of these consists of masses of highly crystalline dark green diorite (sometimes passing into diabase) of medium texture and holding disseminated specks and spots of pyrite, pyrrhotite and chalcopyrite. These masses occur principally among the greywackes, quartzites and clay-slates, and with few exceptions their greatest lengths are in the direction of the general strike of the surrounding rocks. They may have been originally laid down as molten sheets in nearly horizontal positions with the enclosing strata, and subsequently tilted to the present high angles of inclination. In a few cases the lower surface of a greenstone mass may be seen filling inequalities which seemed to have been worn in the underlying rock prior to the advent of the greenstone. As these masses appear to have become incorporated with the strata before the latter had assumed their present positions it becomes uncertain that they are all intrusive, although some of them probably are so, but their original positions with regard to the horizon have been changed owing to the subsequent folding which has taken place in the crust of the earth. Greenstone masses of this kind are found in the Huronian belt all the way from the shore of lake Huron northward to the border of our sheet, and thence for a great distance towards James bay. They are numerous and often large in the Sudbury district, where upwards of fifty occur, and also around lake Tamagami and in the valley of the Montreal river, but towards lake Huron they become smaller and do not form so prominent a feature in the geology of the region as they do further north.

Our second variety of these rocks has a grayer color and more coarsely crystalline texture, while the disseminated specks of metallic sulphides are not by any means so abundant as in the first. Its composition appears to be always that of a diabase. This rock forms three distinct belts among the granites and gneisses of the Sudbury district, and they appear to cut through them as intrusive masses. They all run northeast and southwest.

Windy lake on the main line of the Canadian Pacific Railway lies upon the central portion of the most northwesterly belt, which has there a breadth of about one mile, but narrows to a point in the northeastern part of Levack on the one hand and in Trill on the other, the total length being about eighteen miles. The second belt runs northeastward through Morgan towards Sagi-tchi-wai-aga-mog lake, while the third runs from the township of Creighton to the vicinity of Whitson lake.

The third variety differs from the first mainly in being schistose in some parts, and in frequently containing rounded and angular pebbles and masses of all sizes and of various kinds of rocks, but especially of quartzites, other varieties of greenstones, granites and greywackes, thus constituting agglomerates and breccias. These portions appear to run in ill-defined bands about parallel with the longest diameters of the masses. The greenstone belt which extends from Garson to Graham belongs to this class, as do also the areas of this rock in the fourth and fifth concessions of Denison. All these lie against the southeast side of a long granitic area, and it may be that they have suffered more from lateral pressure coming from the southeastward than the dioritic masses described under the first division, which may have been protected by the more yielding rocks with which they are surrounded. Examples of the greenstone agglomerates and breccias referred to may be seen near the Blezard, Stobie, Copper-cliff, Crean and Vermilion mines, and also where the main line of the Canadian Pacific Railway crosses lot 8 in the fourth range of McKim, and again where it crosses lot 5 in the fifth concession of Moncrieff.

DIABASE DYKES.

Dykes form an interesting feature among the rocks of our district, and they may also prove to have some bearing upon its economic geology. They consist of gabbro and olivine diabase, and are of rather frequent occurrence in some sections. As far as direction is concerned they may be said to belong to two sets, the course of one varying from west-northwest to northwest, and of the other from north to north-northeast. Most of them decompose more rapidly than the containing rocks, and their positions may be recognized by the depressions they form on the land and the channels in the lakes. On the shore of lake Huron some of those belonging to the northwesterly set may be seen in the vicinity of Shibaonaning or Killarney, and around Frazer bay. Many dykes of both sets are shown on the geological map of Sudbury district by the writer. Around Ministic lake in Ermatinger and Cascaden, where a number of them cut the gneiss, their general course is northwest. Almost in continuation of these, a large dyke at the junction of Agnes river with the Spanish in township 108 cuts the granite there in the same direction.

Dykes belonging to the northwesterly set may be seen here and there along the main line of the Canadian Pacific Railway between Sudbury Junction and Straight lake. Between Sudbury and the Murray mine and again between Windy lake and Cartier station they have facilitated the building of the line by the depressions which now mark their courses through the rocky hills whose general course lies across that of the railway. In the granitic region between the Onaping and upper Vermilion river dykes belonging to both sets are met with. A large dyke running north-northeast crosses the Vermilion river near the middle of the east line of township 66.

The basin of Onaping lake appears to be excavated along the course of parallel dykes cutting the granite and gneiss in a northerly direction. The lake is about twenty-six miles long, and except towards the south end is very narrow. In some parts the shores are formed by the dyke walls, to which patches of greenstone are still adhering. A large dyke running a little west of south is traceable along the east side of the southern part of the lake. A dyke which may be a continuation of this occurs also on lot 4 in the third concession of Moncrieff.

A short distance north of the head of Onaping lake we pass over the height-of-land and come to the head-waters of the Mattagami river, which flows northward in nearly the same longitude and falls into the western side of the lake of the same name. Mattagami lake has about the same length as Onaping, and is also narrow. Its outlet flows northward in the continuation of the valley, and at about seven miles falls into the head of Kinogamissé lake, another long narrow sheet of water, also running north and south and having a length of twenty-two miles.

On the course of the river connecting Mattagami with Kinogamissé lake a great north-and-south dyke makes its appearance, and below the latter lake large dykes, cutting the Huronian and Laurentian rocks and all having a northerly course, are met with at intervals along the Mattagami river until it enters upon the Silurian and Devonian basin extending to James bay. Several of these occurrences may be only different sections of one great dyke. Some of them are 300 to 400 feet wide. They are more compact near the walls than along the centre, which has been more easily eroded and in some parts forms the channel of the river.

The head waters of Moose river, from the Missinaibi to the Abittibi, covering a breadth of 120 miles in the lattitude of Abittibi lake, comprise upwards of a dozen nearly parallel north-flowing branches which afterwards converge to form the main river. The Montreal river is remarkable for drawing its waters from several nearly parallel streams, also flowing north, but they fall into a valley in which they are immediately turned round to the eastward through more than a right angle and pursue almost a straight line southeast to the Ottawa. The north and south valleys of these streams belong, as far as their origin is concerned, to the same set as the extraordinary parallel valleys of the basin of Moose river. Dykes and elongated masses of greenstone with a general north-and-south course were found along both the east and west branches of the Montreal river, and it may be assumed that they also exist along the other parallel tributary streams and lakes of this system.

As far as our present knowledge goes, this parallelism of the water-courses in both the hydrographic basins which have just been named is due to the guiding influence on eroding agents of the large greenstone dykes with which the whole region is seamed. There is no doubt that dykes like these have played an important part in determining the present topographical features of this part of the country. Previous to the glacial period the dykes probably decomposed to a greater depth than the enclosing rocks, and when the ice passed over the land the trenches which would soon be excavated along them under this powerful denuding agent would act as guiding lines for further erosion, and the depressions along them would become deepened and enlarged until they had formed the various lake basins and river valleys that lie upon their courses. In the upper parts of the Moose and the Montreal river basins the general direction of the glaciation was sufficiently near that of the great dykes which have been mentioned for it to adjust itself locally to them.*

These dykes, whether of diabase or gabbro, when undergoing decomposition at the surface weather into rounded boulder-like masses, the result of the disintegration and crumbling away of their angles and edges along the joints which had originally divided them into blocks. After they have been reduced to the rounded form they scale off in concentric layers, and this gives them a concretionary appearance. This is a common characteristic of such dykes everywhere, and often causes their outcrops to resemble rows or ridges of boulders. When fresh, both of the above-named dyke-rocks are very tough or difficult to break. The gabbros are as a rule of a lighter color, and resemble granites more than the diabases do; but they are generally deeply penetrated by the effects of the weather, which gives them a brownish discoloration, and it is only when deep-seated or completely unexposed portions are broken that the true color is seen. One of the principal differences between the two rocks is that in the gabbros the augite or pyroxene takes the form of diallage.

Microscopic Characteristics.

Samples from both these varieties of the dykes of the region have lately been examined microscopically for the writer by Professor George H. Williams, lithologist of Johns Hopkins University, and in order to convey a correct idea of their structure, composition, etc., we cannot do better than quote a description of each by this distinguished authority.

On the Spanish river, opposite the foot of the 5th portage, or just below the junction of the Agnes river, in township 108, there is to be seen a dyke of medium-grained gray olivine diabase 240 feet in width, running north 40° west, from which a specimen was submitted to Prof. Williams. He says:

The microscope shows this specimen to be a fresh aggregate of olivine, reddish augite, plagioclase and ilmenite, with accessory apatite and biotite. Its diabase or ophitic structure is very typical. The olivine in this rock is remarkably fresh. It is in small pale yellow grains, which rarely show external crystal boundaries. It has a very high refractive index, no pleochroism and contains glass inclusions. The augite is of the reddish and slightly pleochroic variety common in diabase. It not uncommonly shows zones of growth, having different shades of color. In form the augite is allotrimorphic, filling the interstices between the laths of plagioclase. The felspar (probably labrodorite) is idiomorphic, and forms an interlacing net-work of lath-shaped crystals. It is

* The agency of dykes in forming a river valley is sufficiently clear in the case of the Mattagami river, one of the parallel branches of the Moose, and which has been already described.

the only constituent that shows any alteration, and this is comparatively slight. The opaque iron oxide is probably ilmenite. It is without distinctive form or alteration, and is sometimes surrounded by a narrow rim of biotite. Apatite is abundant.

At the Dominion Mineral Company's mine on lot 4, second range of Blezard, there is a dyke from 30 to 50 feet wide, running north 35° east, a specimen from which is described by Prof. Williams as a quartz hypersthene gabbro with accessory biotite. He says:

The microscope shows this to be an eruptive rock of quite exceptional character and interest. It belongs to the general type of gabbros, but has traces of a diabase-like structure in its long idiomorphic felspars; is related to the norites by the abundance of its hypersthene, and contains what is exceptional for all of these rock-types—an abundance of original quartz. The rock is quite fresh, but shows the effect of dynamic action in the bending of felspar crystals and the uralitization of the pyroxene. The felspar is in stout lath-shaped crystals of good size which produce a coarse ophitic or diabase structure, as in many of the well known Scandinavian gabbros. They present a brownish color in the thin section from an abundance of ultra-microscopic dust-like inclusions. They exhibit, in a beautiful manner the effect of strain, in the bending of the crystals and the production of secondary twinning lamellæ. The pyroxene is both monoclinic (diallage) and orthorhombic (hypersthene) in about equal amounts. Both are undergoing alteration into compact green hornblende. The mica is an intensely pleochroic biotite. It is abundantly present in large flakes of irregular size and has all the properties of an original constituent. Quartz is also quite abundant in large clear grains of irregular shape, and was apparently the last mineral to crystallize. Apatite, zircon and magnetite are also present in considerable amount. This rock, although a typical gabbro, is unusually acid and approaches in its quartz and zircon to the augite granites.

Lines of Crushing.

In the region we are considering the effects of cleavage and bedding, fissures and joints, rock-crushing, intrusive dykes, etc., on the topography are so well marked that it is worth directing attention to some points in connection with the subject. The joints, fissures and dislocations of the rocks in any given district generally run in two sets, those of each one being nearly parallel to one another. One set is usually more strongly marked than the other and exercises an important influence in the decay and disintegration of the rocks, and this in its turn affects the contours and other topographical features of the district.

Greenstone dykes, even when thin, are often remarkable for persistence in length. They are also often parallel, or nearly so, and transverse to the strike or cleavage, and in these respects are allied to both joints and dislocations. This is only what might have been expected, for the igneous matter could not have come up from below to form them unless the rocks had first been rent. The forcing asunder of the walls of the original fissure or joint may have been due to the hydrostatic pressure of the molten matter itself, which must have been very great on such extended surfaces. In the various processes of decay, denudation and erosion of dykes, joints—fissures and dislocations have co-operated to produce parallelism in the natural features of many parts of our district, as well as in other regions underlaid by crystalline rocks.

Among Archæan rocks evidence of intense pressure is almost universal, which is not the case with regard to the newer and undisturbed strata. When thin slices of these rocks are made, so that their elementary structure may be examined under the microscope, it is found that in some parts they are crushed, while in others there is evidence that they have been slowly stretched, proving that they have been subjected to great and long continued strain. In this process the patches and grains of rock had time to constantly adjust themselves, and they have been kept firmly cemented together by the contiguous mineral matter, so that the strength and outward firmness of the rock have not been affected by this internal rearrangement of its component particles, and therefore when lithologists speak of a rock as "crushed" they do not mean that its present strength is weakened. But this latter state has been produced along certain lines of more recent movements affecting only the present outward condition. This phenomenon will be more fully described further on.

Although the textural crushing just described may be detected so generally among the ancient crystalline rocks, it is particularly manifest at points unusually exposed to the action of the forces which produced it. One of these occurs on the west side of lake Wahnapitae, where a promontory of the granitic rocks projects into the Huronian belt at its narrowest point.

The spaces which have been left by the inequalities along lines of fracture after dislocation in certain Archæan rocks have sometimes been filled by the debris ground off the walls, and which now forms dykes of breccia. An example of these may be seen at the first rapid in the Maganetawan river, eastward of the head of Byng inlet. The breccia dyke runs eastward with the course of the stream. Its matrix is amorphous and very brittle. Some of the fragments consist of a dark reddish-brown opaque cherty rock, and others of a dark variety of syenite. The mass holds a little calcspar and specks of iron pyrites.

But these long lines of fracture are not often marked by any consolidated filling. The conditions near the surface may not have been favorable to the formation of such a filling, and many of these fractures are perhaps too recent to have allowed of sufficient time for this process to have taken place. Close to these lines the rock all along is broken into small pieces, which however have been only slightly moved from their original sites; but as we recede from the lines of crushing the angular pieces become larger and larger till the whole rock has resumed its normal solidity.

This broken condition has permitted the percolation of the surface waters to great depths, which has been followed by the decay of the fractured rocks more or less rapidly in proportion to the fineness of the pieces into which they have been crushed. The joints for some distance on either side of these lines are stained with the oxide of iron, resulting from the general decomposition.

The disintegration of the rock on such lines, as well as that of the greenstone dykes, has caused valleys to be formed along them as the result of glacial and other eroding agencies. In the district under consideration the writer in referring to this subject in 1876 said:

"Between the mouth of the Maganetawan river and the first fall, especially along the north side, the gneiss, which runs in various directions, is of a dry, crumbling character along a set of joints which run parallel to the stream and are lined with oxide of iron. The course of Byng inlet and of the Maganetawan river (in continuation of it) is remarkable for being comparatively straight and crossing the general course of the gneiss and mica and hornblende schists, as well as that of the lakes and the numerous smaller streams of the district. This would appear to indicate that the formation of this channel has had something to do with the existence of the brecciated dykes or the joints above described."*

Lines of crushing in the Laurentian rocks were seen by the writer in some of the precipices in Hudson strait, where they were observed traversing walls of gneiss, and were well marked by the crumbled gneiss, still quite fresh.

Transverse depressions or gaps in crystalline rocks have also been formed in the following manner: The parallel joints which so frequently traverse granite, gneiss, quartzite, etc., are apt at intervals to occur in groups closer together than usual, or two or three may run side by side, which are stronger and more persistent than the single ones and comparatively distant from the nearest of them. The narrow walls of rock between such joints have suffered decay or injury from the surface influences in pre-glacial times, and, yielding to erosion more easily than the rest, have formed the starting lines of depressions and valleys. This phenomenon was referred to in connection with the erosion of water-channels in the French river region, and it may also be observed in various rocks in other parts of our district.

Two sets of nearly vertical joints often traverse crystalline rocks at angles approaching 80° or 90° to each other. When such rocks are cut by a third set almost horizontally they are then divided into rhombohedral blocks, and are much more easily removed by abrading and disintegrating forces. It not unfrequently happens, as in the case of some granites, that there may be four sets of joints, thickly penetrating the rock and dividing it into comparatively small triangular pieces. This imparts a shattered

*Report of the Geological Survey for 1876-7, p. 202.

character to the whole mass, and renders it useless for building or monumental purposes. Some masses of granite have been saved from the forces which produced these numerous joints or cracks, apparently by the protection afforded by yielding belts of schist. At all events the more solid and serviceable granites are often thus sheltered.

Crystalline Schists.

The Huronian system comprises a great variety of crystalline schists in both the lake Huron and lake Superior regions. In the latter the older portions of the series are to a great extent formed of mica, hornblende, diorite and chlorite schists, while these and other varieties of schists are interstratified with different rocks higher up in the scale. In the Sudbury district the northwestern border of the Huronian belt in the townships of Waters, McKim and Blezard is largely made up of crystalline schists, of which dioritic, hornblendic, silicious and felsitic are the most abundant. Further to the northeast similar schists are abundant on lake Temagami. Silicious and felsitic schists are largely developed between lake Wahnapitae and the line of the Canadian Pacific Railway. Coarsely crystalline hornblende rock, such as is found among the Huronian strata of lake Superior, has been met with just east of the Stobie mine in Blezard, in the fifth concession of McKim, and near the McConnell mine in the fourth concession of Snider; also at the southwest bend of Spanish river and at Lamorandiere bay in the northwest corner of Rutherford. Green schists, schistose greywacke and gneissoid schist, the latter enclosing boulders, occur among the rocks of the Straight lake Huronian outlier.

In illustration of the mode of occurrence of crystalline schists among the Huronian rocks of the lake Huron region, the following examples on the Spanish river are selected from the descriptions in the report of the writer for 1888-90.

Half a mile up the west branch of this river a rock was met with which consisted of a mixture of green schist and fragments of granite. At the bend of this branch, four miles from the main stream, there was found what Professor Williams describes as a "pinkish to brownish crypto-crystalline banded rock, which might be macroscopically described as a banded jasper or felsite. The microscope shows that it is a clastic rock, consisting mostly of quartz which has been wholly re-crystallized under the influence of intense pressure, and that it has thus had the parallel structure developed in it by an elongation of its grains in one direction that is commonly known as stretched."

On lot 1, sixth concession of Baldwin, just below a large island in Spanish river, the rocks in the bed of the stream consist of fine-grained pink quartzite in thin layers, interstratified with rough-surfaced black slate, dipping southward at a high angle, while at a greater elevation there is exposed a heavy band of dark green mica-schist formimg the top of a long ridge.

At the narrows of the river, on the east side of lot 12, first concession of Hyman, there is a coarse gray glistening schist and a small quantity of a dark greenstone. Below the narrows, on the next lot (11 in the same concession) a glossy dark bluish grey schist and a slaty greywacke strike northeast along the flank of a mass of diabase which has a length of more than a mile in a northeasterly direction. A fine-grained hornblende rock also occurs at this locality. In the same vicinity, where the line between lots 10 and 11 intersects the north bank of the river, quartzite occurs dipping south at an angle of 55°.

In the northwest corner of lot 8, first concession of Hyman, there is a chute in the Spanish river with a fall of 15 feet. At this locality there is an extensive exposure of rather fine-grained silver-gray mica-schist with crystals of staurolite, thickly scattered over the cleavage surfaces.

In the middle of lot 5, second concession of Hyman, the river passes through a cañon or narrows, with gray schist on the northern side, and the northern flank of a ridge of fine-grained splintery greenstone running north 70° east on the southern. At a rapid in the north half of lot 3 in the same concession, a bluish gray satiny schist strikes due north and south, the dip being east at an angle of 45°. This sudden change in the strike is accompanied by an equally sudden turn in the course of the river.

The rocks at Kettle falls, on lot 2, second concession of Hyman, are gray and satiny schists with a three feet band of nearly black hornblende schist, all striking north 76° east, with a southerly dip of 75°. On the line between lots 2 and 1, first concession of the same township, and opposite the west end of an island in the river, the rock is a glossy gray, finely-arenaccous schist nearly on edge and striking north 85° west. A gray glistening schist, standing vertically and striking north 75° east, occurs at the falls on the south side of the island.

A soft bluish-gray schist striking eastward with the course of the river is found on lot 11, first concession; and on the northeast corner of lot 9 there is a glossy green schist, but without strong cleavage.

A gray hydro-mica schist running southwest occurs where the Canadian Pacific Railway crosses the Spanish river, in the centre of lot 11, second concession of Nairn.

SERPENTINE, STEATITE AND DOLOMITE.

These three kinds of rocks may be mentioned among those which occur in minor volume in the Huronian system. Serpentine has not yet been found at all within our present region, but some exposures of it were met with at Pigeon lake on the west branch of Montreal river, a short distance to the northward. The serpentine occurs by itself, or associated with calcspar, or passing into limestone, on some small islands in this lake.

On the shores in the vicinity are fine-grained and massive reddish-gray quartzite, greenish-gray clay-slate, fine-grained reddish-gray syenite, light greenish-gray finely crystalline diorite, with disseminated grains of iron pyrites and gray porphyry very thickly speckled with opaque-white crystals of felspar and a few of shining black hornblende. The serpentine on fresh fracture shows different shades of green, and is somewhat mottled. Under the weather the natural surface becomes rough and of a rusty color. It contains oxide of chromium, both in the form of small grains and in chemical combination with the rest of the rock, and thus resembles the serpentines of the Eastern Townships in the province of Quebec. The writer has been shown specimens of serpentine said to have been collected among the Huronian rocks some miles north of Pigeon lake. On the point about the middle of the west shore of Abittibi lake the late Mr. Walter McOuat of the Geological Survey met with dark green serpentine, weathering dull white, strongly magnetic and containing grains of chromic iron. Mr. E. B. Borron informed the writer that he had heard of serpentine having been found in the country lying north of the west end of Abittibi lake.

On the Mattagami river, thirty chains below the junction of the Muskoota branch, there is an exposure of massive gray semi-crystalline steatitic rock, holding grains of specular iron and cut by small veins of whitish bitter-spar. Although this locality, as well as those for serpentine which have been mentioned, are outside of the limits of our sheet, both of the rocks referred to above may be looked for wherever similar rock associations exist within this area. The greenstone of the Evans mine, near Sudbury, has changed in some parts into a variety of steatite or soapstone.

Dolomites or magnesian limestones, having certain characters in common, occur sparingly in the Huronian system in the most widely separated areas of these rocks. They are usually fine grained to compact, silicious and marked by strings and fine threads of quartz and sometimes of calcspar, which have commonly a reticulating arrangement. Most of them are ferruginous, and the weathered surface is generally yellow, brown or red, but sometimes gray or black. The iron is often present in large enough proportion to form a spongy crust of the oxide. Occasionally these dolomites become rather finely crystalline, like saccharoidal marble, and nearly white. In our present region they have never been traced far on the strike, although they attain from 100 to 300 feet in thickness.

Midway up the northeast side of Pigeon lake, already mentioned, on the west branch of Montreal river, there is a bluff thirty feet high of semi-crystalline, yellowish-gray limestone, mottled with green and reddish-brown patches and full of reticulating strings of white calcspar. The weathered surface has a ferruginous crust, from one-half to one inch thick, showing the rock to contain a large proportion of iron. A thickness of upwards of one hundred feet of the limestone is exposed at this place, and it continues northward along the shore for a quarter of a mile or more. The other rocks in the vicinity of this dolomite consist of syenite, diorite, serpentine, porphyry and different varieties of quartzite.

On the eastern side of South bay, lake Wahnapitae, and thence round the promontory towards Outlet bay, Mr. Alexander Murray described a calcareous breccia associated with quartzites and greenstones.*

In Geneva lake, about a mile and a-half northeast of the outlet, there is an islet entirely composed of thinly bedded light gray, dove-colored and nearly white dolomite, striking north 35° east, and dipping to the westward side at an angle of 80°. It is compact and has a conchoidal fracture, but is traversed by fine threads of quartz, which prevent it from taking a good polish, otherwise it might be suitable for marble. The same rock is exposed on the east side of the lake on the point just southward of the above islet, but the band could not be found on the northern side of the lake, towards which it strikes in the opposite direction. On the railway track three-quarters of a mile south of the outlet of Geneva lake there is a fifteen-feet bed of gray to dove-colored fine-grained dolomite, weathering dark brown. It strikes north 45° east, and the bedding is about vertical. This dolomite band is separated from hornblende granite to the southeast by about three hundred feet of ash-gray greywacke. The granite towards its contact with the latter becomes mixed with coarse breccia and conglomerate. On the other side, or to the northwestward, the dolomite is followed by coarse felspathic sandstone and silicious greywacke-conglomerate or breccia. At the outlet of Geneva lake the rock is a greywacke passing into granite, and it includes some black slate and a patch thirty feet thick of impure dolomite.

A band of magnesian limestone occurs at Island Portage on Wahnapitae river, about four miles below the outlet of the lake of the same name. It has a width of at least 300 feet across its general strike, but owing to the undulation of the strata the true thickness of the band could not be determined. On fresh fracture it is mostly light greenish-gray in color, fine grained, soft, somewhat impure, and weathers to a brown color. The weathered surface in some parts is marked by small corrugated ridges, like that of the Huronian limestone of Echo lake, which result from the weathering out of minute silicious streaks following the bedding. An exposure of the limestone at the head of Island Portage shows a more massive variety with a brownish gray color on fresh fracture.†

Referring to the magnesian limestones of lake Panache Mr. Alexander Murray says :

On the north shore of lake Panache, about midway between the inlet from lake Lavase and its western extremity, a band of limestone occurs which when first observed appears to be both underlaid and overlaid by syenitic slate-conglomerate. The mass of this limestone, which measures about sixty yards across and may be about 150 feet thick, is of a pale gray color on fracture, weathering to a bluish gray, with thin layers which have the appearance of chert, but are in reality only harder portions of the limestone, weathering quite black. About the base of the calcareous strata some of the beds are blue, holding more silicious matter than the gray beds, while others are of a brecciated character. The beds are all more or less intersected by small veins of fine greenish jaspery-looking trap which weathers brown or yellowish.

To the eastward of this exposure the only indications observed of the presence of limestone were on the east side of the large island at the entrance of the south bay, and in the peninsula on the north side at the entrance of the eastern arm ; in both of these localities small exposures of a black-weathering brecciated rock, which proved to be calcareous, came up in one or two parts just over the surface of the water. On the island the calcareous rock is overlaid by a black-weathering slate which, though without pebbles, resembles the matrix of portions of the slate-conglomerate. On the peninsula at the eastern arm the brecciated rock comes directly in contact with greenstone.

At the head of the lower south expansion of lake Panache the limestones are again seen on both sides, and also on the two islands near the middle, striking about east by

* Report of the Geological Survey for 1856, p. 177.
†Report of the Geological Survey for 1875, p. 296.

north and west by south, and showing a southerly dip on the north side of the exposures; but the slate conglomerate with which it seemed to be associated at other parts onl; appears on the south side of the large island lying at the entrance to the northern army and between this island and the exposure of limestone on the west side of the bay there is a point to the northeast of the limestone displaying fine-grained green slate which, though very much disturbed and intersected by quartz veins, appears to show a general dip to the northwest.*

Mr. Murray thinks that some of the above strata might yield good stone for burning into lime. A specimen from the section on the north side of lake Panache was analysed by Dr. T. Sterry Hunt, and gave in 100 parts 55.10 carbonate of lime, 6.50 carbonate of magnesia, 38.40 insoluble sand and a trace of iron. A specimen of the limestone at the lower end of lake Panache, analysed by the same chemist, gave 41.97 per cent. carbonate of lime, 2.40 carbonate of magnesia and 55.63 insoluble residue; and a specimen from the lower lake near the outlet, lying between the two ridges of the mountain range, gave 36.50 per cent. carbonate of lime with a little magnesia.†

Along the northern arm of the larger La Cloche lake calcareous rocks or impure limestones occur at several places passing below a considerable thickness of slate conglomerate, and they are again met with on the smaller lake to the northwest. High ridges of quartzite, standing nearly on edge and forming part of the La Cloche mountains, rise on either side of the southern arm of the larger lake, while greenstone and quartzite are found on the northern side of the smaller one. It would therefore appear that in this part of the great Huronian belt the magnesian limestones occur among the quartzites, and are sometimes more immediately associated with slate-conglomerate.

A band of finely crystalline limestone occurs among the Huronian rocks in the northern part of the township of Rutherford. The locality is near the boundary line between red granite to the southward and a great thickness of quartzites to the northward. The junction of the granite to the southeast with the Huronian quartzite and hornblende schists to the northwest occurs at the south side of a rather elevated rocky island in a cove about one mile north of the western entrance to "the passage" or channel, on the north side of which Killarney village is built. The geology of this locality and the relations of the limestone referred to can best be given by quoting the description in the Geological Survey report by the writer for 1876, page 209:

On the west side of the township of Rutherford, from the northern limit of the granite (at the elevated rocky island above mentioned) quartzites and hornblende schists hold the shore as far as Lamorandiere bay, in the northwest corner of the township. A blackish green massive and rather coarsely crystalline hornblende-rock, having an exceedingly rough or irregularly pitted surface, is exposed on either side of the narrow entrance to this bay. Upon the slope of the hill, about 100 yards in from the north shore of the bay, at a point about half-a-mile from the above-named narrows, a band of finely-crystalline limestone occurs among the Huronian rocks. It has a vertical attitude and runs about north 70° west at the part examined. Its total thickness is about 75 feet, of which the 25 feet along the northern side consist of a single solid band of nearly white finely-crystalline limestone, clouded with light greenish and grayish patches. The remaining 50 feet are mixed with shaly patches of hornblende, together with a little shining granular magnetic iron ore. Adjoining the limestone on the north side is a band, only a few feet in thickness, of dark smoke-colored chert-rock, ribboned with streaks of a dull red color. It breaks easily with a fine conchoidal fracture, and appears to be identical with a rock which was used by the mound-builders for making some of their arrow-heads. This is followed to the northward by a dark-colored dioritic conglomerate, in which the pebbles are mostly small and generally widely scattered, and farther on by a very dark gray, soft massive-looking micaceous schist, most of which is full of small pebbles. Measured from the limestone band, a thickness of between 100 and 200 feet of these rocks is exposed.

On the north shore of Lamorandiere bay, a few hundred yards eastward from the outcrop of limestone above described, are two exposures of very tough massive hornblende rock, and between the two arms of the bay is a more fissile variety, interstratified with a reddish gray quartzite, which also overlies the mixed rocks. The dip is here northwestward at an angle of 60° to 70°, and the series is underlain by granitoid gneiss.

*Report Geological Survey for 1856, pp. 181-183. †*Ib.* p. 190.

Intrusive Granites.

The red granite of George island and the township of Rutherford may be of intrusive origin, notwithstanding that it shows an approach to lamination towards the edges of the mass. "Its position is along the junction of the Laurentian with the Huronian series, and it appears to belong to the latter rather than the former. It has a medium texture, and is composed of reddish felspar and bluish-white quartz with a little hornblende, which however is often wanting. Excepting at the sides it has a massive homogeneous structure, but in a few instances a single reddish or yellowish-green shaly streak, an inch or two in thickness, was observed running in a northeasterly direction with a dip to the southeastward of about 50°. Towards each side the grain of the rock begins to assume a sort of parallelism or a gnessoid structure."*

Reference has already been made to an area of red granite measuring about four miles in length by two in breadth between the western and middle outlets of French river, and also to a brick-red granite or syenite along the upper part of the lower north channel of that river just below Grand Recollet falls.

Red granitic rocks border the newer ones which lie to the south of them all the way from the township of Cascaden to lake Wahnapitae. Although the macroscopic appearance of these rocks is that of a red granite, yet in some parts, as on the east side of Windy lake, the textural arrangement of the component minerals is more like that of a quartz-diorite, and they are certainly of eruptive origin. Professor George H. Williams examined under the microscope a thin slice of a fine grained variety of these rocks from Kin-ni-wabik lake in the township of Levack. He pronounced it micropegmatite, and stated that it was an undoubted eruptive. Towards lake Wahnapitae similar rocks continue to be fine grained, but in that direction they become dark grayish-red in color. Around Washai-gamog or Fairbank lake the rocks have a similar color and texture to the last, and their appearance is the same except that they are distinctly stratified and occur in very even beds. The granitoid rocks above described merge into gneiss at varying but not great distances to the northward.

About a mile east of the angle formed by the intersection of Proudfoot's east-and-west with his north-and-south line red hornblende granite was found. Its extent has not been ascertained, but it may continue a considerable distance northward.

A Laurentian inlier has been mentioned as occurring around Paul's lake on the upper part of Sturgeon river. Where first entered upon in ascending the river at four miles below the lake the rock of this inlier consists of a rather coarse dull red quartz-syenite, or hornblende granite, but this passes into gneiss before the lake is reached. An area of coarse red granite crosses lake Temiscaming about the middle.

General Nature of the Huronian Rocks.

While the greater portion of the Huronian rocks show the agency of water in their formation, there is also abundant evidence of widespread contemporaneous volcanic action. These detrital or clastic sediments were largely derived from igneous matter which had been more or less recently erupted, and hence they may be called pyroclastic, as indicating both phases of their nature. Besides rocks of this character, we have seen that the Huronian system contains large igneous or crystalline masses. The whole series having been considerably metamorphosed, the true origin of some portions may not be at first apparent. But our study of them on a large scale in the field as well as the microscopic examination of hand specimens go to show that the above is the general nature of the Huronian rocks in all the areas which have been explored. The pebbles and boulders of the conglomerates of the Huronian system consist of binary-granite, schists, quartzite, white quartz and red jaspar, greenstone, gneiss and other rocks derived from older parts of the same series or from the underlying Laurentian.

The presence of these conglomerates and the ripple-marks which are sometimes plainly seen on the surfaces of beds of quartzite prove the existence in those days of either dry land or of seas which were very shallow in some places. The limestones or dolomites are

*Dr. Bell in Report of Geological Survey for 1876, p. 208.

only of local extent. They are sometimes nearly pure, or, as we have seen, they may be largely mixed with insoluble matter, or they may be brecciated with silicious fragments. The lime and magnesia may have been derived from the decomposition of the pyroxene and hornblende of the greenstones. Some of the masses may be of a segregated or a concretionary character, while others were precipitated from water.

Newest Rocks of the Sudbury District.

The newest rocks of the Sudbury district form a distinct basin extending from near the west side of lake Wahnapitae southwest to about the centre of the township of Trill, a distance of thirty-six miles, with a breadth of eight miles in the centre. This basin constitutes a prominent feature in the geology of the district, and it may prove to be of lower Cambrian age. Along its northern side it is bounded by the granitoid rocks already described, and on its southern by a belt of Huronian schists and greywacke. The rocks of the basin consist of two principal divisions,—(1) the lowest being a band, probably three or four thousand feet thick, of dark colored or almost black silicious volcanic breccia or vitrophyre tuff, most strongly developed along the northern side and passing into black slate and black slate-conglomerate along the southern; and (2) drab and dark gray argillaceous and nearly black gritty sandstones with shaly bands which vary in color from greenish drab to black. At the base of the volcanic breccia a conglomerate consisting of a grey silicious matrix with rounded white quartz pebbles is seen in some places, but this may belong to the underlying series.

The area of this geological basin corresponds in a striking manner with certain well marked physical and geographical features. The volcanic breccia forms a range of hills more conspicuous and rugged than any others in the district, while the sandstones and shales constitute a low and nearly level tract from which lakes, elsewhere so common, are absent. The Vermilion river flows southwestward with the strike all along the northern side of this division, and Whitson creek flows in the same direction along the southern side.

The silicified glass-breccia or vitrophyre tuff maintains the same character and apparently about the same thickness all the way from the vicinity of lake Wahnapitae to the township of Trill. It occurs in massive form and falls from cliffs or ridges in large blocks. It breaks with a conchoidal fracture, and when fresh is seen to be made up of angular fragments, mostly small and closely crowded together and flecked with irregular white spots. The fragments are not so dark as the matrix, and present various shades. When examined with a lens many of the fragments show a distinct vesicular structure. Prof. George H. Williams has examined this breccia carefully both in hand specimens and under the microscope, and says that it is "composed of sharply angular fragments of volcanic glass and pumice, which, in spite of almost complete silicification, still preserve every detail of their original form and microlithic flow-structure with a distinctness not to be exceeded by the most recent productions of this kind . . The fragments even down to those of the smallest dimensions have the angular form characteristic of glass shreds produced by explosive eruptions. The flow-structure is as perfectly marked by sinuous lines of globulites and microlites, which terminate abruptly against the broken edges of the glass particles as in the most recent vitrophyre. Minute spots of opaque pyrrhotite are scattered through the section. The groundmass is of a dark color, owing to the massing in it of minute black globulites, to whose nature the highest magnifying power gives no clue . . . After a careful study of this rock I find it possible only to interpret it as a remarkable instance of a very ancient volcanic glass-breccia, preserved through the lucky accident of silicification. Nor did this process go on as is usual through devitrification and loss of structure, but rather like the gradual replacement of many silicified woods, whose every minute detail of structure is preserved. The rarity of such rocks in the earth's oldest formations is readily intelligible; but, for this very reason, the exceptional preservation of a rock like this is all the more welcome proof that explosive volcanic activity took place at the surface then as now, and on a scale if possible even greater than that with which we are familiar."*

*Bulletins of the Geological Society of America, 1890, pp. 138-40.

A fresh section of this rock is exposed in a cutting on the Canadian Pacific Railway at the high falls of Onaping river, twenty miles northwest of Sudbury Junction. An analysis of an average specimen from this place was made by Mr. Hoffmann of the Geological Survey, and it was found to contain 60.23 per cent. of silica. A smoothed surface of this dark rock has a handsome appearance, but it is incapable of a high polish.

The dark argillaceous sandstones and drab and dark shales of the higher division of the rocks of this newer basin may be seen at all the southward bends of the Vermilion river from Onwatin lake nearly to Vermilion lake. The strike corresponds with the general course of the river, and the dip is southeastward at rather high angles. The sandstones are characterized by disseminated grains of transparent quartz, and they often hold rounded or ovate spots from an inch or two up to three feet in diameter, of a lighter color than the rest of the rock. On exposed surfaces these spots weather into depressions. Several parallel ridges of this sandstone with a northeasterly course cross the Canadian Pacific Railway line diagonally between Larchwood and Chelmsford. It appears to be well suited for building purposes. This sandstone, both as regards the spots just described and its dark color and massive character, bears a strong resemblence to the silicious rocks which, in the form of boulders and smaller pieces, are scattered so abundantly around the shores of James bay and over the country for a great distance to the southwest of it. A similar rock is found in place on Long island on the east coast, and at Churchill on the west coast of Hudson bay, and there are reasons for believing that it is very extensively developed on the floor of that sea.

LOWER SILURIAN OR ORDIVICIAN SYSTEM.

The islands of the La Cloche group and the peninsula of the same name in the southwestern corner of our sheet consist of flat-lying fossiliferous rocks of the Lower Silurian or Ordivician system, with some ridges and knobs of Huronian quartzite protruding through them. The middle portion, which constitutes the bulk of this group, is made up principally of rather thinly-bedded, lumpy and uneven surfaced gray limestones, with many thin, shaly beds and partings interstratifying them. But underlying these measures are from 50 to 100 feet, or perhaps more, of reddish and chocolate colored calcareous marls with greenish layers and mottlings, together with some beds of fine grained white and reddish sandstones, while overlying them and interstratifying the upper portion are beds of hard, compact, dark gray magnesian limestone, which weathers to various yellowish and reddish shades.

The lower or marly and arenaceous portion of the series has yielded no fossils by which its age can be identified, but it is believed to represent some formation older than the Trenton group, and it was thought by Logan that it might be the equivalent of the Sault Ste. Marie sandstones, which he considered to be Chazy, but which are referred to the Potsdam formation by the United States geologists.

The upper beds of the Trenton group are seen at the north end of Strawberry island, and in the north-facing bank at Little Current at the northern extremity of Manitoulin island. At these localities they are overlaid by the black bituminous shales of the Utica formation. The breadth across the strike from the north side of La Cloche island to the commencement of the Utica shales on Strawberry island is eight miles. The average dip to the south is assumed to be 40 feet in the mile, so that the total thickness of the Trenton group would be about 320 feet. The fossils which have been collected among these rocks from the summit of the marly and arenaceous portion up to the highest beds on La Cloche island, and also from the islands just west of the latter, belong to the Birdseye and Black River divisions of this group, so that the Trenton formation proper in this region is confined to a strip bordering the shore for six miles in the neighborhood of Little Current and thence round into West bay, the northern part of Strawberry island and the peninsula between Manitowaning and Smith bays. On Heywood or Rat island, along with a little Utica shale there is some limestone which appears to belong to the Trenton formation. Patches and margins of fossiliferous gray limestones resting on the quartzite and dipping into the lake are found here and there along the high point which runs from Killarney bay towards Heywood island and on the islands just south of it. These rocks appear to be identical with those forming the central part of La Cloche island, and they would therefore belong to the Birdseye or Black River formation.

As already stated, the black shales of the Utica formation rest upon the top of the Trenton limestones in the village of Little Current and cover the greater part of Strawberry island. They are found near the quartzite ridge at Sheguiandah village, also at the base of the Hudson River formation between Manitowaning and Smith bays, and in a similar position at cape Smith.

ECONOMIC MINERALS.

Only a small part of the district represented on the accompanying map has yet been explored for useful minerals, but the discoveries already made are sufficiently numerous and important to lead to the belief that a promising future is in store for this part of Canada as a mining region. The metallic ores appear to be confined to the Huronian rocks, which are here so extensively developed. The Sudbury district has become well known for its extensive nickeliferous deposits, and prospecting has been as yet confined chiefly to that region. Ores of several other metals have also been found in the district, and the indications are in favor of meeting with some of them in paying quantities. What has been accomplished in the Sudbury district may be repeated in various parts of the great unexplored Huronian belt to the northeastward.

But the useful minerals of our present region do not consist entirely of metallic ores. The non-metallic mineral products, such as building and ornamental stones, rock for lime and glass-making, etc., are also important. Some of these occur among the Laurentian and others among the Huronian rocks. As the district is only beginning to be inhabited, and the need of such materials has scarcely been felt, little or no effort to find them has yet been made; but as soon as there is any demand they will no doubt be found in many new localities. The possibility of discovering workable deposits of phosphate of lime among the Laurentian rocks of the district, and of asbestos along with the Huronian serpentines, as well as of other substances usually found among these rocks, should be borne in mind.

IRON.

Among the quartzites of the La Cloche region small isolated deposits of magnetite and one or two of hematite have been found, but none of those yet discovered appear to be sufficiently extensive to justify mining operations. From analyses reported to have been made of the ores from two or three of these deposits they would appear to be sufficiently free from titanium, phosphorus and sulphur to constitute first-class ores. It is to be hoped that further explorations among these rocks may bring to light larger masses of iron ore.

Thin veins of good magnetite, accompanied by quartz, occur in the red hornblende-granite two miles north-northwest of Cartier station, and again in the same rock on the Spanish river a short distance below The Elbow. But the granitic districts do not appear to be promising for the ores of iron.

The existence of iron ore on Iron island in lake Nipissing is only known to most of those interested in the minerals of the district by vague report. It may therefore be worth while to quote the description of it given by the late Alexander Murray of the Geological Survey.

Small masses of specular iron ore are common to most of the rock in the island, and in the crystalline limestone there is a very great display of it. For a breadth of about forty yards along the cliff on the east side the rock holds masses of the ore of various sizes, sometimes running in strings of an inch thick or upwards and at other times accumulating in huge lumps, some of which probably weigh over half a ton. The beach near the outcrop is strewn with masses of all sizes, from great boulders weighing several hundred pounds to small rounded pebbles not bigger than marbles. The limestone with which the ore is associated is frequently cavernous, and the crevices and small fissures are thickly lined with crystals of blue fluor-spar and red sulphate of baryta or cockscomb-spar.

Crystalline limestone crops out on the opposite or west side of the island and, judging by the strike on the north side, it must correspond with that holding the iron ore on the east. The same minerals were found disseminated through the rock and strewn upon the beach. At the extreme southwest point of the island the rock is again crystalline limestone, and a long beach running out from it to the westward is perfectly covered with boulders of specular iron ore. Iron ore occurs also at the southeast point of the island, although not in such great abundance and only in detached masses strewn upon the beach.*

In the Huronian iron-bearing region of lake Superior the ores have two different sets of associations or modes of occurrence. In the one case they are associated with hornblendic or chloritic schists which appear to belong near the base of the system, and in the other they occur with fine grained silicious and jaspery rocks. The magnetite of the Atik-okan region is an example of the first, and that of Hunter's island and Kaministiquia river of the second.

Nickel.

The comparatively recent discovery of workable deposits of mixed copper pyrites and nickeliferous pyrrhotite over a large area in the Sudbury district is one of the most important events in the history of mining in Canada. Although masses of pyrrhotite are known to exist in other parts of the Dominion, there is no other region where they are so numerous and in such proximity to one another, and with the exception of one near St. Stephen in New Brunswick they do not appear to be nickeliferous to an economic degree, whereas in Sudbury district all the deposits so far tested are comparatively rich in nickel. The pyrrhotite of this region is found in the midst of rocks of different characters and belonging to different horizons, but it is always more immediately accompanied by greenstone. Indeed this rock may be regarded as the parent of the ore. These facts would seem to indicate that in the Sudbury region the greenstone had a common and deep seated origin. The area over which the ore has been discovered is of an eliptical form, and measures about 70 miles from southwest to northeast and 50 miles from southeast to northwest.

The first discovery of nickel in this region was made about 1846, at the Wallace mine in Bay of Islands on the north shore of lake Huron, about a mile west of the mouth of Whitefish river. This mine was opened in 1847 and was visited in 1848 by the late Alexander Murray of the Geological Survey, but at that time mining operations had been temporarily suspended. The ore consists of chalcopyrite with magnetic and arsenical pyrites rich in nickel, occurring in chloritic and quartzose schists close to a mass of greenstone. The extent of the deposit cannot at present be seen on account of the debris on the surface and the shaft being full of water. Mr. Murray in his report says:

> The temporary condition of the mine at the period of our visit rendered it impossible to obtain such specimens as might be considered an average sample of the material excavated from the shaft; but with a view of ascertaining the quality of the nickeliferous portion of the ore a specimen of it, as free as possible from the copper pyrites, was submitted to analysis by Mr. Hunt, who found it to contain 8.26 per cent. of nickel with a trace of cobalt; but as nearly two-fifths of the specimen consisted of earthy materials which might readily be separated by dressing, the quantity of nickel in the pure ore which this would represent would equal nearly 14 per cent.†

The existence of nickel and copper in the greenstones of what is now the Sudbury district was first made known by Dr. T. S. Hunt and Mr. Alexander Murray of the Geological Survey in 1856. In that year Mr. Murray explored Salter's base line, running northward from Whitefish lake, and in what is now the township of Waters he found a mass of magnetic trap which proved to contain disseminated nickel and copper. He says:

> Specimens of this trap have been given to Mr. Hunt for analysis and the result of his investigation shows that it contains magnetic iron ore and magnetic iron pyrites generally disseminated through the rock, the former in very small grains; titaniferous iron was found associated with the magnetic ore and a small quantity of nickel and copper with the pyrites.‡

*Report of Progress for 1854, page 123.
†Geological Survey Report for 1848, p. 44.
‡Report of the Geological Survey for 1856, p. 180.

Again referring to this subject Mr. Murray says:

The magnetic trap discovered on Mr. Salter's meridian line north of Whitefish lake was observed to hold yellow sulphuret of copper occasionally; and Mr. Hunt's analysis of a hand-specimen of the rock, weighing ten ounces, gave twenty grains of metalliferous material, of which eleven were magnetic and consisted of magnetic iron ore, with a little titaniferous iron ore, and magnetic iron pyrites containing traces of nickel. The nine grains of non-magnetic mineral consisted of iron pyrites, containing from two to three per cent. of copper and about one per cent. of nickel. Many large quartz veins occur on the lower lakes of the Whitefish river, but iron pyrites was the only metalliferous substance which they were observed to contain.*

In constructing the Canadian Pacific Railway line in 1882 the mass of ore which is now being developed as the Murray mine, three miles and a half northwest of Sudbury Junction, was cut through at the surface. This discovery was followed in 1883 by the finding of ore at what are now the Stobie, Copper-cliff, McConnell and other mines in the neighborhood. These occurrences were at first regarded as of value only for the copper which they might contain, and, notwithstanding that the existence of nickel among the associated rocks of the region had been pointed out by Murray and Hunt so long before, it was not till three or four years after the above discoveries had been made and a thousand tons of dressed ore had been sent to England from the Copper-cliff mine that the value of the ores for nickel was recognized.

The ore is very much the same at all the occurrences in the Sudbury district. It consists of a mixture of nickelif rous pyrrhotite or magnetic pyrites, with more or less chalcopyrite or copper pyrites. The larger ore-masses generally approach lenticular forms, with their longer diameters parallel to the strike or to the line of junction of the enclosing rocks. Their attitude is usually nearly perpendicular, the dip or underlie being sometimes apparently at higher angles than those of the adjacent rocks.

Each of the larger ore-bodies is made up of a brecciated or a conglomerate-like mixture of the above-mentioned sulphides and the country rocks next to it, the fragments of the latter varying in dimensions from mere grains and very small pieces up to immense boulders, but the average size is a few inches in diameter. In some cases the stony fragments constitute so large a proportion of the mass that they come almost into contact with each other, the interspaces being filled with the sulphides, while in others there are considerable bodies of nearly pure ore with only occasional rocky fragments scattered through them. In a few instances a granitoid filling between the fragments takes the place of the sulphides. A good example of this may be seen at an opening in one of these ore-masses on lot 3, fifth concession in the township of Levack.

The usual site of these ore bodies is at the junction of greenstone with some other rock, especially granite, gneiss or felsite. Another circumstance which appears to have influenced the localization of the ore is the intersection of the ore-bearing planes by one of the dykes which have been described, or by a throw, or a number of minor dislocations. The existence of one or other of these conditions has been noticed at or near most of the larger ore-bodies of the district.

These deposits have not yet been worked to a sufficient extent to prove much in regard to their persistence or otherwise, in depth. The Copper-cliff mine however has been already wrought to a depth considerably greater than the horizontal length of the ore-mass, either on the surface or in any of the levels. Ore deposits of a similar character in other parts of the world have sometimes proved on working to possess a much greater depth than horizontal measurement. In the absence of any indications to the contrary, it may therefore be expected that the nickeliferous deposits of the Sudbury region will prove equal in depth to their horizontal extensions.

As to the genesis of the ore bodies, the evidence points to their origin from a state of fusion. The fact that the ores always accompany the greenstone (itself of igneous origin) is a strong proof of this supposition. These sulphides fuse at about the same temperature as the greenstone, and in the cooling of the latter they would naturally tend to coalesce in small and large masses. The dissemination of both the chalcopyrite and the

* Report of the Geological Survey for 1866, p. 189.

pyrrhotite so generally throughout the whole mass of the commoner varieties of the greenstones, and the rich impregnation of these rocks with the same sulphides in the vicinity of the ore bodies, are additional evidence in the same direction. In the isolated kernels of ore, often scattered so thickly through the greenstone in the vicinity of the workable deposits, we find groups consisting of either of the sulphides, separately or intermingled, and often the individual kernels will be made up of the two kinds mixed together. These kernels, together with larger patches of the ores, constitute every proportion of the rock, from a small percentage up to half the total weight or more, when the mass has become sufficiently rich to put upon the roast heaps. In the mixed sulphides of these ore bodies the pyrrhotite generally contains a certain proportion of disseminated grains of quartz and other stony matter, while the chalcopyrite is usually tolerably pure. This may be owing to the manner in which the latter separated itself from the former, whether in a state of fusion or by some subsequent process. Although most of these ores appear to have separated themselves from a cooling magma, we find occasionally evidence of subsequent modifying processes. Still there can be little doubt that the larger ore bodies of this district were not originally deposited from aqueous solution like the gangue and ore of ordinary metalliferous veins.

The above ores do not contain a very high percentage of nickel or copper, their value depending more on their abundance and the facility with which they can be mined than on their richness. The Canadian Copper Company, after having smelted thousands of tons of the ores from the Copper-cliff, Evans and Stobie mines, found the average yield of nickel for the year 1890, to have been 3.52 per cent. and of copper 4.32 per cent. The ore smelted at the Blezard mine up to March, 1891, averaged 4 per cent. of nickel and 2 per cent. of copper; that smelted at the Murray mine up to the same period averaged 1.5 per cent. of nickel and 0 75 per cent. of copper. Mr. F. L. Sperry, late chemist to the Canadian Copper Company, found the average of nine assays of ores from the mines of his company to be 2.38 per cent. of nickel and 6.44 of copper. Assays of eleven samples of the ores of the district made under the supervision of Mr. Hoffmann, chemist to the Geological Survey, gave an average of 1.69 per cent. of nickel. The average of all the above smeltings and assays gives us 2 62 per cent. of nickel, which may be taken as the general average of the ores of the Sudbury district. Exceptionally rich ores however have been found in smaller quantities, especially at the Worthington mine in Drury and the Vermilion mine in Denison.

COBALT.

Cobalt amounting to little more than a trace has been detected in many of the Sudbury ores. In connection with the Wallace mine it has been mentioned that in 1848 Dr. Hunt ascertained the presence of cobalt in the ore which Mr. Murray had brought from this locality.

COPPER.

Reference has already been made to the copper always contained in the ores of the Sudbury district. The result of smelting several thousand tons of the ores from the three mines worked by the Canadian Copper Company was a yield of 4.32 per cent. of copper from these ores as placed on the roast heaps. It has been mentioned that the roasting ores smelted at the Blezard mine yielded 2 per cent., and at the Murray mine 0.75 per cent. of copper. In the ores of all the mines the chalcopyrite or copper pyrites is generally so intimately mixed with the pyrrhotite as to make it almost impossible to separate it by any mechanical process. But at the Stobie mine masses of several tons of almost pure copper pyrites are occasionally encountered, and the Copper-cliff mine when first opened showed a large body of the same ore near the surface.

At the Vermilion mine on lot 6 in the fourth concession of Denison copper has been found in paying quantities. The ore consists of chalcopyrite, which however is remarkable for having a deep purplish-blue tarnish, causing it to resemble bornite or purple copper ore. It occurs as a streak about four feet wide in greenstone, but it has no distinct walls like a vein, nor any gangue except a mixture of the country rock. A shaft had been sunk on this deposit to a depth of twenty feet when it was visited by the writer in 1888.

The upper ten feet was decomposed to a loose gossan, mixed with fragments of rock, which had probably been held in the ore streak before its decomposition. The recently discovered mineral sperrylite, which is an arsenide of platinum with a little tin, and which occurs in fine crystalline grains, was found by washing this gossan. Copper pyrites has been found on almost every lot in the fifth concession of Denison, along the southern border of a belt of greenstone that runs nearly east and west through this concession.

A short distance north of the region under description the writer in 1875 met with a group of copper-bearing quartz veins running north 70° west, and south 70° east, crossing the east branch of the Montreal river ten miles and a half before it falls into the main stream. This group of veins is about a quarter of a mile wide. They vary in thickness from mere strings to thirty or forty feet, and contain a good deal of specular iron, and in some places promising indications of copper in the form of pyrites. Mr. Hoffmann found a sample of the specular iron to contain 39.41 per cent. of the metal. The country rock here consists of massive beds of quartzite and greenstone, both holding large bunches or "clouds" of fragments of syenite, quartzite and Huronian schists, and all interstratified with sandstone and clay-slate.

On the north shore of Narrow bay or Baie Fine, and two miles east of its entrance, a small vein cutting the quartzite contains gray copper ore. This bay lies between Frazer and McGregor bays, and the above-mentioned occurrence of copper ore has been described by Mr. James T. B. Ives in the Transactions of the American Institute of Mining Engineers for 1889-90.

The most productive copper mines ever worked in Canada were those of the West Canada Mining Company, which included the Bruce on the east, the Wellington in the centre and the Huron Copper Bay mines on the west. These mines are situated at the western extremity of the north shore of lake Huron, and although they are outside of our present sheet they deserve a brief notice as affording the best examples of the occurrence of copper in the Huronian greenstones. These mines were opened in 1846 and worked till 1875, a period of thirty years. The actual workings extended for a distance of over two miles east and west. The ore occurs principally as the yellow sulphide in veins of white quartz, cutting a dark grayish-green diabase. But when the veins on the Bruce location were first opened a good deal of the purple sulphide was found near the surface. On this location several nearly parallel veins running about east and west were worked, the thicker ones being about four feet wide. But on the other two locations work was carried on chiefly on two master veins called the Main lode, which varied from three to fifteen feet in thickness, and the New or Fire-lode, a branch of the latter, and about equal to it in breadth. On the Bruce location the veins were worked to a depth of only about thirty fathoms, but on the other two locations the average depth was from forty to sixty fathoms. Between the latter levels an almost barren floor was generally encountered, although in some places profitable mining extended to seventy fathoms in depth.

The vein-matter as mined contained an average of five per cent. of copper, but it was concentrated by crushing and jigging to about twenty per cent. before shipping to England, which was the chief market. At different times in the history of these mines both smelting and cementation had been tried upon the ground, and abandoned. From information supplied by Captain Benjamin Plummer and other reliable authorities the writer ascertained that copper ore, precipitates, ingots and slags amounting to 40,515 tons, and realizing about $3,300,000, had been shipped from these mines in the thirty years during which they had been worked.

LEAD AND ZINC.

Small quantities of galena and zincblende have been found in veins in the belt of black volcanic breccia and slate, which has been described as occurring in the Sudbury district, and they are worth mentioning as possible indications that these ores may be discovered in greater abundance in these rocks. One of the localities is on Pawatik river, about a mile and a quarter northward of the Vermilion, in township 65 ; a second is just below Onaping falls, and a third on the south side of Vermilion lake, near the outlet. Vein-like masses of blende mixed with pyrite occur at Stobie falls on lot 10, sixth con cession of Creighton. Galena has been detected with the pyrrhotite in the Copper-cliff mine, and on lot 6, third concession of Graham. It is also associated with this mineral on Moore's location on lots 2 and 3 in the fifth concession of Craig. It occurs in small quartz veins in dioritic schist on lot 5, fourth concession of Denison.

Gold.

In 1887 a rich auriferous bunch was found in a vein of light gray finely granular quartz about two feet thick on lot 6, fourth concession of Denison. The opening made on this vein came known as shaft No. 2 of the Vermilion mine. The gold was mostly in the form of small nuggets scattered rather plentifully through the quartz. It is said that several thousand dollars worth were mined, but the gold did not appear to hold out in depth. The country rock on this part of the lot resembles a fine grained greenish gray greywacke, but on critical examination it is found to be an altered greenstone full of very small grains of iron pyrites. Prof. George H. Williams, who examined thin slices from two specimens of this rock under the microscope, describes it as an extremely changed basic eruptive, probably originally a gabbro or a diabase—most likely the former. Its present composition is a confused aggregate of chlorite, biotite, epidote, sericite, quartz, pyrite, opaque iron oxide, leucoxene, calcite and apatite needles.

Among the quartzites and greenstones on the south side of lake Wahnapitae a discovery of gold in visible specks was made in 1888. It occurs associated with mispickel in some thin veins of quartz following a belt of quartzite, boulder conglomerate and reddish felspathic quartzite having somewhat the appearance of granite. A sample of the quartz from one of these small veins, which also contained mispickel and pyrite, was assayed by Mr. Hoffmann of the Geological Survey and found to contain 5.425 ounces of gold and 0.233 of an ounce of silver to the ton of 2,000 pounds, but the quartz from another of these small veins contained neither gold nor silver. A band of fine grained dark colored greenstone runs parallel to and at no great distance from either side of this gold-bearing belt of quartzite. It is not unlikely that gold may be found among the rocks of the western part of lake Wahnapitae, which, as already mentioned, have been subject to much crushing in past ages. Gold is reported to have been found by Prof. Heys and others in quartz from veins in the northwestern part of Creighton and the eastern part of Fairbank. Out of a considerable number of samples of quartz from the Sudbury district assayed for the precious metals by Mr. Hoffmann of the Geological Survey, the following results were obtained: From vein No. 1 on mining location W. R. 3, township 40 (southeast of lake Wahnapitae), the property of Mr. Donald McLaren, 0.117 oz. of gold per 2,000 pounds; from location M. 3, at the south extremity of lake Mattagamashing, a short distance east of lake Wahnapitae, owned by Donald McLaren, 1.167 oz. of gold and 0.233 oz. of silver per 2,000 pounds; from Simpson's mine, lot 11, second concession of Graham, near Whitefish station on the Canadian Pacific Railway, 0.350 oz. of gold per 2,000 pounds.

Some distance to the west of our district, or in the western part of the township of Galbraith and about fifteen miles north of Bruce Mines, a large vein of auriferous quartz occurs in a country rock of greenstone. The vein runs about west-northwest, is of a mottled gray color, contains a considerable sprinkling of various sulphides, and is tolerably rich in gold. Of three assays made by Mr. Hoffmann, the highest result was .583 oz of gold per 2,000 pounds.

Platinum.

Sperrylite, already referred to as occurring at shaft No. 1 of the Vermilion mine in Denison, was first determined to be a distinct mineral species, containing 52.57 per cent. of platinum, by Prof. H. L. Wells of Yale College early in 1889. Some months previously however Mr. Robert Hedley had ascertained the presence of platinum in the ore of this shaft, the proportion in one assay amounting to about five ounces to the ton It is unlikely that the occurrence of platinum at the Vermilion mine will prove to be the only one in the district; it is more probable that intelligent research will show the existence of this valuable metal in other places among the Huronian rocks. It is reported to have been detected in small quantities at one of the mines on Lake of the Woods.

Building and Ornamental Stones.

The red granite of George island and vicinity would make an excellent stone for massive structures and monuments, as well as for ordinary buildings. Many of the evenly and somewhat thinly bedded gneisses of the French river region and of the shore of Georgian bay from French river to Parry Sound would serve as very substantial and tolerably easily wrought building stones.

The nearly horizontal beds of limestone of the Trenton group on the islands in the North channel, at Little Current and on Strawberry island are well adapted for ordinary building purposes and are very conveniently situated for transportation by water. They are mostly fine grained or compact, and of dark bluish and grayish colors.

The dolomites of the Niagara formation further south on the Grand Manitoulin island are more heavily bedded, softer or more porous and much lighter in color.

The light gray and cream-colored dolomites of the Guelph formation are found on the southeastern extremity of Grand Manitoulin island and the south end of Fitzwilliam island, but in these localities they are coarsely spongy or full of small cavities.

On the shores of the high points and islands to the north and west of Killarney the light gray and whitish quartzites in many places would make very serviceable building stones. The bed-planes are generally very even and parallel, and layers can be found of almost any thickness desired.

Some varieties of the greywackes, so common among the Huronian rocks, split readily in any direction, and as they are tolerably easily dressed they may be found suitable for purposes of heavy construction. The argillaceous sandstones of the supposed Cambrian basin of the Sudbury district also afford good building stones and they have been quarried to a small extent on the line of the Canadian Pacific Railway between Larchwood and Chelmsford.

In regard to ornamental stones, the dolomites of the Huronian system when cut often show good colors for marbles, but as already stated they generally contain silica in scattered grains and as strings and threads running in all directions through the mass, which prevents them from taking a good even polish. Exceptions to this general rule may however be found in such cases, for example, as the finely crystalline and nearly white variety found on the north side of Lamorandiere bay in the township of Rutherford, which has not yet been tested as marble.

The olive and greenish argillites barred with black, such as occur at the northern outlet of Temagami lake, and which were so highly prized for ornamental stones by the ancient Indians, may be found serviceable for the manufacture of a variety of artistic objects.

The brecciated green chalcedony, which occurs in abundance at the outlet of White Beaver lake, at the head of the east branch of Montreal river, would form a handsome stone for fine ornamental purposes.

Roofing Slate.

It sometimes happens that clay-slates show a good cleavage in natural exposures resulting from the long continued action of surface influences, while the same rock, when freshly quarried deeper down, will not split readily under artificial treatment. It is therefore difficult to pronounce upon the value of such slates without practical experiment. In our district slates showing fair natural cleavage have been observed in various localities, among which may be mentioned the banks of the Matabechawan river which discharges Rabbit lake into lake Temiscaming, Maskinongéwagaming lake and the lower part of Mattagamashing lake, and Spanish river both above and below the Great Bend. It has been already mentioned that a good cleavable slate occurs on the line of the Canadian Pacific Railway within a mile or two east of Algoma Mills. While these slates may not be as good as those of Melbourne and Shipton in the province of Quebec, they are better than the slates used for roofing purposes in many parts of Great Britain, and it is considered worth while to call attention to them among the mineral products of economic value occuring in this region.

Lime.

The limestones and dolomites which make up the bulk of the rocks of the various Silurian formations of the islands of the La Cloche group and of Grand Manitoulin island are well adapted for burning into lime, the calcined dolomite passing under this name. Stone suitable for burning into lime and also for metallurgical purposes may be found among the Huronian magnesian limestones already described at Limorandiere bay, lake Panache, on Wahnapitae river, near Cartier station and on Geneva lake.

Stone for Glass-making.

Suitable material for glass-making may be found almost anywhere among the Huronian quartzites near lake Huron, where they are nearly all of light colors. In addition to their occurrence in the La Cloche mountains and on the high points and islands towards Killarney, these quartzites are met with on the north side of La Cloche island, at the southern extremity of La Cloche peninsula and in a ridge which runs into Manitoulin island from the head of Sheguiandah bay.

Apatite or Phosphate of Lime.

This mineral has not yet been found in economic quantities within our district. It exists however as a constituent of all the greenstones of the region which have been examined under the microscope, and large crystals of it have been met with among the ores of the Copper-cliff and some of the other mines in the district. Numerous crystals of apatite were found in a vein near Nasbonsing station on the Canadian Pacific Railway, east of lake Nipissing. As this mineral may be looked for among the Upper Laurentian rocks generally, it would not be surprising if it should be discovered in commercial quantities in the Nipissing or Parry Sound districts. It occurs in various localities in other parts of the province among the Upper Laurentian crystalline limestones, but elsewhere it is found in larger masses in association with pyroxene rock among gneisses and quartzites, as in the county of Ottawa. Five bands of crystalline limestones among the Upper Laurentian rocks were traced through the Parry Sound district by the writer in 1876, but the region northward of Georgian bay has not yet been sufficiently examined to determine whether pyroxene rocks exist there or not. Should they be met with in sufficient abundance the finding of apatite in economic quantities would be pretty sure to follow.

STRUCTURAL MATERIALS.

There is no lack of materials for building purposes in Ontario, either as regards quantity, quality or variety. And yet it is by no means unlikely that some of the most valuable of these materials remain to be discovered, inasmuch as every year brings something new to light. The great extent of the province, the want of a careful survey of even any part of it, and the lack of interest in ascertaining and developing its mineral wealth are no doubt the chief causes which have combined to keep back a knowledge of the extent and character of the structural materials which we possess; but interest is being slowly aroused, and doubtless our knowledge will keep pace with our opportunities of turning it to practical account. The sandstones, granites, marbles and serpentines which exist in vast bodies on the north shore of lake Superior have not yet been tested in a way to fully prove their value for building material, chiefly because they are too far distant from available markets. But the ease with which shipments may be made to the large cities which border the great lakes give an assurance for the future of quarrying enterprise on the Ontario side of lake Superior when international trade will be put on a better basis than it now is. The same remark applies to the utilization of our material for the manufacture of pressed brick and terra-cotta, for there is probably no portion of the continent in which are to be found such extensive deposits of first-class material as along the northern and eastern limits of the Medina formation, or the outcroppings of the next lowest formation along the north shore of lake Ontario. In so far as building materials of the best quality go Ontario is pre-eminently rich, and it is a safe prediction that within the next half century this fact will be clearly and boldly stamped upon the architecture of the country.

BUILDING STONE.

Building stone is plentiful in Ontario. Granites, sandstones, limestones and marbles are to be obtained in great abundance, although some of them may be at too great distance from the markets to make their quarrying a profitable business yet. The granites and marbles too are so likely to be fractured and flawed by the influence of the weather that it is not easy to procure good samples without opening the beds to considerable depths. Sandstones and limestones are not so susceptible to weather effects, being often found well covered by soil or later formations of rock. This is the case especially in the formations which make up the Niagara escarpment, and convenience of situation to the larger towns and cities of the province encourages the working of quarries there. The Niagara escarpment is indeed rich in building material, for it not only furnishes building stone of the sandstone and limestonê classes, but also the materials for lime, cement and brick.

THE QUEENSTON QUARRIES.

The Queenston quarries are located on lot 48 on the Queenston and Grimsby stone road, in the township of Niagara, two miles west of the village of Queenston The lot is the property of William M. Hendershot of Thorold, and the quarries are worked by P. A. Johnston & Co., who have held them under lease since 1881. Previous to that time they had been worked for three years by Hunter, Murray & Cleveland, who had the contract for building the Welland canal aqueduct at the town of Welland ; while for the preceding four years, beginning with the spring of 1874, they had been worked by Belden, Denison & Co., who had contracts for the construction of locks on the new canal. It is said that the quarries were first opened during the construction of the Grand Trunk Railway.

Seven quarries have been opened on the property, all of which are in the limestone beds of the Niagara formation.

The several beds differ essentially in color and texture—from light gray to blue, and from soft and porous to dense and crystalline.

After stripping from two to ten feet of clay a gray limestone bed is reached, whose surface has been deeply grooved by glacial action. It is a fossiliferous rock, consisting of lime and sand, and is used in the production of lime and for culvert and bridge works on railways.

Below the gray is a bed of blue limestone of ten to twelve feet in thickness, composed in some of the quarries of two bands, the upper of which is a light and the lower a dark grayish blue; in others it is composed of the dark blue only. Both are crystalline. but while the upper is coarse grained the lower is fine grained, approaching marble, and is much superior in quality to the other. This bed contains a large variety of fossil shells, is hard and durable, tools well, and takes a fair polish. The stone taken from it is used almost wholly for the bases and shafts of monuments, for which a large business has been built up. But it is used also for building purposes, the post offices at Cornwall, Niagara Falls and St. Catharines having been constructed with it, besides many private dwellings and business houses.

Below the blue limestone is a bed of dark limestone, which has a proportion of clay in its composition, is from four to six feet in thickness, and suitable for the manufacture of cement.

Johnston & Co. employ an average of 75 men at their quarries.

Brown's Quarry.

This quarry is in the township of Stamford, on the line between that township and Thorold, and consists of 11½ acres. It was opened about forty years ago by Messrs. Brown & Zimmerman to procure stone for the old canal, and was worked again in 1874 by Belden & Co. during the construction of the new canal.

The land is the property of Mr. James Brown, but the three quarries upon it are worked under lease by Messrs. Walker Bros., of Merritton; they have been opened to a depth of eighteen feet.

There are two bands of limestone, the upper of yellowish gray and the lower of gray color. Under the gray is a bed of blue limestone, which however cannot be worked for want of drainage. Stone from the upper band is used for curbing, street crossing, flag stones and bridge works, and from the lower for monument bases and window sills.

The firm have a mill at Merritton which runs a gang of ten saws, where stone is cut for window sills, flagging, street curbing, etc. Four quarrymen and three stone-cutters are employed at the quarries.

The Mountain Quarry.

The Mountain quarry is on parts of lots 4 and 5 in the township of Thorold, on the townline between Stamford and Thorold, and consists of 28½ acres. It is owned by Mr. William R. Cartmell, and has been worked by him since 1854, a large quantity of stone having been taken out.

About twelve feet of clay covers the limestone here, which has been stripped from an area of three or four acres.

The quarry has been worked to a depth of twenty-two feet, yielding two qualities of stone. The upper bed, which is nine to ten feet in thickness, is of dark blue color and poor quality, the courses ranging in thickness from two feet at the top to six or eight inches at the bottom of the bed; the stone is used chiefly for backing work.

The lower bed is twelve feet in thickness, and is of light gray color. It is a fine grained stone, and is used for bases of monuments and building purposes.

Gibson's Quarries.

These are the property of Mr. William Gibson, M.P., and are situated on the top of the mountain a mile and a half south of the village of Beamsville, in the township of Clinton, and two and a half miles from Beamsville station on the Grand Trunk Railway. The property embraces an area of 45 acres, and the limestone rock where not exposed is covered with only a few inches of soil.

The quarries were opened by Mr. Gibson in May, 1884, and have been worked continuously since with a large force of laborers, quarrymen and stone-cutters. The amount paid for wages in 1890 was $87,440, but last year the staff of workmen was increased, and in the month of June 160 were employed; the wages paid to quarrymen alone in that month being $7,500.

There are two workable beds of gray limestone, the upper being seven and the lower eight feet in thickness. The upper is usually the best quality, being firm, hard and crystalline; but both contain many fossils, and have openings or vughs which are lined with crystals of iron pyrites. In some parts of the quarries the beds are three in number, but the lowest is not more than two or three feet in thickness. Below these workable beds is a bed of porous gray limestone, but it is rarely of a quality fit for use.

Three large derricks are worked by as many engines, one of which is 24 and the other two of 18 h.p. each, the more powerful one driving a steam drill in addition. Three other derricks are driven by horse-power. A fourth boiler of 35 h.p. drives three steam drills. Three small drills are used for plug and feather work.

The stone is all cut by hand, and is used largely for the construction of bridges, culverts, tunnels and buildings on the lines of the Grand Trunk Railway. The tunnel under the St. Clair river was built by Mr. Gibson with stone taken from these quarries.

The quarries are about 200 feet above the level of the station, down to which the stone is carried in cars over a tram-road built along the side of the public highway. It could be conveyed the whole distance by gravitation, but to prevent accidents the cars are stopped before they reach the main street of the village. From that point they are taken by horses to the station, and empty ones are drawn back to the quarries.

Grimsby Quarries.

The Grimsby quarries are in the gorge of Forty-mile creek, above the village of Grimsby, which cuts through the limestone into the Medina sandstone and extends back through the mountain to the falls on the creek, a distance of half a mile. The quarries are the property of the Grimsby Quarry Co., of which Stephen Webster of Toronto is president and Frank Webster manager. The location is about half a mile in length, extending from the edge of the escarpment on either side of the gorge to near the falls, and occupying an area of 18 acres.

The bottom and sides of the gorge are covered with a talus of limestone and sandstone, and these stones are being removed preparatory to opening the sandstone in place. A tram-road has been built to the docks at the lake shore, a distance of one mile and a half, down which the cars run by gravitation and up which they are drawn empty by horses, as at the Gibson quarries at Beamsville.

The mountain here is about 350 feet above the lake, and about 100 feet of the top consists of limestone and shale. Underneath the shale are bands of gray, brown and mottled sandstone, alternated with bands of shale. At one place where it is well exposed the brown band, slightly mottled, is about 15 feet in thickness, of good texture, solid and capable of being cut into any suitable size for building purposes.

The company was organised in 1890 with a capital of $20,000, seventy-five per cent. of which was paid up, but although work was commenced in November of that year no stone was taken out until the spring of 1891.

Stone is being supplied for the crib-work at the eastern and western gaps of Toronto harbor, but no dimension stone has yet been taken out. The company employs from thirty to forty men.

CARROLL AND VICK'S QUARRIES.

Messrs. Carroll & Vick, who took over the contract of the late Lionel York for the new Parliament buildings, are the owners of extensive sandstone quarries at the Forks of the Credit. They began to work No. 1 quarry in June, 1890, and purchased the Adjuda Quarry Co.'s property in January, 1891. During the season of last year they worked No. 1, 2, 3, 4, 5 and 6, but No. 3 was worked only part time.

All the best stone taken out was shipped for the Parliament buildings, while stone of lower grades was furnished to builders and dealers at Toronto, Hamilton, Guelph, Berlin, St. Marys and other places.

No. 1 quarry is on the northern side of the west branch of the Credit. It was first opened by Scott & Pattullo and a lot of fine brown stone was taken out, the limestone overlying it having been stripped back a short distance. Last year Messrs. Carroll & Vick began to mine the brownstone at a point where the face showed about twenty-five feet of limestone above fourteen feet of sandstone. Openings have been made along the face of the sandstone for a length of one hundred feet and back to a depth of eighty-five feet, the roof of limestone being supported by timbers and stone. A beginning is made by taking out two or more beds of limestone and putting in supports of timber two or three feet in length. Then the first bed of brownstone is taken out and the work is carried back and down regularly. Limestone and poor grades of sandstone are used to fill the place of the stone removed, at first by the construction of a regular wall four or five feet thick at the opening, and then by a second wall about fifteen feet farther on, the intervening space being filled up with rubble. When all the sandstone of a section has been taken out the floor is begun again at the roof and the timber supports carried forward. The brownstone of this quarry is about six feet in thickness, one bed of which is four feet thick. Below the brown band is four feet of gray, followed by three or four feet of a mixed stone, off color, and extremely hard on its lower side, which consists largely of iron pyrites.

No. 2 quarry is in rear of the railway station on the north side of the Belfountain road. Mining work was commenced there in January of last year in a fine bed of brownstone, which here has a capping of broken shale and limestone about three feet in thickness. The work has been carried in a depth of sixty feet and along a face of seventy-five feet. There are two gateways to the works, between which supports of stone have been built back some sixty feet. This quarry yields the best quality of brownstone found at the Forks, the upper bed or course being nine feet and the lower two feet in thickness. One section of the upper bed was found to measure twenty-five feet between joints, and apparently free from checks or dries.

No. 3 quarry is on the opposite side of the Belfountain road. It has been worked only part of the year, as a suitable quality of stone was not found there.

No. 4 is the quarry on the east side of the north branch of the Credit. It has not turned out to be as good as appearances at first promised, and all the stone of first quality has been taken out. A considerable quantity yet remains for coursing, sills and small work, as well as for bridge or culvert work or rough masonry. The color is a dirty mixture and the bedding is very irregular. Below the sandstone is a layer of green shale about two feet in thickness, followed by a deposit of red shale suitable for the manufacture of pressed brick and terra-cotta whose depth to the foot of the bank is not less than a hundred and twenty feet. It is well situated for this industry, being easily reached for quarrying and convenient to the railway for shipping. An outcrop of this shale is also seen on the opposite bank of the river, through which the railway has been cut, and is exposed at intervals for more than a mile in length.

No. 5 is on the south side of the main stream, below the Forks, and is known as the York Estate quarry. Four gates have been opened and brownstone has been taken out along a face of two hundred feet back to a distance of sixty feet under the heavy capping of limestone. The brown band is here eight feet deep, and consists of two beds of equal thickness. It is of excellent quality, and one section was measured a length of one hundred feet between the jointings. Mining work was commenced at this quarry in May, 1890.

No. 6 is the property of Dr. Pattullo, and lies east of No. 5, in the same escarpment. It has been leased to Messrs. Carroll & Vick under royalty, and they have been mining stone in it since March, 1891. Two gates are open and one has been abandoned. Work has been carried back a distance of sixty-six feet into a bed of good brownstone seven feet in thickness.

All these quarries except No. 4 are worked as mines, the stone being taken out and the roof supported as described of No. 1.

Myers' Quarry.

This quarry is situated on the south bank of the Credit river, on lot 7 in the second concession (west) of Caledon. The property consists of 200 acres, and the quarry was opened by the late M. M. Elliott of Brampton three years ago. In April, 1890, it was purchased by Alexander Myers of Toronto, who has been working it since.

The rock has been stripped along a face forty rods in length, and for a distance of twenty-five rods a large quantity of sandstone has been quarried. It is chiefly gray and gray and brown mixed, making a light shade of brown. The band is about ten feet in thickness, but the color cannot be depended on as it changes in the course of a few feet from brown to gray and piebald. Some of it is being taken out for the Toronto court house and city hall, and it is likely to be used extensively for the inside walls of that building; it is being used also for the Woodstock court house and for various buildings in Toronto.

The machinery at this quarry consists of three engines, three steam drills and a hoisting derrick. The latter is operated by wire cables driven by steam power for lifting and moving, whereby blocks of any size are raised and carried to any desired point for piling or loading. No tag line is necessary, but the engineer with his hand on a lever controls and directs the work swiftly, easily and without interruption, and it is as valuable for stripping as for quarrying. Mr. Myers intends to patent his invention.

The stone is loaded on cars which are taken down a cable road to the railway.

Other Quarries at the Forks.

Several other sandstone quarries are worked on a smaller scale at or near the Forks of the Credit.

Mr. John Price has leased part of Pattullo's property on the north side of the west branch and has been working it during the past year with a small force.

Armstrong & Dent are also working a small quarry east of Carroll & Vicks' No. 1. They have taken out a little of brownstone, but the bulk is gray and brown.

Another quarry is being opened on the south side of the west branch by William McLaren of Belfountain.

Near Inglewood, below the Forks, Mr. Murray is also opening a quarry of sandstone.

Hoover & Jackson's Quarry.

This is a limestone quarry situated on the railway line a mile south of Orangeville. It was worked for a short time last year, and a portion of the stone taken out was cut for window sills.

Owen Sound Stone Co.'s Quarries.

The Owen Sound Stone Company has been carrying on operations for several years at the town of Owen Sound, where it owns a limestone quarry, but recently it has acquired a sandstone property on the Centre road in the township of Mono, two and a half miles north of Orangeville, and began to open it in 1890. It is situated on a flat on the north side of a tributary of the Nottawasaga river, the bed of which is sandstone, eighty feet below the tableland.

After stripping a thin cover of earth and two or three feet of shale, a band of Medina sandstone is reached which is fourteen feet in thickness. It is of a dark bluish color in place, but lightens to gray when dry. The two upper beds of the band are each four feet in thickness and are of fine quality, being free from dries, easily worked and may be taken out of any required size. The bottom of the third bed is of flinty hardness, being made up largely of iron pyrites, so that it cannot be tooled, but the upper part of it is of fair quality. The sandstone rests on a bed of greenish shale, which here as elsewhere constitutes the lowest bed of the Medina formation. One block taken out of the top bed measured 5,780 cubic feet and split as straight as if cut by a saw; upon being cut down for convenience of handling it was found to be perfect, without a dry or flaw.

Towards the northern side of the property the first and second beds appear to run into each other and have there a thickness of eight feet. The dip of the formation is northward about 5°.

Shale forms the bed of the stream for a distance of nearly three miles below the quarry, where a hard bluish rock crops out which is supposed to belong to the Hudson River formation. The thickness of the Medina shale is estimated to be about a hundred feet, as measured by the fall of the stream.

The company has erected a machine shop on the tableland above the quarry in which hoisting, sawing and planing machinery have been placed, driven by a 20 h. p. engine. The saw and planing machines have been imported from Scotland, and are the same as are used in large stone quarries there. They work rapidly and are a very great improvement on hand labor.

The company intends to build a railway spur to connect with the Canadian Pacific system at or near Orangeville, and when this is completed it will be in a position to carry on operations with much greater economy than at present.

Black Bay Mine and Quarry Co.

The Black Bay Mine and Quarry Company has its principal office in Chicago and its western office at Duluth. It has been organised to acquire and work a location of jasper and dolomitic limestone in the township of Dorion, near the north shore of Black bay. The property was not secured until late in 1891, and only specimen blocks have been taken out. Both kinds of stone are beautiful in color and take a fine polish, but the specimens seen are more or less flawed, owing no doubt to the influence of the weather on rock so near the surface. The following account of the quarry has been furnished by A. M. Stearns of Duluth, manager of the company:

The company's lands as patented by the Crown are described as the west half of lot 3, concession 4 of Dorion, containing 146½ acres.

The property lies about one and one-tenth mile from navigable water in Black bay, upon the Canadian Pacific Railway. The outcropping of quarry stone occurs about a quarter of a mile west of the railway, on a gradually ascending slope, at about 100 feet altitude, and lying between immense granite hills on the northerly and southerly sides.

It has been noticed and commented upon by explorers as a peculiar formation, but it was left to our company to demonstrate that it is a very large and valuable bed of jasper, underlaid with a stone so like mahogany when polished that we offer it to the trade as mahogany stone. The jasper lies at and near the surface, is from three to five feet in thickness, and can be quarried in blocks about three feet wide by five to seven feet long.

The mahogany stone upon which the jasper rests occurs first in thin beds, which soon thicken to an apparently unstratified ledge and may be quarried in even larger sizes than the jasper.

Though harder than marble the jasper saws readily and can be satisfactorily reduced with hammer and chisel, taking a polish equal to plate glass.

If one-third of these measurements be allowed for dressing we shall have net dimensions remaining without flaw suitable for wainscoting, tables, mantels, sideboards, and sizes suitable for turned columns and carved pedestals in fine architectural work.

The whole formation dips slightly to the northwest, and judging from the number and uniformly sloping surfaces of the several exposures and the slight stripping between them as far as tests have been made it must cover an area of at least forty acres.

The color and the polishing qualities of stone taken from this location will readily commend it to public favor; and should it, as may reasonably be assumed, prove to be free from flaws when a greater depth from the surface is reached it ought to find a ready market.

QUARRIES ELSEWHERE.

Numerous other quarries are worked in different parts of the province, but none others were visited last year excepting one on Pelee island and another in the township of Dunn, near the village of Dunnville, the property of Dr. McCallum. Neither of these were actively worked, although there are at both places large quantities of limestone suitable for building and lime-making purposes.

Hugh Ryan & Co., who are the contractors for the Sault Ste. Marie canal, have taken out large quantities of limestone at White's quarry on the Detroit river, in the township of Anderdon, near Amherstburg, and also from a quarry on Manitoulin island. The stone from the former quarry is got out in large blocks and carried by vessels to the Sault, where it is cut to the sizes required. The Manitoulin stone is not so good for dimension purposes as that from the Anderdon quarry, and is used chiefly as rubble. About seventy men were employed by Messrs. Ryan & Co. at White's quarry last year, and fifty at Manitoulin Island.

In the eastern parts of the province there are numerous limestone quarries, and a few also of Potsdam sandstone, but they are worked on a small scale.

On the north shore of lake Superior there are extensive beds of sandstone, easily accessible by boat, readily worked and of superior quality, in gray, red and other colors; but although some have been opened and worked the business has not proved to be profitable for want of a good market.

PRESSED BRICK AND TERRA-COTTA.

The manufacture of pressed brick and terra-cotta has made good progress in Ontario since the first works were opened near the town of Milton four years ago. There are now seven establishments in operation, and they turned out last year nearly 14,000,000 pieces, valued at $156,700. With form, color and quality in their favor, the products of this industry seem likely to come into extensive use, and they can hardly fail to very much improve the architecture of our towns and cities. The raw material is abundant and easily reached, constituting as it does the lowest beds of the Medina formation, which outcrop along the base of the Niagara escarpment from the Niagara river to Georgian bay, and a large portion of the upper beds of Hudson River shale in the vicinity of Toronto. In Pennsylvania and Ohio the clay used in the manufacture of pressed brick is chiefly drift material, and is neither so firm nor so uniform in its constitutents as our Medina and Hudson River clays.*

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* Volume v. of the Geological Survey of Ohio describes the clay used in the manufacture of pressed brick at Zanesville, which is the principal seat of the industry in the state of Ohio, and also the process of manufacture, as follows:

"The clay, which is probably not far from the level of the Lower Freeport horizon, though there are no coal streaks near by to identify it, is yellow and irony; very like the best clays of the drift, though it is a true bedded formation. In its situation it lies within ten feet of the surface on the tops of several ridges near the town, and it may be an ordinary fire-clay vein weathered to the state in which it is found. It is dug and thrown back in loosely-piled heaps, so that it may further soften and weather. Enough is kept dug to allow it to weather a year before using. It is hauled to the works near by, and is then put into a soaking vat. This consists of a semi-circular depression 3 feet deep, and whose diameter is 30 feet. In the centre of the diameter stands a pug mill delivering away from the vat. This pit is filled with clay by dumping in successive cart loads from the circumference; when full, the vat is flooded from a hose near by until the amount added will make the whole into a stiff mud. It soaks all night in this way in summer; in winter, water is heated in a large cauldron at one side, the flues from which circulate beneath the vat. In this way the clay is warmed first by the water and then kept warm by the fires underneath. The expense of this apparatus for softening clays is light, and it may easily be put up by any mechanic, and it is found efficient in keeping the works going without interruption all winter. The clay is pugged as usual and delivered to the moulder who shapes it. The bricks are covered with a yellow moulding sand or earth which, from the large percentage of iron it contains, assists in giving the bricks the cherry-red color which has done so much to recommend them. The drying is done on an ordinary fire-brick floor. The bricks are pressed in a Miller Brick Press and again dried. They are all rubbed to remove the wire edges, etc., and are ready to set in the kiln. The kilns employed here are very large; at the works visited the two kilns were of 320,000 and 215,000 brick capacity respectively. The walls are permanent and massive; there is no roof but a temporary plank one; the fire-places are large compound ones, each fire-place heating three arches of the kiln. The burning is from ten to twelve days, and the cooling three or four. The setting of the kiln is done very carefully; the common brick are used to make the arches, and are piled up to an even height of about four or five courses above the top of the arch. At the ends and sides they are piled up about one yard thick. In the space left the pressed brick are piled to within one yard of the kiln.

BEAMSVILLE WORKS.

William Tallman & Son have been engaged for eighteen years in the manufacture of common brick and drain tile on lots 22 and 23 in the 1st concession of the township of Clinton, near the village of Beamsville. In February, 1890, a sample of the red clay from their land was sent to North Baltimore, Ohio, for experiment, and the product was found to be so excellent that the firm determined to erect works at once.

The clay is the same as is found in the Medina formation all along the escarpment, and is colored a rich brown, with layers or streaks of green near the top. It is disintegrated at the surface, but is found to be solid at a depth of two or three feet, and is so hard at a depth of fifteen or twenty feet as to require a pick for its removal. Three openings have been made from which the clay is taken, but they are down only a few feet.

The works were erected in the spring of 1890 and were opened about the beginning of June in that year. The main building is 30 by 40 feet, the engine room 30 by 24, and the clay shed 60 by 102. The engine is 70 h. p., and the pressing machine is of the Simpson patent, with a capacity 15,000 per day of ten hours. The clay is prepared for the press by grinding and sifting it in a machine which has a capacity of 40,000 per day. The crusher is a revolving disc, nine feet in diameter, in which run two wheels with 18-inch face. Into this the clay is shovelled in a dry state, and being crushed under the wheels it is elevated to a sieve of 16-mesh, through which it falls into a hopper and thence into the press where it is moulded into shape under a pressure of fifty to one hundred tons. From the press the bricks are taken direct to the kilns, which are three in number, and are there burnt to the required hardness.

The works are situated alongside the Grand Trunk Railway, where cars are loaded on a switch to be conveyed to Hamilton, Toronto, Montreal or other market places.

Forty men are employed in the various departments, including wheelers, moulders, setters, burners, sorters and shovellers.

MILTON PRESSED BRICK CO.'S WORKS.

The works of the Milton Pressed Brick Company, of which David Robinson of Milton is president, are on lot 1, concession 1, township of Esquesing, on the line of the Credit Valley Railway, one and a half miles west of Milton. They were erected in 1890, and the first kiln of brick was burnt in October of that year.

The machinery consists of a 90 h.p. boiler, a 75 h.p. engine, crushing and sifting mill, a Boyd press for plain brick, and a hand press for fancy brick. The crusher has two wheels of 14-inch surface and reduces a cartload of clay to powder in from four to ten minutes according to the quantity of water fed upon it. The power press is made for 15,000 per day of ten hours, but in practice it does not exceed 12,600. There are three up-draft kilns in the main building, each having a capacity of 140,000. Wood fuel is used to dry off the brick in the kilns about ten days, after which the burning is finished with soft coal in ten days more.

The clay which supplies the raw material lies on the slope between the works and the mountain, and a pit has been opened into it to a depth of twenty-five feet. After stripping off the surface soil of yellowish clay; which is about a foot in depth, a bed of

top; above, the common brick are again piled, so that the pressed brick are in shape of a rectangular solid, separated by at least a yard of common brick from the walls on all sides or the air above and the fire below. By this means the utmost uniformity of burning is secured, and of the production at least nine shades of color are separated. The brick are each one subjected to a critical examination, and are rejected for a defect invisible to one unpractised in the examination. Many ornamental shapes are made to relieve the monotony of a plain wall; some of them are truly artistic, such as tiles, one foot square, containing well-drawn designs, etc. The price of the plain pressed article of any shade is $20 a thousand, or two cents apiece, and ornamental shapes are just twice as much. These Zanesville brick are well known in the markets, and they meet but little competition in Ohio, though Cleveland and Liverpool both make pressed brick. The sharpest competition and the best market is in Chicago." (pp. 704-5).

A more detailed account of the process of making pressed or repressed brick is given in Morrison's Brickmakers' Manual (Indianapolis, 1890) pp. 67-77, but it does not appear to be an improvement upon the one described above. For plain and ornamental brick the clay is mixed with water, moulded, dried in part, then well sanded and pressed again, after which it is burnt in the kiln.

reddish-brown clay with streaks of green is exposed twelve feet in thickness. The green clay burns white when used alone, and when mixed with the red the brick is light and irregular in color; therefore it is picked out by the quarrymen to be worked by itself, or to be mixed with the dark clay so as to produce brick of uniform color. Under the twelve-foot bed is one three feet in thickness of red and green clay, the latter partially decomposed so that the clay has a worm-eaten appearance. It is almost as hard as stone, and as it burns light in the kiln it is not now used. The third bed is of a uniform reddish-brown color, lighter than the upper one, but very compact and of unknown depth. It is apparently the shale of the Medina formation in place, while the upper beds are a redeposit. The clay of the first layer is found to shrink more in burning than the third, although the color is more pleasing; but the best quality is obtained from a mixture of the two clays.

Twenty men are employed at the works, including quarrymen and shippers. The brick is carefully selected, packed into cars on the siding, and shipped mostly to Toronto

Toronto Pressed Brick and Terra-cotta Co.'s Works.

The Toronto Pressed Brick and Terra-cotta Company was organized in 1888 with Hewson Murray, Q.C., of Toronto at the head of it, and is the pioneer of the pressed brick industry in Ontario. Its works are on the line of the Credit Valley Railway, on the mountain slope about two miles west of Milton. The quarry lies between the works and the mountain, and the beds of clay resemble very closely those of the Milton company's quarry. The uppermost bed, which is covered with a foot and a half of soil and yellow clay, is a loose friable clay about four feet in thickness; it is of fine brown color, but contracts in the burning. A foot of green with two or three feet of streaked and light colored clay makes up the second bed, which is more compact and less friable than the one above it. The third bed is worked to a depth of five feet and has the consistency of rock. It is found in practice that the best quality of brick, uniting color and strength, is obtained by mixing clays of the first and third beds.

The company has an extensive plant, consisting of an engine and boiler of 105 h.p., grinding and refining machinery, three power presses, five hand presses for fancy brick and tile, pug mills to prepare clay for terra-cotta work, and seven kilns with a total capacity of 750,000.

The fuel used in the kilns is bituminous coal, and the average time of burning is about two weeks. The average capacity of the presses is 30,000 per day of ten hours.

The product of the work is chiefly pressed brick, red, brown, buff and white in colors; but a specialty is also made of moulded and ornamental bricks, terra-cotta in pattern for walls and interior decorations, and tile for roofing, including in the latter finials, hips, valleys and angles.

The market for the output of the works is found largely in Toronto, where a number of handsome dwellings and office buildings have been erected with material which this company has supplied, including among others the Confederation Life building on Yonge street, one of the largest and most imposing structures in the city. But sales have been made in all parts of the Dominion, from Charlottetown in Prince Edward Island to Victoria in British Columbia.

The works employ an average of sixty men for ten months of the year, but are closed during the very cold weather for necessary repairs.

Ontario Terra-cotta and Pressed Brick Co's Works.

The Ontario Terra-cotta and Pressed Brick Company was organised in 1889, with Mr. M. L. Livingstone of Toronto as president, and in the same year operations were commenced at Campbellville station on the line of the Credit Valley Railway.

The buildings are of brick material and are well equipped throughout. The plant consists of an engine of 75 h.p., grinding and screening machinery, a pug mill to mix clay for terra-cotta work, two steam presses for plain and moulded brick, three hand presses for roofing and flooring tiles and ornamental brick, six round kilns, a large square kiln and a trial kiln.

The larger of the power presses is used only in moulding plain brick and has a working capacity of 13,000 per day ; the smaller, used in making moulded brick, has a daily capacity of 2,500. The round kilns take in 30,000 each at a burning, and the large square one 65,000, the fuel used in them being wood and soft coal, the latter in the finishing stage. A new and more powerful engine is being placed in the works this year, and the plant in other respects will be enlarged and improved. Architectural terra-cotta in many large and handsome designs is a special feature of these works. Except in the preparation of the clay, terra-cotta is a product of the sculptor's hand, unless a number of pieces of the same pattern are required, when a cast in plaster of Paris is made. Four skilled designers are employed in this branch of the work.

The company's quarry is at the falls of Limestone creek in the township of Nelson, on the Guelph road, about three miles south of the works. The gray band of the Medina sandstone crops out here at the surface and has a thickness of ten feet. Underlying it is a bed of green shale three feet in thickness, and below the green is the red shale of the Medina formation which has an exposure in the gorge of the creek below the falls of a hundred feet in thickness.

It is a very solid deposit and shows jointings at intervals, the edges of which have been stained about six inches on either side by the decomposed green shale which has percolated from the bed above. Lateral streaks of green shale are also seen in places, but the body of the deposit is very uniform in color. It has the compactness and firmness of stone when first taken out, but soon yields to the disintegrating influences of the weather.

The shale has been worked to a depth of thirty feet along a face of two hundred feet, and without doubt there is an immense body of it on the company's location, which extends along both sides of the gorge below the falls.

The brick made from this clay has a distinct metallic ring, and the percentage of loss from fracture or the chipping of edges in the kiln is comparatively very small, fully 75 per cent. of the whole turning out firsts in the grading. The shale contains so large a proportion of the oxide of iron as to be suitable for the manufacture of mineral paint, and this industry was carried on here for many years.

The clay is teamed by farmers of the locality to the works at Campbellville during the winter and when farm work is not pressing in other seasons of the year, for which they are paid a certain rate per ton.

The number of men employed at the works and the quarry, exclusive of teamsters, ranges from 25 to 30 for the whole year.

The best market for the product is in Montreal, where it has been used in the construction of several large buildings, but it has also been in good demand in Toronto and other cities and towns of Ontario.

Don Valley Pressed Brick Works.

The Don Valley pressed brick works are the property of Taylor Brothers of Toronto, and are located at the mouth of the third ravine on the west bank of the river, between the Belt Line Railway and the Don spur of the Canadian Pacific.

Experiments made with the clays of the locality resulted in showing that pressed brick of superior quality could be produced from the shale of the Hudson River formation which outcrops at the base of the bank at several points along the river, and early in 1891 Taylor Brothers started to erect works and fit them with plant of the best and most modern description. This consists of two power presses having a capacity of moulding 30,000 brick daily, one with a capacity of 10,000 and a fourth of 4,000, or a total of 44,000 per day, together with grinding and screening machinery in which the clay is prepared for the presses. These machines are driven by an engine of 175 h.p.

Several buildings have been erected on the premises for burning the brick, eight kilns in which have an aggregate capacity of 1,100,000. The period of burning depends on the size of the kiln and ranges from four or five days to three weeks.

The Hudson River shale, where a quarry has been opened about fifty yards from the works, rises ten feet above the level of the valley. A bed of till three feet in thickness overlies it; this is a tough, indurated clay, the general character of which has been well described by James Geikie in his work on the Great Ice Age.* Over the till is a bed of sand twenty-five feet in thickness, interbedded with thin layers of clay, and over the sand a deep bed of stratified Saugeen clay which rises nearly to the top of the bank, 140 feet above the valley of the river. This clay contains a proportion of lime, is light in color, fine in texture, and burns a beautiful buff. When mixed with the clay of the Hudson River shale, which burns a deep red, a variety of pleasing colors is produced, from which handsome effects in the architecture of outside and inside walls, fireplaces, etc., may be obtained.

The Hudson River shale has been quarried to a depth of twenty-five feet. Thin seams of limestone occur in the shale, which have to be culled out before the material is sent to the grinding mill. The soft shale which makes up much the greater part of the formation as seen in the quarry decomposes readily and is easily worked in the mill, but some beds of it are much harder than others and disintegrate slowly. It burns to a deep red color, the brick is strong and heavy, and has a clear, sharp, metallic ring.

The dip of the Hudson River formation is southward, and the shale disappears below the level of the valley near the crossing of the Belt Line Railway. The jointings have an east and west course, and their presence greatly facilitates the work of quarrying.

The number of men employed in the works and at the quarries is fifty-five, exclusive of teamsters.

Markets for the product of the Don Valley works have hardly been established yet, but there is a fair prospect of shipments being made to Buffalo and other American cities.

Other Works.

Works for the manufacture of pressed brick and terra cotta upon a small scale have been erected in the counties of Frontenac, Huron and Peel, and a new company has been organized which is erecting large works in the Don valley between the second and third ravines of Rosedale.

* "The deposit known as till is usually a firm, tough, tenacious, stony clay. So tough indeed does it often become that engineers would much rather excavate the most obdurate rocks. Hard rocks are more or less easily assailable by gunpowder, and the numerous joints and fissures by which they are traversed enable the navvies to wedge them out often in considerable lumps. But till has neither crack nor joint—it will not blast, and to pick it to pieces is a very slow and laborious process. Sometimes the stones in the till are so numerous that hardly any matrix of clay is visible. This, however, does not often happen. On the other hand they occasionally appear more sparsely scattered through the clay, which may then be dug for brick-making; but this occurs still less frequently. As a rule it is hard to say whether the stones or the clay form the larger percentage of the deposit in a mass of typical till. . . There is something very peculiar about the shape of the stones. They are neither round and oval like the pebbles in river gravel or the shingle of the sea shore, nor are they sharply angular like newly fallen debris at the base of a cliff, although they more closely resemble the latter than the former. They are indeed angular in shape, but the sharp corners and edges have invariably been smoothed away. Each is smoothed, polished and covered with striæ or scratches, some of which are delicate as the lines traced by an etching needle, others deep and harsh as the scores made by the plow upon a rock. But what is also worthy of note, most of the scratches, coarse and fine together, seem to run parallel to the longer diameter of the stones, which however are scratched in many other directions as well. . . Each stone in the till gives evidence of having been subjected to a grinding process. Almost every fragment has been jammed into the bottom of a glacier, and, held firmly in that position, has been grated along the rocky surface underneath, or over a pavement of the tough stony clay itself. In such a position the stones would naturally arrange themselves in the line of least resistance; hence it is that the most distinct ruts and striæ coincide with the longer diameter of the stones." pp. 10, 11, 14, 76.

The cutting of the Canadian Pacific Railway in the township of York, a short distance east of the north fork of the Don, is an illustration of the difficulty of excavation here referred to. The contractor for that section once told me that it was the hardest piece of work he had ever experienced in railway construction; it could neither be picked nor blasted. The bed of till in this cutting however is considerably thicker than in the exposure at the brick works. The stones are for the most part of Hudson River formation where examined, but they belong also to older formations, including granites and gneisses and all are glaciated. The new sewer on Wellington street cuts into this bed of till at a depth of fifteen feet below the street level, out of which fine specimens of striated stones and small boulders have been picked.

Hydraulic cement is of two kinds, known generally as the Natural and the Portland cements. The former is the product of an impure limestone found in certain parts of the Trenton and Niagara formations, and composed of lime, magnesia and clay in more or less definite proportions, found in the native state. The latter is an artificial product, obtained by mixing and treating carbonate of lime and clay in certain proportions. In his valuable pamphlet on Hydraulic Cements, Mr. Uriah Cummings of Buffalo thus describes the Portland cement:

In the manufacture of Portland cement in England the clay is mostly selected from the river beds and the carbonate of lime from the chalk deposits which form a large portion of England's surface, and is a nearly pure carbonate of lime.

Limestone is used wherever the chalk is unobtainable in some parts of England and Germany and elsewhere, and is finely pulverized preparatory to its mixture with clay.

These two ingredients are usually mixed together in a pug mill, with a free use of water.

Sometimes however they are ground together in a comparatively dry state.

But in either method the quality of the cement depends greatly on the thorough admixture of the two materials, it being more important even than a proper combining proportion, although the latter is essential to the production of a first-class cement.

After these materials are incorporated into a homogeneous mass it is dried and made into blocks or bricks and placed in suitable kilns for calcination.

The material as it enters the kiln, whether it be an artificial mixture or a natural cement stone, is a mechanical combination of two chemical compounds, *i. e.*, silicate of alumina and carbonate of lime.

The preliminary operation in calcination is the expulsion of moisture, which is soon followed by the carbonic acid contained in the carbonate of lime.

Then a chemical reaction takes place. Under a high temperature in the kiln the lime rendered caustic by the expulsion of the carbonic acid, and in intimate contact with the silicate of alumina, the latter is decomposed and a new combination is formed, known as silicate of lime and alumina.

If magnesia be present, then a triple silicate of lime, magnesia and alumina is formed.

In a Portland cement, however correct may be its proportion of ingredients, the clay and carbonate of lime must be thoroughly and intimately mixed.

Each atom of silicate of alumina must come into close contact with its equivalent of lime carbonate.

A failure in this regard will result in the production of a cement that will heat, check and expand, thus showing the presence of free or caustic lime, or free clay, and no amount of subsequent grinding or mixing will change these conditions, thus showing conclusively that the silicates can only be formed during calcination, with the silicic acid and the bases in the closest possible contact.

The Portland cement manufacturer has it in his power to control the proportions of the materials he uses, and renders it possible for him to make his product uniform.

Careful attention to proportions and mixing and care in the matter of calcination will produce a cement that seemingly leaves little to be desired.

But so long as these details are entrusted to the hands of ordinary laborers—and there seems to be no other way—so long as the natural cements sustain their present reputations, and through their very cheapness keeping down the price of Portland, none but the cheapest class of labor can be employed in the manufacture of artificial cements, and no matter how vigilant the superintendent may be there will be failures, and sometimes disastrous ones.*

The same authority in referring to natural cement says:

In all natural cement rock formations we find the deposit to consist of several layers or strata, and these layers rarely contain the same proportionate amount of ingredients.

As a rule the lower layers contain more clay than those above, the proportion of clay gradually diminishing and that of carbonate of lime increasing as we ascend in the series of layers.

There are exceptions to this rule, but with these included there are no cement rock deposits in this country that are known and operated that do not show a variation in the proportions of clay and lime carbonate among the several layers, amounting in some deposits to as high as 20 per cent. And so it may be seen that although the cement produced from such deposits may after a thorough mixing—first in the kiln and then in the grinding—exhibit by analysis a cement made up of very fair proportions, it also shows that it is not impossible to find that a cement may be heavily over-clayed, and still contain free or caustic lime. And it must be seen that although the proportions may be correct, yet

*Hydraulic Cements, Natural and Artificial; their Comparative Values, by N. Cummings, pp. 3-5.

the amount or percentage of the true silicates cannot be predicated on such analysis, for the reason that two distinct layers of diverse proportional ingredients, when placed together in a kiln, cannot form a chemical combination. The excess of lime in one fragment of a rock cannot combine with the excess clay in another, and it is only a mechanical mixture when ground together in the mill.

Variations are sometimes found in a single layer of the same quarry, and it is a rare thing to find uniform quality in quarries of the same neighborhood.

Fortunately excessive variations are rarely to be met with, but it is to these facts alone that may be attributed about all the superiority that can reasonably be claimed for an artificial cement over the natural production.*

Again as to the enduring qualities of cements Mr. Cummings says in the same pamphlet:

The setting of a cement becomes slower as the proportion of lime is increased, until we pass up through the slow-setting hydraulic limes and arrive at the pure limes where crystallization ceases.

All doubts in regard to the superiority of the over-limed cements must disappear when we study the wonderful record made by hydraulic limes, a material containing so much free lime as to prevent its induration when subjected to immediate immersion, and usually so after several days in the air. Although the free lime may have been thoroughly hydrated, they therefore pass beyond the limits of what may be termed hydraulic cements. Yet if given four to eight weeks in the air in masonry or concrete they will bear immersion as well as the best hydraulic cements, and it is yet to be proven that they are not superior in that respect, and for exposed masonry they are immeasurably so.

If we care to build for all time, we must remember that that which causes a cement to set promptly under water is also the cause of its comparatively early disintegration when exposed to the atmosphere.

A cement therefore that carries so much lime as to require three to six months to harden in exposed masonry will be found in perfect condition ages after the mortar made from quick-setting cements has crumbled out and disappeared.

When the famous civil engineer John Smeaton of England built the Eddystone lighthouse, commencing in 1757, he used the Aberthaw hydraulic lime, the analysis of which was as follows: lime 81.16, clay 18.84=100.

According to the analysis the lime contained 62 per cent. silicate of lime and 38 per cent. free or caustic lime, and of course was slow-setting, so slow in fact that Smeaton resorted to the use of plaster of Paris to cover the joints in the masonry to protect them from the sea, and he found it to remain long enough for the lime mortar to harden.

This lighthouse stood in perfect condition over 100 years, and until taken down to make way for a larger one.

Here we have an illustration of the durability of a natural cement containing so much free lime that it could not bear immediate immersion, and it is doubtful if it would stay up under water after a week's exposure to the air. To be sure he used Italian pozzulana with his hydraulic lime instead of sand, but there is nothing hydraulic about that. It is simply burnt clay containing occasionally a small proportion of lime. . .

The hydraulic lime of Teil in France, the composition of which is substantially the same as the Aberthaw lime, has been in use in the form of concrete made into blocks for sea walls for the past 55 years, without showing any signs of disintegration. The manufacture of Teil lime exceeds two million barrels annually.

Neither of these hydraulic limes can be made to test 10 pounds in 24 hours, if given but an hour in air, and they would stand a poor show in this country where quality is gauged by the testing machine.†

Mr. Cummings is not a wholly disinterested man, having himself been for many years employed in the manufacture of natural rock cement; but probably the favor with which artificial cement continues to be received to the present day is due in some measure to prejudice. Makers of the natural rock cement in Ontario complain that it is impossible to obtain a fair test where works of an important character are being carried on, and since streets have commenced to be laid with asphalt pavement in our larger towns and cities the demand for cement has largely increased. Yet artificial or Portland cement has the call over natural cement at less than half the price.‡ There may however be some compensation in this now that the production of artificial cement has been commenced in Ontario.

*Cummings' Hydraulic Cements, pp. 7-8. †Ib. pp. 20-22.

‡In two years 1890 and 1891 there were used on corporation works in the city of Toronto 28,000 barrels of Portland and only 200 barrels of natural rock cement, the former costing about $2.70 and the latter about $1.15 per barrel. In 1890 10,000 barrels of natural rock cement from the Thorold works was used in the construction of the St. Clair tunnel.

Queenston Cement Works.

These works are on the Hendershot lot in the township of Niagara, on the Queenston and Grimsby stone road. The quarry was formerly worked for building stone, but a bed of cement rock underlying the blue limestone having been exposed by the removal of the latter it was found that a new industry could be profitably established. The cement bed varies in thickness from two feet on the west to six feet on the east side of the quarry, but the proportion of lime is too great in the upper part of it so that care has to be taken to cull it out.

Messrs. Usher & Son of Thorold are lessees of the quarry, but the works are carried on by Mr. Edwin Tyler, who manufactures for them at a fixed price per barrel. The plant is maintained by Usher & Son and consists of two burning kilns and a mill of two run of stones to grind the rock. After being ground it is run through a cylindrical screen of rolled steel of 55-mesh for which Mr. Tyler has obtained a patent. This screen has a capacity of 150 barrels per day, but is run at 100 barrels. The kilns and grinding mill have a capacity of 600 barrels per day.

Mr. Tyler has had an experience of twenty years at the Akron cement works in the state of New York, and from his knowledge of the trade there he does not doubt but cement could be produced in Ontario at a cost to compete in the markets of that state even in the face of the present duty. The works employ six men, four of whom are quarrymen, and with the service of a steam drill 500 barrels of rock can be taken out per day.

The Thorold Hydraulic Cement Mills.

The business of the Thorold Hydraulic Cement Mills is carried on under the title of Estate of John Battle. The quarries are in the town of Thorold, on the east bank of the new canal, and were opened by the late John Brown in 1841, the location having an area of 44 acres. The cement bed is overlaid with ten feet of crystalline limestone, capped with ten feet of clay. In the summer season the stone is quarried in an open cut, but in the winter and in broken weather the men work under rock cover, the bed having been tunnelled and mined out to the extent of an acre. The limestone roof is supported by pillars which have been left standing at intervals, or which have been built up after the removal of the rock. The bed of cement stone is from ten to twelve feet in thickness, and is generally of uniform quality; but in the upper layer and sometimes in the body of the bed the proportion of limestone is too high for the production of a strong cement. From the quarry the stone is carted to a bank of five kilns, where it is built up with layers of soft coal and fired. The process of burning is accompanied with loud detonations, caused by the conversion of the moisture in the stone into steam, and fragments are occasionally thrown out of the kilns with considerable force; one of the attendants last year lost an eye from a blow received in this way. Five or six days are required to burn a kiln; or rather this time elapses before the work of drawing off begins after the kilns have been fired. Cinder or slag is formed in the burning, and care must be taken to cull out such pieces as their presence would prove injurious to the cement. The calcined stone is taken from the kilns to the mill, which is situated on the old canal and is driven by water-power which the canal supplies. It is first run through a breaker, and thence by elevators it is carried to three-run of buhr stones and ground to the requisite fineness. The grinding capacity of the mill is twenty-four tons per day, or 200 barrels of 240 lb. The yearly output is 30,000 barrels, the usual selling price of which is $1 per barrel.

The cement is submitted to a daily test; bricks of it are made which are left in the air to dry for one hour, put into water for twenty-three hours and then tested for breaking strain with an Acme machine. A breaking strength of from 75 to 100 lb. is regarded as satisfactory, but it runs up to 200 and over. Should the test fail it is assumed that the rock of the quarry contains a too high per centage of lime and the part from which it is taken is abandoned.

Limehouse Works.

The Limehouse cement works are the property of the Toronto Lime Company, and are situated on the main line of the Grand Trunk Railway where that road makes the ascent of the Niagara escarpment. The occurrence of the cement rock is the same as at Thorold, being at the base of the Niagara limestone. The works have been carried on for many years, but the industry is not so important as lime-making and the output of last year was not very large.

Rathbun & Co.'s Cement Works.

The cement works of Rathbun & Co. are located at Napanee Mills, in the county of Lennox. The manufacture of natural rock cement has been carried on there for ten years, the material being found in the Trenton limestone of the locality. For the last three years this cement has been used on Government works; it has been carefully tested and is found to give good satisfaction.

For the past five years the company has been experimenting with Portland cement, using for that purpose the shell marl found in several deposits along the line of the Bay of Quinte Railway. The principal deposit is near Marlbank station in the township of Hungerford, and covers an area of eight or ten square miles, occupying the basins of White lake and Dry lake. Pole tests have shown it to be in places twenty feet deep. Clay to mix with the marl is found on the company's land at Napanee Mills, and it is claimed that the composition in certain proportions makes a cement of the best quality. As shown by analyses the average consists of

Carbonate of lime	64.04
Magnesia	1.98
Silica	21.57
Lime and alumina	12.21
Carbon dioxide	0.25
	100.05

A record of the tensile strength per square inch of Portland cement produced at these works shows at three days 303 lb., at four days 425 lb., at six days 460 lb., and at seven days 500 lb. This is for cement containing 22 per cent. moisture. With cement containing 28 per cent. moisture the breaking strain at eleven days was 510 lb. A sample broken at 400 days yielded at a strain of 833 lb., and one at 420 days at 865 lb.

Three kilns have been erected for Portland and three for natural rock cement, and the grinding capacity of the mills is 500 barrels per day.

English Portland Cement Co.'s Works.

A company organized under the title of the English Portland Cement Co. commenced last year the erection of works at Marlbank, in the county of Hastings, and expects to begin operations some time this year. The material is found in great abundance in the locality.

North American Chemical Co.'s Works.

The North American Chemical, Mining and Manufacturing Co. was organized at Owen Sound in 1889 for the manufacture of Portland cement. Its capital is $100,000, of which it is stated that $60,000 has been paid up.

The works are situated on the shore of a lake, known as Shallow lake, in Keppel township in the county of Grey, occupying lots 6, 7, 8 and part of 9 in the 7th concession. The area of the location is 596 acres, including several small islands, and about 500 acres is under water for half the year.

Two streams flow into the lake, and in the dry season they unite near the works on the northern side, the channel continuing about 300 yards in a farther northwesterly direction towards the margin of the lake, where the waters disappear with a loud rumbling noise through a series of sinkholes in the limestone bottom. Evidence of the suction power here is seen in the mass of timber and debris which has been drawn around the sinkholes, as well as in the arrangement of the limestone boulders themselves, which take the shape of an inverted cone. Doubtless this is the source of many of the springs in that section of country, as the Niagara limestone is much fissured. The height above the level of Georgian Bay is here about a hundred feet.

The streams continue to flow the year round, but are highest in the months of April and May when the lake has an average depth of five feet. In June or the latter part of May the water begins to fall, and about the first of July the lake becomes dry over its whole bed, showing white masses of marl at many points of its surface; in December it begins to fill again.

The bed of the lake is covered with shell marl to depths ranging from one to six feet, the average being about four feet. Underlying the marl is a bed of clay two feet in depth, which by experiment has proven to make a strong Portland cement when mixed with the marl in definite proportions. Below this clay are alternate layers of sand and clay of a tough, spongy nature, and in places where excavations have been made the ground quakes like a bog. The marl and clay used in the manufacture of cement are taken out during the dry season and carted to the works.

The main building of the works is constructed of rubble stone, 270 feet by 40 feet, and was erected in 1889.

The wet process was first adopted in the manufacture of cement, the mixture being burnt in a Ransome cylinder, but it did not prove satisfactory. Operations were also delayed for some time on account of litigation between the company and the owner of the location, and when matters were finally settled it was decided to remodel the works according to the English system. For this purpose the manager of the company, Mr. Butchart, visited England last year and spent some time in examining a number of the best works there. He secured the service of three experienced men to have direction of the works, and after his return the improvements were commenced and carried on to completion by the end of the year.

Kilns have been substituted for the cylinder, a new mixing machine has been constructed and an engine of 250 h.p. has been put in to drive all the machinery of the works except that used in the manufacture of heading and staves for barrels.

The capacity of the works as completed last year is 75 barrels per day, but it is proposed to increase it during the present year. In the month of September forty men were employed by the company, constructing the works and taking out material.

GYPSUM.

Although gypsum is used largely as a fertilizer in districts within easy reach of the mines—the charge for freight circumscribing it for this purpose to comparatively narrow limits—its employment as a building material is now gradually extending, so that it may be properly classified under this head. Large quantities of gypsum are reported by explorers and officers of the Geological Survey to form the upper beds of the Devonian system on the Moose river and its tributaries, but these are too far distant for any available means of communication, even were the demand much larger than it now is or is likely to be for many years to come. The only workable deposits in the province within reach of markets occur in the Onondaga formation along the Grand river, and their occurrence is described as follows by Logan:

The outcrop of this gypsiferous formation extends from the Niagara river to the Saugeen on lake Huron, a distance of about one hundred and fifty miles; but the gypsum mines at present known are all found within about thirty-five miles, on the Grand river, extending from Cayuga to Paris. It is probable however that as the country to the northwest of Paris becomes more settled farther discoveries of gypsum beds will be made in that direction. To the southeast of Cayuga the overlying Drift conceals any beds of gypsum which may be present. All of these deposits seem to be confined to one stratigraphical position, which is probably about the middle of the formation. The gypsum occurs in beds which thin out in such a manner that they present the form of lenticular masses. These vary in horizontal diameter from a few yards to a quarter of a mile, and are from three to seven feet in thickness. The strata above them are arched and broken, while those beneath present an undisturbed level floor, the two coming into contact at the edge of the masses. This peculiar structure gives rise to mounds on the surface, which are regarded by the inhabitants of the region as indications of the presence of beds of gypsum below.*

Grand River Plaster Co's Mines and Works.

The mines and works of the Grand River Plaster Company are on lots 2 and 3 in Huff's tract in the township of North Cayuga, four miles southeast of Cayuga village, near the junction of Naughton creek with the Grand river. Two mines have been worked on this property, but one was shut down twenty-five years ago.

The mine on the more northerly lot opens near the bank of the creek and an adit has been driven a distance of about three hundred yards to a shaft sunk through the Drift and overlying limestone to the bed of gypsum, a depth of thirty feet. Four side drifts have also been extended to lengths ranging from fifty to a hundred yards, and from these the gypsum is now being mined.

A tramroad is laid down on the main adit and its branches, along which the rock is drawn out by a mule, and as the height of the roof is only four and a half feet, mule and workmen are bound to carry their heads low. The track is level, or nearly so, from the shaft to the mouth of the adit, and about a ton of rock is taken out with each carload.

The quality of the rock is variable, being in places nearly clean white gypsum and in others the gypsum occurs as nodules of different sizes in the limestone.

In former years twenty men were employed at the mines and works and thirteen cottages have been erected on the property for the accommodation of workmen, but during the past year only two miners were employed. A mill for grinding plaster of Paris was erected about twelve years ago, and works for the manufacture of calcined plaster four years ago.

Teasdale's Mine.

On lots 1 of the Huff tract and 4 of the Jones tract, in the township of Cayuga, Mr. Thomas Teasdale began opening a mine two years ago and has driven in an adit a length of eighty yards. The work however is much hindered since the raising of the dam on the Grand river at Dunnville, the waters at some seasons of the year rising to the level of the mine and flooding it.

The depth of the gypsum bed is four feet, and the upper portion of it is of fine quality, being a pure white color and free from limestone. The drift clay generally rests upon the gypsum where openings have been made, but in places a thin bed of shale intervenes.

Two shafts have been sunk on this property about thirty rods from the mouth of the mine, one twenty-five and the other seven years ago, and the bed of gypsum was struck at a depth of forty feet.

Mr. Teasdale says his father, who was a practical miner, came from England in 1842 or 1843 to open the mines on the Grand River Company's property. The product of this quarry is sold to the Alabastine Company of Paris.

Adamant Manufacturing Co's Mine.

The Adamant Manufacturing Company has its headquarters at Syracuse in the state of New York, but it has branch establishments in Toronto and in several cities of the United States. Its mine is located on lot 2 of the Jones tract on the River road in North Cayuga, and has an area of 65 acres. It was opened in 1875 by the late A. W. Thomson and four years afterwards was acquired by Gill, Allan & Brown of Paris, who in September, 1890, disposed of it to the present company.

A working shaft through clay with a descent of one foot in ten reaches the limestone cap rock at a perpendicular depth of 45 feet from the surface. This bed is five feet in

* Geology of Canada, p. 762.

thickness, and is of sufficient strength to support the weight of overlying clay where the opening does not exceed six feet in width.

The gypsum bed ranges from three to six feet in thickness, the average being about four feet, and it rests on limestone of extreme hardness.

The working shaft has been driven through the gypsum a total length of two hundred yards from its mouth, and near the extreme end it intersects a ventilating and draining shaft at a depth of fifty feet from the surface.

Five side drifts have been opened, one of ten, one of twenty, one of twenty-five, one of fifty and one of a hundred yards, which have been worked laterally in places to widths of 25 or 30 feet. The capping is at first supported by timber and afterwards with rubble stone from the mine securely built in.

The bed of gypsum runs parallel with the surface, and the foreman claims to have no difficulty in determining the boundaries of the field from the contour of the surface.

The bottom of the mine is near the level of the Grand river, four hundred yards away, and when the water in the river rises the mine is threatened with inundation. Last spring, during floodtime, the water poured in between the cap rock and the gypsum bed, and the two pumps were tested to their fullest capacity to keep it under control. The pumps are driven by wind power.

The upper portion of the bed is a nearly pure white gypsum, but the lower contains a large percentage of limestone and is not suitable for the best classes of work unless carefully selected.

A mill to grind plaster was built on the location soon after the mine was opened and was run until 1879, when the output of the mine intended for plaster was shipped to Paris and ground there.

ADAMANT WALL PLASTER.

In May, 1891, calcining works were started, the product of which is shipped to the Adamant mills in Toronto. These mills are at 100 Esplanade street east, having been established in October, 1889, in connection with the company of the same name in Syracuse. Seven grades of adamant are manufactured here, the material being used instead of lime to plaster walls. It is a prepared mortar, put up in bags ready for use at any season of the year, and when water is added it is put on with a trowel in the ordinary way. It is mixed by machinery, so as to secure uniformity in the proportion of ingredients, and the manufacturers claim that four hours after application it is as hard as marble.

The product of the mills last year was 15,000 bags, three-quarters of which consisted of 140 lb. bags for the first coat of plaster and one-quarter of 90 lb. bags for finishing. The value of the output was $10,000.

MARTINDALE'S MINES AND WORKS.

Gypsum mines were worked more than fifty years ago on the right bank of the Grand river below the village of York, in the township of Oneida. The only one now worked is owned by Thomas Martindale, but there were three others lower down the river. A plaster mill in connection with one of these was erected by a Mr. Cook in 1838.

In 1846 or 1847 Thomas Martindale the elder opened a mine on his farm half a mile below the village of York, on the opposite side of the river, and three or four years later a saw mill in the village was converted into a plaster mill which is being run now as the property of Thomas Martindale the younger. It has a capacity of fifteen tons per day if the water is high, but when the river is low it grinds only four or five tons per day.

The miller states that he came to the locality in 1840, and Cook's mines and the first plaster mill were in operation then.

The Martindale mine is on the property of Frederick Martindale, but is worked by his brother Thomas. The rock is mined by the contract system, and under favorable circumstances one man can take out seven or eight tons per day. The works extend under five fields of the farm.

The gypsum is carted to the mill where it is ground in the raw state and shipped to warehouses in Caledonia, Brantford and other neighboring towns and sold to farmers as land plaster.

THE CALEDONIA MINE.

The Caledonia mine is situated on lot 13 in the fifth concession of Oneida, and is the property of Mr. N. Garland of Toronto. Gypsum was discovered here by Mr. Joseph Brown, the former owner of the lot, while sinking a well for water, and about twenty years ago he sold it to Mr. Garland. Two acres was added from the lot on the opposite side of the highway and an opening was made where the ground slopes northward towards Mackenzie creek.

A shaft was driven southwestward under lot 13 and the mine was worked for fourteen years; but owing to the carelessness of the miners it filled in with soft clay for a length of thirty or forty yards, to remove which would cost more than to open a new mine.

A new shaft was accordingly commenced in June, 1887, about thirty rods south of the fifth concession road, the grade of which was one foot in nine through clay. The gypsum bed was struck at the end of eighty-six yards and the bottom of the bed at ninety-six yards, fifty-seven feet in perpendicular distance from the surface.

The cap rock is a soft limestone two to fifteen inches in thickness, and the depth of the gypsum bed ranges from four and a half to six feet.

At first the working in the gypsum was driven southward about twenty-five yards, the rock being mined laterally a width of three to ten yards, and about 1,000 tons taken out. This is near to the southerly limit of the property, and the timber supports having been taken out the overlying rock and earth cracked and sunk from the surface.

A side drift has been carried northwestward thirty-five yards with an average width of ten yards and about 2,500 tons of gypsum taken out. An escape and air shaft has been sunk from the surface to the main drift, 52 feet.

A tramroad is laid down the inclined shaft, and over it a horse draws out about one ton per load; the height is 5 feet 9 inches to the timbering, and the width 4 feet.

The mine is worked eight months in the year with four men under the contract system, who raise about six tons of assorted gypsum per day.

From the mine the gypsum is carted three miles to Caledonia, where it is ground into land plaster. This mill has been idle during the past year owing to a break in the dam across Grand river, but a new one is being erected in connection with a steam flouring mill at the railway station.

The area of Garland's gypsum field is computed to be six acres, but a well put down to a depth of sixty-two feet on an adjoining farm to the west shows the existence of a bed six feet in depth there.

ALABASTINE COMPANY OF PARIS.

The Alabastine Company of Paris was organised in 1885 with a capital of $50,000, of which $28,000 has been paid in. Its place of business is the old mill where land plaster has been ground for nearly seventy years, the gypsum having been supplied principally from the mines on the west bank of the Grand river, about a mile below the town of Paris, on the farms of Messrs. Miller and Martin, but the company has acquired the mining right *

* The History of the County of Brant gives some account of the early history of gypsum mining and the manufacture of land plaster at Paris. Henry Capron, who founded the town of Paris, was born in Vermont in 1796, came to Canada in 1822 and joined Joseph Van Norman in the manufacture of pig iron from bog ore in the county of Norfolk. It was hard work, but Capron made money, sold out his interest in the iron furnace May 7, 1828, and visiting the Forks of the Grand river in 1829 he bought 1,000 acres of

The manufacture of alabastine was commenced in 1885 and plastico in 1889, under an American patent. Both materials are used in the finishing of walls, the former for tinting and the latter for tinting, stippling and heavy relief work Both also go through the same process of manufacture, but differ in the component materials for the production of relief work.

After the plaster is calcined it is run through a pair of patent French buhr stones where it is ground by attrition and mixed with colors, sizing, and (if intended for plastico) with the necessary ingredients to produce a relief effect. All parts are fed mechanically, so that exact proportions are always attained. Afterwards the compound goes through a screw mixer and is then ready for boxing.

The quantity of alabastine manufactured in a year is 75 to 100 tons, and the market for it extends from St. John, N.B., to Vancouver, B.C.

Plastico is only beginning to be known, but it appears likely to grow in demand where artistic finish finds favor. The chief difficulty experienced with its introduction, the manufacturers say, is in the procuring of workmen with the requisite taste and skill; but as the American patentee bought out the works of the company in November of last year it is not unlikely that this drawback will be overcome.

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land there from William Holmes. This included nearly all of the present site of Paris. In the same year he hired a Mr. Cushman, a wheelwright, to build a mill with two run of stones, one for grain and the other for plaster. This mill stood on the river Nith, a little way from the junction of that river with the Grand. One Charles Conklin was employed as manager, and at the end of 1830 he rented the mill from Capron and threw himself into the business with great energy and success, mining and grinding gypsum, making brick, etc. "The first mill for manufacturing gypsum was built in 1823 by William Holmes. From him it passed into the hands of Thomas W. Coleman. It is now worked by Gill, Allan & Co. of Paris" (p. 473). Mr. Gill has been employed in the works for twenty-nine years.

NATURAL GAS.

Natural gas is not a mineral of recent discovery. Its existence has been known for thousands of years in the old world, and in the new its discovery goes back at least as far as the earliest exploitations for salt in Pennsylvania and Virginia. But the extent and number of gas fields on this continent have become known for the most part in connection with the borings for petroleum, a mineral with which gas is now known to be intimately associated. It is more than thirty years since the first petroleum wells were bored in Pennsylvania, but although gas was obtained in many of them its value as an article of fuel only began to be recognized about ten years ago. During those ten years many wells have been put down in Pennsylvania solely for gas, the relations of the mineral to geological formations and conditions have been carefully studied, and as a result of the information gained in this way exploratory work has been undertaken in many other parts of America with varying success. Here in Ontario we have two fields whose limits are known in part, both on the north shore of lake Erie, but separated from each other by a distance of 150 miles. Excepting wood and petroleum it is the only natural fuel we possess—unless peat can be so claimed,—and as it is pretty generally recognized that the supply admits of being exhausted, no matter how plentiful it may seem to be, the question of economizing it and getting the best service out of it for our own uses is deserving of the most careful consideration.

THE ESSEX COUNTY GAS FIELD.

The Essex county gas field in Ontario owes its development to the discovery of gas about three years earlier in Hancock county in the state of Ohio. The preliminary report upon Petroleum and Natural Gas in Ohio by Prof. Edward Orton in 1886, in which was demonstrated the relations of the occurence of these products to the Cincinnati arch, had the effect of inducing an exploration of that portion of Essex which was known to be traversed by the same arch. This fold or anticlinal extends from Alabama through the states of Tennessee, Kentucky, Indiana and Ohio, under lake Erie and the western counties of Ontario and Manitoulin island, to the northern shore of lake Huron, and perhaps far beyond. In a paper on the Petroleum Field of Ontario read before the Royal Society of Canada in May, 1887, Dr. Robert Bell states that the anticlinal theory in connection with the accumulation of gas and petroleum was mentioned to him by Sir William Logan in 1860, who was then in the habit of comparing the filling of a soda water bottle with gas and water with the process which he believed went on under the impervious strata of an anticlinal; but Dr. Bell believes that the idea originated with Dr. Sterry Hunt.

According to this hypothesis gas and oil, following hydrostatic laws, accumulate at the highest points or the domes along anticlinal folds. All the transverse joints and fissures and the spaces or channels between beds in deep-seated, unaltered, sedimentary rocks are believed to be filled with water. The particles of gas and oil as they are generated or become liberated in bitumeniferous rocks naturally tend to rise through these waters, aided perhaps by earth-tremors and earthquake jars and rocks such as are common in Canada and the northern United States. Downward projections and irregularities in the forms of the water spaces would arrest the gas and oil till these receptacles became filled to overflowing. Ultimately the lighter fluids from all points, following upward the slopes of the strata, would accumulate in largest quantity under the summit of the dome. The gas would take the highest place, the oil the next, while the water would be forced downward to an extent which would counterbalance the elastic force of the gas and the weight of the accumulated petroleum. The compressed gas would force back the oil and water alike from all the upper spaces. If the crown of such an anticlinal dome were tapped by a bore-hole from above the gas would of course escape first, followed by the oil and then by the water. This is what actually takes place in productive oil regions, and experience in Canada, the United States, Galicia, Baku, Burma, etc., has shown that the accumulations of petroleum are connected with anticlinals in the manner just described. The more extensive the anticlinal, as to either breadth or depth, the greater are the quantities of gas and oil which become collected as the result of what may be called the larger drainage area. Profitable supplies of petroleum and gas are therefore not to be looked for on anticlinals of small extent.*

The Cincinnati arch has an exposed width of about 130 miles in Kentucky, where it is supposed to have reached its greatest elevation. At Cincinnati, in southwestern Ohio, its breadth is about 90 miles, and the rocks of the formation—the Cincinnati group, which are the equivalent of the Hudson River and Utica shales—are shown by surface exposures to cover almost the whole area of the basins of the Miami and Little Miami rivers. Thence northward to lake Erie, between Toledo and Sandusky, it narrows gradually and possesses a northerly as well as an easterly and a westerly dip, so that whereas in Highland county north of Cincinnati the surface is 500 feet above the level of the lake it is at the lake shore about 400 feet below.† And as the elevation of the Cincinnati axis occurred during the period between the Lower and Upper Silurian ages the difficulty of tracing it on the Ontario side of the lake is obvious. It could only be done, as in northern Ohio, after the records of numerous borings had been obtained. Logan and Hunt traced it by means of the distribution of the formations to the head of lake Ontario, running in an east and west line across the peninsula; but Dr. Bell by careful study has come to the conclusion that the arch maintains its northward course and runs into the southern extremity of lake Huron.

The trend of its crown varies locally of course, but the geological distribution of the formations at the surface shows that this axis, coming northward from Kentucky and passing under the town of Findlay would strike the shore of lake Erie about midway between Toledo and Port Clinton, but in this vicinity the general wave is divided by a small synclinal into two subordinate anticlinals. Professor Orton has shown by the result of borings that the form of the Trenton area in northwestern Ohio, as indicated by a horizontal plane at 500 feet below the sea level, would prove that the axis at that depth points directly towards Toledo. Notwithstanding the difference in the courses of the deeply seated and surface folds, the main axis of the anticlinal will intersect the north shore of lake Erie in the vicinity of Little's point in the county of Essex; then running about north-northeast through Essex, Bothwell and Lambton, it will reach the southern shore of lake Huron near Kettle point. Its general bearing from lake Erie to lake Huron is about north 30° east, but it appears to curve gently to the southeast of a straight line and to pass under Petrolea. . . The Cincinnati anticlinal in southwestern Ontario as elsewhere is a gentle swell of great breadth, but within its general area and especially near the summit are minor anticlinals sometimes of a sharper form, running both parallel with and transverse to its general course.‡

Knowledge of the course of the Cincinnati arch across Ontario was in this way clearly indicated, and it only needed the revelations of Prof. Orton's first report to infuse the hope that the conditions under which petroleum and natural gas were found at Findlay in Ohio obtained also along the line of the same arch in Ontario. The following extract from this report was itself an inspiration:

The Trenton limestone is one of the most widely extended strata of the North American continent. It stretches from the islands north of Hudson bay to Alabama, and from Quebec to Minnesota. It has thousands of outcrops within these wide boundaries. It is known to be bituminous in New York; in Canada it yields a little oil; in Kentucky and Tennessee also it has been credited with oil and gas production; but it was a geological

*Transactions of the Royal Society of Canada, vol. v. section IV. p. 103.

†Geological Survey of Ohio, vol. I. pp. 89-111. See also Report of 1890, in which Prof. Orton describes the bearing of the uplift as revealed by recent borings. It now appears that instead of pursuing a uniformly northeast course, as was formerly believed, the Cincinnati uplift bears to the northwest into Indiana, whence there is a northeasterly offshoot back into Ohio through Lima to Findlay which is 20 to 30 miles wide at its narrowest portion. "The structure at Findlay," Prof. Orton says, "is that of a well-marked monocline, descending to the westward, and often at the rate of one foot in eight, for 1,000 to 1,200 feet of horizontal distance. The break can be traced with perfect distinctness to the north of Findlay, passing a little westward of Van Buren, North Baltimore, Bowling Green, Monclova and Sylvania." (p. 48.) At Findlay the uplift bends abruptly and bears due north or a little west of north to the Michigan boundary, which it reaches near Sylvania. In Sandusky and Ottawa counties there is a two-forked axis of no great force which extends from the vicinity of Tremont northward to the shore of lake Erie, and this is probably the one which crosses over into Ontario. Prof. Orton now proposes to abandon the "Cincinnati group" in the geological nomenclature of Ohio, as a result of discoveries recently made in the underground geology of that state, and to revert to the old names of Utica shale and Hudson River group. (p. 15.)

‡Transactions of the Royal Society of Canada, vol. v. p. 107.

surprise when it was found to be a great storehouse of fossil power underneath the flat country of northern Ohio. It had already been tapped at various points in the state, and had given no sign of such contents. The drill had reached it at Eaton, at Cincinnati in numerous wells, at Columbus, and at a few other points, and in none of them had it given rise to even the suspicion of being heavily charged with oil or gas. The discovery of this new horizon is certainly one of the most remarkable and important discoveries in the geology of the state. The rock is already yielding many million feet of gas per day, of enormous value as a source of power. It is also producing 1,000 to 1,500 barrels of oil per day, and the development is going forward with great rapidity and with all the excitement that everywhere attends such exploitation. At least a half million dollars will have been spent in drilling wells in the new field by the close of the present year, according to present indications. Tankage on the large scale and pipe lines are being introduced into the chief centers of production, and in short all the familiar exreriences in the opening of a new oil field are going forward here, with a Lower Silurian limestone that lies a thousand feet and more below the surface, and the nearest outcrops of which are 500 miles distant, as the base of operations. All this is a complete geological surprise. The practical driller has a maxim to the effect that "geology never filled a tank." Certainly geology takes no credit for the discovery of Trenton limestone oil and gas in northwestern Ohio.*

Encouraged by the success of borings for gas and oil on the Cincinnati arch at Findlay in Hancock county, Ohio, a number of local capitalists in the county of Essex undertook the task of exploiting that county over the continuation of the arch on the north shore of lake Erie, and the place chosen for the first test well was in the vicinity of Kingsville, in the township of South Gosfield.

KINGSVILLE NATURAL GAS AND OIL COMPANY.

The Kingsville Natural Gas and Oil Company was incorporated by letters patent October 3, 1890, the officers being Dr. S. A. King president, J. H. Smart vice-president, S. T. Copus secretary and Dr. E. Allworth treasurer. The capital stock is $40,000, all subscribed and one-ninth paid up.

The company was at first known as the Kingsville Citizens Natural Gas Association, and was formed in the latter part of 1888 to bore for gas and oil. It had its origin in this way :

The Ontario Natural Gas Company, of which Mr. Coste of Amherstburg was president, had in January, 1888, put down a well on the northwest corner of lot 7 in the first concession of Gosfield, the property of Mr. Wesley Wigle, and the council of Kingsville sought to make terms for the supply of gas. But owing to a dispute which arose between members of the company, and of legal proceedings which ensued, the president refused to make any arrangement with the village, although a pipe had been laid along the surface of the ground to light the streets, which was afterwards taken up. The service however had given the villagers a demonstration of the value of gas for the purposes of light and fuel, and the Citizens' Association was one of the results.

In May, 1889, the Association began to bore its No. 1 well near the lake shore, on the farm of Mr. Angus Wigle, lot 3 in the first concession. No oil or gas was obtained here, and although the failure was reported in August no further attempt to explore was made until the summer of 1890.

Meantime negotiations were re-opened with the Ontario Company, but they were fruitless ; this company had leased every farm in the locality and felt secure in its ability to dictate terms. But the villagers found a way out.

In the spring of 1890 application was made to the township council for leave to bore on the public roads, and a lease was granted for this purpose for one year at the rental of $1, renewable for a term of four years at a rate of $50 per well. The location selected for the first boring (being No. 2 well of the Kingsville Co.) is at the crossing of the Wigle sideroad and the second concession line, seventy yards northwest of the Ontario Company's well, and embracing an area 110 feet long by 30 wide.

President Coste offered a vigorous opposition to this movement, and besides moving

*Preliminary Report upon Petroleum and Inflammable Gas, by Professor Edward Orton, State Geologist, 1886, p. 30.

for an injunction to restrain the Association from proceeding to sink the well he took steps to quash the bylaw of the council under which the lease had been issued. Work was interrupted for two months until the injunction was dissolved by Justice Street, who held that gas was a mineral and therefore that the council was authorized by statute to lease the highway for mining purposes. This judgment was appealed, but in November, 1891, it was affirmed by the full court.*

Boring was resumed after judgment had been given by Justice Street, and about the first of August, 1890, gas was struck at a depth of 1,025 feet in what is believed to be Clinton limestone. Gas was found in small quantity at 800 feet, as well as at frequent intervals lower down. On approaching the main reservoir it was observed to rise with a gradually increasing volume from 1,015 feet until boring ceased, and the flow became so strong as to eject water, oil and pieces of rock. The well was then allowed to flow for twelve hours with the object of testing the permanency of the supply.

The flow was found satisfactory and continues to be so, the so-called rock pressure being nearly 500 lb. An exhibition of the well's capacity is occasionally given to visitors, when a stand pipe is opened and the gas allowed to escape at its full volume. On such occasions the roar is so loud as to be distinctly heard in the village two and a half miles distant, and when the gas is lighted the flame shoots fifty or sixty feet into the air.

In beginning to bore a well a pipe eight inches in diameter is driven through the drift to the rock. This pipe is made of wrought iron with a steel shoe fitted on the lower end, and is put together in sections of twenty feet in length connected by screws; as each section is driven to the ground level another is screwed on, and so continued until the rock is reached. Boulders are often met with, but they are either broken or forced out of the way. The core of the drive pipe is spudded, watered and lifted with a sand pump, and on getting to the rock an 8-inch drill continues the boring to a depth of about six hundred feet when it is cased with 5⅝-inch casing to shut off water from the section of the well below. In this No. 2 well a strong vein of mineral water was struck at a depth of about three hundred feet—strongly sulphurous, but clear, sparkling and palatable. It is an artesian supply and flows out in an unintermittent stream between the drive pipe and casing. But for the latter it would run into the bore and destroy the value of the well as a gas producer.

When a well is bored and blown off a 3-inch iron tube is inserted in the casing to within about fifteen feet of the bottom, to the lowest section of which is attached a packer to prevent the escape of gas except through the tube. The packer here used is the Dresser, one segment of which is rubber and is distended by springs which hold it firmly in place. The insertion of the tube is attended with much difficulty as the men are often overcome by the gas, only to get relief when they are dragged out into pure air. But once the tube is placed and securely packed the gas rises freely through it to the service pipe, whence it is delivered to consumers after the pressure has been reduced by a system of regulators.

After the completion of the well in 1890 a 3-inch service pipe was laid to the eastern limits of the village, where the regulating station was constructed. The pressure of gas in the pipe is 470 lb., an estimate of its daily capacity being 9,000,000 cubic feet, and if there was not an effective way of reducing and controlling it so as to obtain a steady flow at low pressure it is obvious that the gas could not be used for domestic purposes at all with safety. But by means of regulators the high pressure at which the gas escapes from the well is brought easily under control. These are two in number, each consisting of a double valve acted upon by the pressure of gas on a diaphragm that raises and lowers a weighted lever to close or open the valves according to the force of the pressure. In its passage through the first regulator the gas is reduced to a pressure of 50 lb., and in the second to 2 or 3 lb., as may be desired.

To insure the free action of the regulators it was found necessary to keep the gas at a temperature above freezing point, but the first chamber constructed for this purpose at Kingsville was destroyed by the heating flame igniting the gas in the pipe. In the new one the pipe passes to the regulators through an outside brick pit, and is enclosed in a sec-

*19 Ontario Reports p. 591, and 18 Ontario Appeal Reports p. 626.

tion of 8-inch drive pipe, the latter being heated by a gas flame which plays upon it and so maintains the required temperature of gas in the inner pipe. From this pit there is a current of hot air flowing to the regulating station and serves to keep it moderately warm, which is necessary for the free play of the parts of the regulators. An auxiliary pipe is provided in case of accident to the regulators, but it is connected with the main pipe at the west end of the village so as to provide for steady circulation. The supply pipe from the regulator house is four inches in diameter, and each consumer has his own regulator to govern pressure within certain limits, or in case of accident.

Besides Kingsville to the west, the village of Ruthven to the east takes gas from this well for light and fuel ; and so cheap and satisfactory is the supply that about nine-tenths of the dwellings, factories and places of business in both villages are patrons of it.

Well No. 3 was put down on the northeast corner of lot 4 in the first concession, about three-quarters of a mile west of No. 2. Work was commenced in October, 1890, and finished in January, 1891. The total depth reached was 1,114 feet, at which a strong vein of salt water was struck. At 700 feet a small flow of gas was obtained.

The Company's No. 4 well is located on the northwest corner of lot 7 in the first concession, about two hundred yards from the Ontario Company's well. Boring was commenced in the summer of 1891 and at first proceeded rapidly, the rock being reached at 116½ feet. The following particulars have been furnished by Mr. Copus, secretary of the company, under date of February 2nd, 1892.

The work proceeded slowly for a time. This was due in the first place to the tools which were required having been missent from the American side ; in the second place to the number of crevices which were struck at a depth of 400 feet in the rock, which gave the drillers much trouble, one being reported nine and another fourteen feet across ; and in the third place to the mistake of trying to case the well before a sound casing rock was reached, the pipe having to be drawn out four or five different times. After the casing had been set properly the tools went down very rapidly, until in the month of December the well came in with a very fair flow of gas.

The total depth of the hole is 1,063¼ feet. The gas was struck at 1,030 feet, but we went down in the hope that the flow might be increased. In this well we came across what has not been discovered in this field before ; after passing through the gas rock we ran into pure chalk. This has not so far as I know been discovered in any of the other wells in this field. *

At one time it looked as if the well would come in with oil, for there was a good showing, but it did not materialize.

When the well was capped and anchored it showed 400 lb. rock pressure, but the volume only shows an output of 2,231,000 cubic feet per day according to the scale of computation used on the American side.

I think we have every reason to congratulate ourselves so far on our works. During the past cold snap it has proved to our customers what a blessing gas is for domestic use. Of course the cold weather entails more vigilance on the part of the superintendent and men employed, for if anything should happen the line or regulating stations with the themometer below zero it would be a serious time with the householder who had no wood.

As you know, we are supplying the village of Ruthven, a small place four miles east of us, and since you were here the line has been extended to the west, until at present we have upwards of ten miles of pipe line, with five reducing stations. The pipe lines vary from one to four inches. Our main high pressure line to Kingsville is three inches to the reducing station. After leaving the station the main low pressure line is four inches, from which different sized lines branch.

In the village of Ruthven we carry from one-and-a-half to two pounds pressure. In Kingsville we carry from two to three pounds.

We have about 350 cook-stoves attached, 175 heating stoves, 25 house furnaces, besides open grates, lights, etc. Then in addition to this we supply gas to the woollen mill, grist mill, sash and door factories, turning factory, grain elevator, the Mettawas summer resort, fruit drying establishment, the churches, halls, lodge rooms and many other places. It also furnishes the fuel for burning lime, the stone for which is brought here from Pelee island.

Since the plant has been running we have not had to close down once for repairs or any other cause. This a pretty good showing when we see that such large companies as the one in Detroit and many others frequently have to turn the gas off from customers from one cause or other.

* A sample of this rock which was sent to me by Mr. Copus has been identified by Prof. Coleman of the School of Practical Scicence as magnesian limestone.

In the month of October last the price of gas to consumers was increased 20 per cent. for all uses except indoor lights, and the following rates are now charged under contract:

To private houses.—Cook stove No. 5 mixer, $1.50 per month for whole year: heating stove $1.50 and furnace $2.40 per month of seven months: open grates where furnace is used 75c., and if furnace not used $1.50 per month of seven months.

To hotels.—Furnace No. 5 mixer, $3 and No. 7 $3.60 per month of seven months, and for cooking range $2.40 per month of twelve months

To stores, offices, etc.—Heaters No. 5 mixer, $1.80 per month of seven months.

For indoor lights the rates are 16c. per month for one light, 14c. each for two, 12c. each for three and 10c. each for four or more.

Special rates are given to manufacturers, but although the fuel is cheap and abundant it does not appear to have yet brought any new or important industry into the locality.

The gas is wastefully used by consumers, the opinion seemingly prevailing that the store is inexhaustible. Street lamps are in some cases allowed to burn all day, perhaps because it is thought by the authorities to cost less to let the gas burn day and night than to turn it off in the morning and on in the evening. A number of the lamps are flambeau lights, whose flare at night when seen at a distance recalls the oldtime sight of burning log-heaps in the settler's clearing. The experience of gas-producing districts in the neighbouring state of Ohio, where like wastefulness was the rule a few years ago, might have taught the citizens of Kingsville a lesson in the economic use of natural gas. It is an excellent fuel, but the supply has limits in the richest fields, and in Gosfield the producing area as far as proved is very circumscribed.

BORINGS AT MARSHFIELD.

Several other wells have been bored in the Kingsville field, but gas has not been struck in any of them. In the township of South Colchester two deep wells were put down at Marshfield station by Hiram Walker of Walkerville. One sunk in February, 1890, to a depth of 1,040 feet, struck oil which was pumped for several weeks last year and yielded six barrels per day. Another well about fifty rods farther east was sunk to a depth of 1,300 feet and went through thirty-five feet of rock salt. Three wells were bored to supply water to flood a cranberry farm, one of which is a deep well on the north side of the farm. The other two wells are on the south side and water was struck in them at 160 feet, 80 feet in the rock; the water, which is impregnated with sulphur, flows in a strong and steady stream through a 4½-inch pipe when the tap is opened.

THE GAS FIELD OF FINDLAY, OHIO.

Having in view the collection of some facts on the economic uses of natural gas, I visited the town of Findlay, in Ohio, in the month of September. This town is 45 miles south of Toledo, on a plain 785 feet above the level of the sea and 212 feet above lake Erie. The underlying rock is limestone of the Niagara series, which is covered with Drift to a depth of ten or fifteen feet.

As far back as 1836 gas was found in the locality by a farmer who was digging a well for water. This strike was made at a depth of ten feet, and like experiences soon followed in other wells, but especially within the village limits of Findlay whenever the limestone floor of the country was reached, and where explosions frequently occurred in wells, sewers and other excavations by reason of the accumulation of gas. Gas was also noticed to escape constantly from springs flowing out of the limestone in the valleys of streams, and so general was it that considerable difficulty was found in getting a satisfactory supply of drinking water, owing to the presence of sulphureted hydrogen in the gas.

"There have always," says Prof. Orton, "been surface indications here of pronounced character, the most conspicuous of which are the sulphureted water of wells and springs, the escape of gas from springs and rock crevices, and its presence in numerous excavations that were carried down to the limestone rock."* And he adds that while the presence of

* Eighth Annual Report of the U.S. Geological Survey, 1886-7, p. 523.

gas was universally known, it was likewise universally deplored as a nuisance that must be endured because it could not be abated.

One of the villagers who dug a well with the usual result in 1838 resolved to turn the gas to some account, and used it to heat his house. He arranged an inverted sugar kettle in the well in such a way as to collect the gas, which was then conveyed through a wooden pipe to the sitting-room, where it was burned in an old gun barrel adapted to the purpose, and the fire thus lighted has been continued practically ever since. But of course those wells were all surface wells, and they yielded only a small supply.

The first person who is known to have recognised the larger possible value of Findlay gas, and to have set about devising schemes for developing and utilising it on any considerable scale, is Dr. Charles Oesterlin, an old and highly respected physician of the town. As early as 1862 Dr. Oesterlin made repeated efforts to interest his fellow-citizens in some means for accumulating the escaping gas in quantity enough to light the village streets at night. He experimented upon the gas springs, and gathered all the facts as to the presence of gas in the wells and other excavations in the neighborhood. There was no one however to second his sagacious plans, and nothing came from this discussion.*

In 1882 and 1883 the Pennsylvania gushers in the vicinity of Pittsburgh aroused an interest in many parts of Ohio where surface indications seemed to give promise of successful explorations, and many of the ventures turned out failures. Especially was this the case wherever borings were made in shale. A company organised in Findlay began to drill in September, 1884. The Drift was only eight feet in depth, and was followed by a series of nearly continuous solid limestone beds to a depth of 250 feet. The drill then entered a series of shales about 850 feet thick, and in boring through them gas was found at several horizons. About the middle of November the shale gave way to a solid and highly crystalline limestone rock at a depth of 1,092 feet, and this proved to be a reservoir of high-pressure gas. "As soon as the drill penetrated its surface," Prof. Orton says, "gas in large volume was set free, and the flow was increased for the next ten or twelve feet of descent. The gas was lighted, and its blaze at night illuminated a circle of country 20 miles in diameter. The Pioneer well was successful. A new horizon of gas and oil not dreamed of heretofore was brought to light, and Findlay became the centre and inspiration of a development of fossil power scarcely, if at all, inferior in value to the great petroleum reservoirs of western Pennsylvania and New York." Yet the volume of gas from this well was only 250,000 or 300,000 cubic feet per day. Many others have been bored since, some of which have yielded gas and some oil, and from a few the output has been enormous. And what surprised the geologists as much as anything else was the fact that both gas and oil were found in the Trenton limestone.

THE CITY GAS WORKS.

The Findlay Natural Gas Department is a branch of the city corporation, and the drilling and working of wells and the supply of gas to citizens for fuel and light is under its control. The first company, organised to bore the Pioneer well, sold out in a year to the Findlay Gas, Light and Coke Co., which put down sixteen wells, all within the corporation limits. In 1887 the second company sold to the city corporation, under which the work of development has been greatly extended. Forty additional wells have been put down in the corporation field and thirty-six outside, but all of them in the county of Hancock. Yet although so many wells have been drilled by the city, and many by the Standard Oil Trust and other companies, the gas area of the territory is not clearly defined, saving in this particular, that Main street divides the oil and gas territories, gas being got east of this street and oil west of it.

Every new well is a "wildcat" well.† It often happens indeed that wells bored in the close neighborhood of each other give very different results. For instance, a well 1,170 feet deep at Stewartsville, 3½ miles northeast of the court house, yielded 17,000,-

* Eighth Annual Report of the U. S. Geological Survey, p. 523.

†The term "wildcat" is better understood in Ohio than in Ontario, and was originally applied to the banking system which devastated the Ohio states from 1837 to 1860, under which banks were enabled to issue large amounts of notes while possessing little or no capital. As now understood a wildcat scheme is any wild, reckless, haphazard venture; and applied to boring for gas or oil it is a business of "going it blind." One never knows what a well may bring forth; it may turn out to be a gusher, or only a dry hole.

000 cubic feet per day. The farmers of the locality organised a company of their own and sunk a well to a depth of 1,200 feet, only thirty feet from the city well, and got nothing. But after torpedoing it a flow of 3,000,000 cubic feet per day was obtained, and having been put down to sell, it stood a year unused, when it was found to be charged with salt water and unproductive. The shattering of the rock by the shot had also the effect of reducing the capacity of the corporation well from 17,000,000 to 3,000,000 feet per day.

The producing territory controlled by the city occupies an area of several thousand acres, and 110 miles of pipes have been laid, including the field lines. The latter are six and eight-inch pipes, but it is proposed to lay down twelve-inch pipes instead, so as to reduce the friction. This is found to be necessary as the pressure of the gas is continually diminishing, it having fallen from 400 lb. to a varying pressure of 200 to 300 lb. Forty wells have a daily capacity of 120,000,000 cubic feet, but the quantity consumed does not exceed 40,000,000 feet. A complete high pressure line surrounds the town, and the gas is delivered through low pressure regulators to fourteen supply lines at a pressure of 8 oz. per square inch. If the mains were larger this pressure might be reduced to 4 oz. without impairing the efficiency of the supply, as with the higher pressure a quantity of the gas escapes without being consumed. But even with a pressure of 8 oz. private regulators are not required, for the pressure does not vary.

Among the industries which get their supply of fuel and light from the city wells are fourteen glass factories, employing about 200 hands each, two rolling mills, eight machine shops and foundries, seven boiler works, fifteen planing mills and wood-working factories, besides the water works, electric light works, brick yards, quarries, limekilns, and cooking and heating stoves for almost every citizen.

As evidence of the growth of Findlay since the discovery of natural gas, it need only be said that its population grew from 4,500 in 1880 to 18,000 in 1890, and that a large number of new and substantial industries were established during the decade.

United States Glass Co.

The United States Glass Co., which is one of fourteen similar establishments, sank a well of its own at the outset of its career five years ago. The rock pressure at first was 440 lb., and its daily capacity was 6,000,000 feet. Now its capacity is only 1,000,000 feet per day, and the pressure is reduced to 150 lb. The daily consumption is about 600,000 feet. Other wells in the vicinity of this company's well are also falling off steadily.

Findlay Rolling Mills Co.

The Findlay Rolling Mills Co. formerly carried on its business in the eastern part of Ohio, but was induced to remove to Findlay shortly after the discovery of natural gas there. Gas was supplied to the works at the rate of $200 per month, which, as compared with the company's former payment for fuel, was practically a free grant. But in the course of time the rate was increased to $1,460 per month, and the company then undertook to procure its own supply. This was done by boring seven wells about two years ago at a cost of $1,000 each, whose aggregate capacity is 15,000,000 feet per day, and pressure and supply do not appear to have fallen off since they were opened. There is no way of determining the daily consumption of the works, the only limit being the quantity required. There are nineteen puddling furnaces and one steel furnace whose daily product is fifty tons of muck iron and ten tons of steel. Four heating furnaces are required for the rolling mills and in forging iron which is manufactured into chains; the output of the latter is ten tons per day, and gas is the only fuel used except in heating the iron for two-inch cables. A plant of the same capacity would consume $30,000 worth of coal fuel in a year.

The Standard Oil Trust.

The Standard Oil Trust, working under the name of the Northwestern Co., was early in the Findlay field as a producer, and it has secured a territory which embraces several townships. For this land it pays a rent ranging from 50c. to $20 per acre; but where it could buy outright in good localities it has preferred doing so at prices ranging from $50 to $150 per acre. This company supplies outside places only, and it has pipe lines laid to Tiffin, Fostoria, Toledo and Detroit, the last named city 105 miles distant.

DRIFT GAS IN KENT COUNTY.

In many parts of Kent county natural gas has been found in the deep glacial Drift during the last thirty years, but more particularly along the base and on both sides of the high ridge which extends in a southwesterly direction through the townships of Orford, Howard and Harwich, and reaches the shore of lake Erie in the latter township about three miles west of Blenheim. Numerous borings were made in this district during the period of oil excitement at Bothwell, and although no petroleum was discovered at any point along or near the ridge several wells gave surprising yields of gas from the sand beds of the Drift. It is not at all likely that the gas had its origin in these beds, and no portion of the Drift below them is likely to have yielded it, assuming that gas is a product of organic matter, for as far as observations have been made there are no signs of animal or vegetable life having subsisted in the region during the deposition of the lower beds. The probability is that here as well as in Ohio the gas escaped from some of the older formations and was stored in the sandbeds of the Drift, which are usually overlaid with beds of hardpan or clay. Natural gas is found in greater or less quantity in all formations of the Silurian and Devonian series, where the nature of the rock allows it to accumulate; but unless the overlying rocks are close and compact the gas may have escaped into the atmosphere as fast as it was generated, or whenever earthquake or other disturbances have produced openings for its escape. The existence of surface gas is not therefore a sure sign that a large body of it may be found somewhere in the older formations; it is an evidence rather that vents have occurred by means of which the reservoir has been tapped and wasted. Yet at Findlay, in Ohio, this was not found to be the case, and there is a possibility that at some point in the county of Kent a store of natural gas exists in the deep underlying limestones. This also is to be borne in mind, that there are more "dry-holes" than producing wells in the Findlay field, whereas within the area of a hundred square miles in Kent over which surface shows have been obtained only one deep boring has been made.

BORINGS IN ORFORD.

After the dispute which occurred between the officers and directors of the Ontario Natural Gas Co., and which resulted in the closing down of that company's well at Kingsville, the Messrs. Walker were led to undertake prospecting work in the eastern part of Kent, in the vicinity of the Bothwell oil field. Mr. J. A. McKellar, agent of the Traders' Bank at Ridgetown, took an active part in this enterprise, and through his exertions a large number of farms were leased in the townships of Orford, Howard and Harwich. Two deep wells were bored in 1890.

DEEP WELLS NEAR THE THAMES RIVER.

The first of these wells was put down on the southeast corner of lot 10 in the eleventh concession of Orford, 2½ miles south of the river Thames. An 8-inch pipe was driven 160 feet to the rock. At 585 feet fresh water was struck and sulphur water at 630 feet. When a depth of 915 feet was reached a 5⅝-inch casing was put down to shut off the water, but a second flow of sulphur water was met with at 1,000 feet which rose in the pipe 100 feet, and at this point the drilling was discontinued. Following is the record as given by Mr. McKellar:

		Thickness.	Depth.
Soil, quicksand and gravel	feet	160	160
Broken limestone, gray		81	241
White shale or slate		70	311
Limestone, gray		90	401
Fossil limestone, pink		154	555
Fine sandstone, white		30	585
Fine sandstone, gray		45	630
Fossil limestone, pink to gray		285	915
Fine sandstone, yellow		85	1,000

A small show of oil was obtained in the first bed of fossil limestone, a rock which from being full of shells the drillers called clover-seed. The first flow of sulphur water was found in the white sandstone, but none of the beds gave a sign of gas.

The second well was bored on the east half of lot 23 in the fourteenth concession of Orford, half a mile from the Thames. Here the depth of the Drift was found to be 240 feet, through which an 8-inch pipe was driven. Following is the record as furnished by Mr. Walker from the driller's report :

		Thickness.	Depth.
Soil, quicksand and clay	feet	240	240
Limestone, gray		70	310
Limestone, pink		100	410
Limestone, gray		160	570
Shale, dark		2	572
Limestone, gray to black		628	1,200
Shale, black		3	1,203
Limestone, gray		60	1,265
Slate or shale, white		237	1,500
Limestone, gray		10	1,510
Salt, clear white		171	1,681
Limestone, pink		19	1,700
Limestone, gray		240	1,940
Shale, black		48	1,988
Limestone, gray and pink		212	2,200

Oil and water were found in the upper beds of limestone to a depth of 400 feet, and a small showing of oil again free from sulphur in the pink limestone at 1,681 to 1,700 feet. The bed of salt is of unusual thickness for the Ontario district, and being free from water it might be mined to good advantage if a shaft were sunk upon it, as is now being done in the state of New York, if the water in the upper limestone could be shut off or controlled. The driller reports that salt water occurred at intervals of a few feet in the lowest bed of limestone, and as he considered it would be useless to go deeper for gas or oil the well was abandoned.

The first of these wells is about four miles and the second about seven miles north of the ridge.

SURFACE WELLS ON THE RIDGE.

On the south side of the ridge in the same township a well was bored in 1867 which yielded a heavy flow of gas. It is on the farm of Mr. Jacob Limberger, lot 2 south of Middle road, 3½ miles from lake Erie. Mr. Limberger had hired a man to sink a well for water, and the place chosen was within a few feet of the northern side of his house and near to a small creek. The bore was ten or twelve inches in diameter and was cased with a wooden pipe. At a depth of 100 feet the drill suddenly dropped about four feet in what was supposed to be a bed of quicksand. A strong flow of gas then rose, and water, sand and stones were thrown out to a height of 40 or 50 feet above the surface. This continued for twelve hours, covering an area of two or three acres with mud and starting a stream of water in the creek, and a loud roaring noise was heard which gradually subsided as the flow slackened. The stones were ejected with such a force as to cut off one of the posts of the derrick six or seven inches in diameter. The pipe was slowly filled with sand and mud, but the gas continued to escape from the well for six or seven years, being most noticeable when the wind blew from the east. "I often heard it at night," one of the neighbors said, "like the rumble of a wagon across the bridge." Owing to the nearness of the well to the house no test of the burning qualities of the gas was made.

On the farm of Walter Guyitt, lot 63 north of Talbot road, a mile north of lake Erie and south of the ridge, three wells were bored in the Drift in 1889. The first struck a flow of gas at 180 feet, and the second struck gas at 160 feet ; both were filled up. The third well, some 200 yards farther north, struck gas and water at 140 feet, and upon a light being applied the gas flamed to the top of the derrick. The gas still continues to flow from this well, especially when the water has been pumped for some time to relieve the pressure or when the wind blows in a certain direction. The water is always riled.

On William Coleridge's farm, lot 66 south of Talbot road, a well sunk to a depth of

170 feet yields an abundant supply of water when pumped by windmill power. The water is of a slight milky color at first and is seen to be full of gas bubbles, but clears very quickly when exposed to the air.

Borings in Howard.

On the farm of Duncan Campbell, lot 6 on the sixth concession of Howard, and about two miles north of the ridge, a well was put down in 1889. At 72 feet water and gas were struck, and water, sand and stones were thrown up to a height of 30 or 40 feet. This continued for sixty hours, during which the smell of gas in the vicinity was sickening. A pipe was then inserted in the well when the flow of water and mud was renewed and lasted for a day. The water subsided for a time, but the roar of the escaping gas was maintained for five or six weeks. It is now a flowing well, but the water is discolored and unfit for use. Gas bubbles up intermittently, being strongest when an east wind prevails.

Four wells were bored some thirty years ago on the farm of David Hamil, lot 14 on the west townline of Howard, all of which have yielded gas. One is 630 feet deep, at which a rock was encountered so hard that the drill could make no headway upon it. It is now a flowing well and yields a little gas. A second was bored 30 feet to the north-east of the first, and water and gas were struck in it at 70 feet; the gas still flows strongly when the wind is in a particular direction. A third well a hundred yards to the south-west struck a flow of gas at 70 feet, the last 30 feet of which was bored with a three-inch auger. It was afterwards filled up, but the gas continued to rise through the earth and for three years it was used for cooking purposes, when it is supposed the ground became packed so hard that it ceased to escape. The fourth well was put down at a hotel about a hundred yards north of the third, having been dug 20 feet and bored with an auger a further depth of 50 feet. The well digger was smothered by the flow of gas, and two other men nearly lost their lives in the vain effort to rescue him. Water, stones and mud were thrown up to a height of 40 or 50 feet, and this exhibition continued for a week, when it is supposed the bore became filled. It is found here that a hardpan six to eighteen inches in thickness overlies the gas sand, under which is a bed of soft putty-like clay five or six feet in thickness; but in some cases the gas is found in quicksand under the clay. Almost all the wells in this neighborhood give indications of the presence of gas.

Borings in Harwich.

On the Harwich side of the townline a peculiar deposit is found which is locally known by the names of "Indian soap" and "gum bed." It occurs over a small area in sandy soil, is of a black color and foul odour and is found in irregular seams and pockets in the Drift. A boring has been made on this spot since the time of my visit, and Mr. McKellar informs me that at a depth of 50 feet a flow of gas has been struck stronger than that of any other well in the district. When lighted at night the flame rose 40 feet into the air, and the illumination was observed at a distance of ten miles. The deposit referred to is on the farm of Allen Sutherland.

In May, 1890, William Mead of lot 16 in the eighth concession bored a well on his farm for water. At a depth of 60 feet gas was found and water at 75 feet, but the boring was continued through the sand to the rock at 120 feet. A 3½-inch iron pipe was put down to the rock, but it soon choked with the fine sand. The gas escaped outside of the pipe and made an excavation at the surface four feet in depth and as many in diameter. The pipe was then taken out and a section 60 feet in length was put down instead, the lower end of it reaching to the sand bed. The roar of the escaping gas could be heard at the distance of a mile, and the pressure now does not show any apparent diminution. In July, 1890, Mr. Mead connected the well with his house and has since been using the gas for fuel and light. Several other wells have been bored in the same neighborhood, but gas has only been struck in two of them.

A well was bored on the gravel road six miles north of Blenheim twelve or fifteen years ago, at the Vestor house. A flow of gas was struck which exploded while a man was in the act of lighting his pipe, and the hotel was burnt. Two wells were bored in the same locality last year (1891), but no sign of gas was discovered in them.*

GAS FUEL FOR BURNING LIME.

Samuel L. Hartford is carrying on the business of lime-making in the Shrewsbury town plot south of Blenheim, where for the last three years he has been burning Pelee island limestone in a kiln of sixty barrels daily capacity. Until September of last year he used wood fuel, burning four cords per day, which cost delivered $1.50 per cord. Gas having a few months previously been discovered on Mr. William Muckle's farm in the same neighborhood, Hartford gave a contract for a well to be drilled on his premises. Work was commenced September 5th, and on September 7th gas was struck at the rock, at the depth of 107 feet. The drilling was continued in shale to 114 feet, when a two-inch pipe was inserted and connection was made with the kiln. The new fuel was found to answer the purpose quite as well as the old, and it saved the lime burner $6 per day.†

GAS SPRINGS IN LAKE ERIE.

Gas springs in the lake are a novelty. Two of them are found opposite the farm of Mr. James Claus, lot 4 in the fourth concession west of Communication road. "For twenty years," Mr. Claus said, "I have known of a spring of gas in lake Erie opposite my house, forty rods from the shore and in twenty feet of water. It bubbles up there continually, seed-time and harvest, making a commotion in the water eight or ten feet in diameter I should think. At different times we have gathered the gas there, but once in particular in the spring of this year (1891) when the boys went out and held a tub over the spring until it was filled. Then the tub was towed into the shore and when a plug was taken out of the bottom a match was applied and the gas burnt with a yellow flame for fifteen minutes. There is a smaller spring in four feet of water fifteen or twenty feet from the shore. There in the winter time it may be seen coming through a crack in the ice, and we have often lighted it." These facts are some evidence of the permanency of the supply of natural gas in the region. Mr. Claus went on to say that he had put down no well on his farm, as he takes water from the lake, but two wells had been bored on an adjoining farm about a hundred yards apart to the depth of 126 feet, and a strong flow of gas was found in each. No use is made of the gas as the owner does not live on the farm.‡

A DEEP WELL AT BLENHEIM.

In the summer of 1889 a company was organised at Blenheim to explore for gas, with a capital of $2,500 subscribed, subject to calls. A contract was made with a party from Findlay, Ohio, to drill a well to a depth of 1,200 feet for $1,500, and to a further depth of 300 feet if desired at $1.50 per foot, the contractors to put down an 8-inch

*These are the wells put down to furnish a water supply for the town of Chatham, and which are referred to on p. 57.

†Dr. Samson of Blenheim, to whom I am indebted for valuable assistance in procuring information in this district, informs me that several other wells have since been obtained in Harwich. A very good one has been bored about a mile west of Hartford's, and another near Weldon station on the Canada Southern Railway. The last mentioned yields gas from a bed of dry sand, at a depth of 60 feet.

‡"In parts of Ontario, where I have studied the occurrence of petroleum, I have repeatedly noticed in association with it a large quantity of inflammable gas; and far to the east of that we find this gas as low down as the horizon of the Trenton limestone. I can mention three or four cases near Montreal where it is produced. That gas has been since the days of the old French colonists an object of interest and attraction. It has been gathered and used occasionally for illuminating purposes, rather as a curiosity than otherwise. There is a discharge of the gas also in the St. Lawrence. A considerable amount is constantly discharged in that river, keeping the waters in ebullition. There is another place on the north side of the St. Lawrence, at St. Leon, and another on the Ottawa, where the gas is discharged. These three cases in which the gas rises through the Trenton limestone, and other cases where it comes from the shales immediately overlying, are illustrations of the wide distribution of this natural gas and of its low geological horizon."—Dr. Sterry Hunt, Trans. Am. Inst. M.E. vol. XIII, p. 782. Referring to the occurrence of Drift-gas reservoirs in the district between Montreal and Quebec Mr. C. A. Ashburner of the Pennsylvania Geological Survey says: "It might be well to state that nowhere in America has Drift-gas been found in quantities which could be profitably drilled for and utilized, except in some sections of Illinois; and even there the quantity of gas is so limited that it can only be profitably utilized for domestic illumination and heating in the immediate vicinity of the wells."—Trans. Am. Inst. M. E. vol. XVIII, p. 293.

drive pipe to the rock and $5\frac{5}{8}$-inch casing to shut off water; but in the event of salt water being reached at a lower depth the company would furnish the inner casing. The location chosen was on the crown of the ridge at the west end of the village, where the bed rock was found at 205 feet. After passing through ten or twelve feet of gravel the Drift was found to consist of a tough clay, and under it various beds of shale, limestone and sandstone were passed through to a depth of 1,200 feet. A light flow of gas was struck at 300 feet, which burnt with a red flame. At 625 feet a vein of mineral water was tapped which rose in the well to within 100 feet of the surface. The drillers also professed to have struck salt water at about 1,100 feet, and claimed that by the terms of the contract the company should supply the casing to shut it off. A dispute arose, and soon afterwards the tools were lost in the well and the work was abandoned by the contractors. This I believe is the only deep boring hitherto made on or near the Kent ridge.

Experiences of Well-Borers.

Peter Fleming lives on lot 16 of the west townline range in Howard, and is by occupation a farmer and well-digger. During the past two years he has been pretty constantly employed in putting down wells for water. He has bored about a hundred in Howard north of the ridge, chiefly on the fourth, fifth, sixth and seventh concessions, thirteen of which have yielded gas. In Harwich he has bored ten wells, four of which have produced gas. Water and gas he says are struck at depths ranging usually from 48 to 63 feet; but the nearer the ridge is approached the deeper the well, and the same observation applies in the direction of the Orford line—the one nearest that line having a depth of 86 feet. In every case but one gas and water were found above the hardpan. The Drift is mostly blue clay containing grit until a bed of putty-like clay about four feet in thickness is reached, below which is a bed of sand or gravel in which the water and gas are found. The volume of gas varies in the wells; in some a blue puff is observed when the containing bed is reached, and when the water comes the flow of gas ceases. In others a volume of water, sand and mud is thrown up to a height of perhaps 100 feet, varying according to the pressure. At the well on the farm of Duncan Campbell lumps of clay were ejected nearly a foot in diameter, and one stone more than six inches diameter; it was a smooth limestone boulder. The tools, weighing 1,300 lb., were thrown from the bottom of this well to the surface. The gas flowed from Thursday at 1 p.m. to Sunday at 1 a.m. In other wells the flow lasts from one to three days, and in a few cases the gurgling noise of the escaping gas appears to be permanent. As long as the gas continues to rise the water is of a milky color, but cattle are fond of it. The gas burns with a pale red flame and has a disagreeable odor.

Mr. T. C. Leper is also by occupation a well-digger and a large number of wells have been bored by him for water in the counties of Kent, Elgin and Middlesex. Two wells were drilled on the townline between Harwich and Raleigh, a mile north of the village of Buckhorn, on the north side of the ridge. Gas of 20 lb. pressure was obtained at 160 feet in a bed of course gravel under hardpan, and after shutting it off water was got at 175 feet. At William Muckle's farm, $4\frac{1}{2}$ miles south of Blenheim and within a mile of Rondeau, gas was struck about the first of May at 114 feet, the pressure of which was found to be 47 lb. as measured by a steam gauge. At Hartford's lime kiln in the same vicinity, to which reference has already been made, gas was found at the same depth, but the pressure was not measured. At the fair ground in Blenheim water was found at 196 feet, with only a small show of gas. At John Gordon's, in the Guild's settlement, a pocket of gas was tapped which blew out in a week. At Guild's school house three holes were bored before water was obtained, the deepest of which was 172 feet. One bored to 135 feet yielded gas, but the pressure was very light. At Ransome's school house on the Communication road a well 135 feet deep yielded artesian water and gas. The greatest depth attained on the south side of the ridge was on the farm of Mr. James English on the Communication road, where a well was bored to 170 feet, 42 feet in rock. Gas and water were found in this boring and the water rises within eight feet of the surface. On the sixteenth concession of Raleigh, on the north side of the ridge, water was found under hard pan at a depth of 200 feet. The best show of gas in this district is found in wells drilled in the vicinity of Rondeau harbor. Mr. Leper has bored for water at London and St. Thomas, the greatest depth of which is 130 feet, but no show of gas has been obtained. Three wells bored at the village of Union, south of St. Thomas, to a depth of 70 feet, yield a steady flow of water.

THE HALDIMAND AND WELLAND FIELD.

The largest area of gas-producing territory yet explored in Ontario is in the counties of Haldimand and Welland. It extends from the Grand river at Cayuga to the village of Bertie near the Niagara, a distance of about 42 miles. The producing belt ranges from one to two miles in breadth, and lies nearly parallel with lake Erie; but, as in all other fields, a great deal of uncertainty attends the enterprise of boring for gas. Some of the wells prove to be "gushers," and others only "dry holes." The gas is found about 200 feet nearer the surface than in the Essex field or at Findlay in Ohio, and generally in the Medina sandstone. But although the supply is abundant no large quantities are consumed in the field; the bulk of the gas is piped to Buffalo, where it is used as fuel. There is however some likelihood of glass works being established at or near Port Colborne this year.

THE PORT COLBORNE DISTRICT.

Natural gas has been known to exist in the vicinity of Port Colborne for a quarter of a century. Surface indications have been found there and at various other localities, especially in Welland county, but until the discovery and utilization of gas in Pennsylvania and Ohio no one seems to have heeded either the surface signs or the results obtained by deep borings. In 1886 exploration work began, but it was not until 1889 that capitalists were encouraged to invest on a large scale

THE JEFFERSON STEELE WELL.

In 1866 a well was bored for oil on the farm of Mr. Jefferson Steele, (lot 31 in the first concession of Humberstone) a mile west of the railway station, and gas and mineral water were struck at various depths; but at that time mineral gas was not appreciated for either fuel or light, and the discovery created interest only as a curiosity. The tools were lost in the bottom of the well, and as the water was thrown up with great force the work of sinking for oil was abandoned.

Mr. Steele informed me that sulphur gas was met with at a depth of 420 feet, and at between 600 and 700 feet a vein of water was struck the pressure of which was so great as to throw a column above the top of the derrick, 45 feet high. The water continued to flow in this way for two weeks, so that boring had to be suspended; but at the end of that time it subsided and became irregular, spouting forth four, five or six times a day. The drillers were enabled to resume work however, as a gush of water was always preceded by a warning gurgle, and they sank the well to a depth of 820 (some say 840) feet when the tools were lost.

The intermittent flow has kept on to the present time, but with no regularity. Occasionally the pressure is very strong. A pipe of 1¼-inch diameter which had been put down to a depth of 500 feet and weighted with a heavy beam of timber was in the winter of 1890-1 forced up four or five feet and a column of water was thrown 40 feet into the air.

Three years ago Mr. Steele piped the well for the purpose of supplying his own house and the houses of several neighbors with fuel, and in the summer of 1890 the line was extended to the camp of summer cottages at Solid Comfort on the lake shore. But during the winter the supply fell off, and although the 1¼-inch pipe was replaced by a ¾-inch one the use of gas was discontinued in the summer of 1891, resulting it seems likely from the drain upon the rock reservoir by the opening of numerous other wells in the district. That the chief supply was from the lower formation was proven by inserting the pipe below the vein of sulphur gas and packing it so as to shut off the latter. The gas was separated from the water by means of tanks into which the water flowed, and was thence conveyed to the service pipe; but the whole contrivance was of a pioneer character.

The water is now allowed to escape from the ¾-inch pipe, but the flow is unsteady—at times ceasing entirely for two or three seconds, and again pouring out at the full volume of the pipe. When a match is applied the gas burns with a nice flame; but the gas is as inconstant as the water, and seemingly the one is in no way dependent on the other. For four or five seconds a light may be applied to the mouth of the pipe and no gas is consumed, and then the gas ignites and burns for some time whether the pipe is flowing its full capacity of water or none at all. The water is said to possess medicinal qualities, and to be especially valuable in kidney diseases.

THE PORT COLBORNE GAS LIGHT AND FUEL COMPANY.

The first company to bore for natural gas in Canada was the Port Colborne Gas Light and Fuel Co., and was organised by Mr. Cornelius O'Neal of Port Colborne in 1885. There were ten shareholders, and they expended about $6,000 in sinking a deep well in the village, about 400 yards west of the Welland canal.

The total depth of the boring was 1,500 feet, the last 700 feet of which was in red shale. At 1,230 feet the tools were lost, and to recover them cost $1,000.

Gas in small quantity was struck between 40 and 50 feet and sulphur gas at 432 feet. At 455 feet salt water was met with, which spouted up to a height of 50 feet in the air. The well was then cased in an imperfect way and the boring continued.

At 763 feet, Mr. O'Neal says, a hard rock was struck which at a depth of 25 feet yielded a good flow of gas. This burned with a 6-foot flame from a 2-inch pipe, and although the water interfered with the supply there was sufficient to furnish the customs house, the railway station and a number of other places in the village until the Port Colborne Co. piped the Humberstone district three years afterwards and put in a service for the village.

The well had a capacity of 7,000 cubic feet per day by tank measure, and when the gas is allowed to accumulate it still flows at good pressure for half an hour.

OTHER WELLS IN PORT COLBORNE.

A second well was bored in Port Colborne in 1886, in rear of Noble's drug store, by Mr. Samuel Hopkins. At 773 feet a light flow of gas was struck, but the water had not been properly shut off and boring was discontinued.

In the same year Matthew Richardson put down a well on his own lot on the east side of the canal, a quarter of a mile due east of the O'Neal company's well, to a depth of 770 feet. A small flow of gas was obtained in the red Medina sandstone at 763 feet. At first the yield was about 16,000 cubic feet per day, but it is not so great now.

In 1890 Mr. Henry Cronmiller drilled a well on the Charles Steele farm just west of the village to a depth of 800 feet, but only a light flow of gas was obtained.*

* In the proceedings of the Canadian Institute, vol. XXIV. pp. 338-9, John C. M'Rae of Port Colborne furnishes the following record of the geological formation at that village as shown by drilling for natural gas: Commencing at a spot 12 feet above lake Erie level, the following strata were penetrated by the drill—

Corniferous	1 to 12	feet	Drift.
	12 to 25	"	Corniferous limestone.
	25 to 32	"	Onondaga limestone.
Lower Helderberg	32 to 35	"	Fair cement rock.
Salina	35 to 52	"	Shale and cement rock.
	52 to 60	"	Dark shale.
	60 to 90	"	Shale and cement rock.
	90 to 100	"	Gypsum and shale.
	100 to 107	"	Shale.
	107 to 147	"	Gypsum and shale.
	147 to 152	"	Shale.
	152 to 180	"	Shaly limestone.
	180 to 186	"	Drab colored limestone.
	186 to 190	"	Shaly limestone.
	190 to 302	"	Gypsum and shaly limestone, with transparent particles of *selenite* (?)
	302 to 500	"	Magnesian limestone.
	500 to 700	"	Shaly limestone.
Clinton	700 to 720	"	Clinton limestone.
	720 to 730	"	Clinton shale.

THE HUMBERSTONE DISTRICT.

The village of Humberstone is on the Welland canal a mile north of Port Colborne. Here a number of wells have been bored, and where gas has been found the flow is much greater and the pressure stronger than at Port Colborne.

NEAR'S WELL.

In the summer of 1890 Edward B. Near drilled a well in the west end of the village which was completed on the 2nd of July.

Limestone crops out at the surface in this locality and has a total depth of nearly 700 feet. Fresh water was cased off at 285 feet. Between 508 and 556 feet salt water was found, and this was cased off at 640 feet. At 683 feet the Clinton formation was reached and ten feet of that rock yielded gas. Red Medina sandstone according to the record of the boring occurred from 713 to 760 feet, followed by ten feet of slate or shale; gas sand from 770 to 780, slate from 780 to 815, white Medina from 815 to 822, and thence to 847 feet red shale.

The greatest flow was obtained at 683 feet, and at first the daily yield was computed at 500,000 cubic feet, with a pressure of 375 lb.

Service pipes were put in during the month of August, and 90 houses were supplied with gas for light and fuel during the first winter. Neff & Son's foundry also use it for fuel, and the Ontario Silver Co's. plating works take 1,000 feet per day; but the latter company procures its chief supply from the Natural Gas Co. and holds the Near well as a reserve.

The rate for cooking stoves is $12 a year, for heaters $1.50 per month for six months, and for a light 15 cents per month.

In October of 1891 there were 105 houses supplied by this well, and the pressure at that time with the maximum of consumption was 300 lb. It is delivered to consumers at a pressure reduced to 6 oz.

THE MORNINGSTAR WELL.

On the east side of the canal, fifty yards above the bridge, a well was bored in February, 1891, known as the Morningstar.

A flow of fresh water was found in the rock at a depth of 30 feet and salt water at about 400, but the well was drilled to 613 feet before it was cased. Gas was found in a bed of so-called sandstone at 666 feet, and a light flow in the white Medina at 798 feet.

The total depth of the well is 830 feet, and the total cost was $2,300. It is now sealed.

Medina	730 to 750 feet	Red shale, soft at first but gradually becoming harder.
	750 to 780 "	Red sandstone, mottled.
	780 to 833 "	Sandstone, red and white.
	833 to 1,500 "	Soft red shale, with bands of gray and green.

The Corniferous limestone here has a dip of 15 feet to the mile, and at Fredonia, New York state, 40 miles south of Port Colborne, it is not found until the drill has penetrated over 900 feet, so that further south a stronger dip prevails. The Niagara limestone outcrops 17½ miles north of Port Colborne, and, I am informed, has a dip of about 50 feet to the mile. Accordingly, we should find it at a depth of 875 feet, but we did not, as we had the Medina from 833 feet down to 1,500. Allowing that the dip is too great, it should be found between six and seven hundred feet: but so far I have been unable to find limestone which could be definitely assigned to the Niagara, and it was not until the second well was drilled that I obtained any limestone characteristic of the Clinton, to which Mr. E. Orton, state geologist of Ohio, to whom I am indebted for examining a series of samples, assigns the limestone found at 700 to 720 feet. At first not finding any limestone characteristic of the Niagara or Clinton, I thought that the whole stratum from the lower Helderberg to 1,500 feet was the Salina, and that the red shale was the lower part, but the finding of Clinton limestone shows that this was an error. Permanent water was found at 26 feet. Salt water at 452 feet. A fair flow of gas at 454 feet with a strong odor of sulphureted hydrogon. At 764½ feet the present supply was found which is almost odorless. The well was drilled to 1,500 feet, but there was no increase in the quantity of gas. The accurate flow of the well has not been estimated, but on its being closed for seven hours the hydraulic gauge registered 275 pounds, and was still going up. The gas is used both for light and fuel and gives satisfaction.

On George Zimmerman's farm two miles east of Humberstone, a well was bored by a syndicate where a small flow of gas has been obtained. It is not used.

PORT COLBORNE MUTUAL NATURAL GAS CO.

The Mutual Natural Gas Co. of Port Colborne was organised in March, 1891, with an authorised capital of $20.000, of which $14,000 has been subscribed and paid up.

The object of this company is to supply fuel for domestic and manufacturing purposes in the villages of Port Colborne and Humberstone, but all efforts to bring in manufacturers have so far failed.

The company has bored two wells and leased one in the township of Humberstone, northwest of the village of Port Colborne.

The first one is in the northeast corner of lot 29 in the first concession, and was put down to a depth of 831 feet, finishing in the Medina shale. A small flow of gas was got at 685 feet, which is computed at 100,000 cubic feet per day.

The second well is northwest of the first, on lot 29 of the second concession, and was bored to a depth of 705 feet at a cost of $1.70 per foot exclusive of casing pipe. Water was cased off at 630 feet, and gas was struck in fine sand at 690 feet, the bed continuing to yield down to the bottom of the well. The pressure is 365 lb. and the yield per day is estimated at 1,500,000 to 2,000,000 cubic feet.

The third well, which is a leased property, is on the west side of Humberstone village and is known as the Hopkins well. Its capacity is 500,000 feet per day.

Every street and alley-way of Port Colborne have been piped by the company, making about seven miles of service pipes, and the number of consumers in the village is about 200. It also supplies the Ontario Silver Co's. works at Humberstone.

The rates are $1 per month for cooking stoves, $1.50 for heaters, 18c. per month for ordinary tips, 25c. for medium, and 50c. for large lamps.

ONTARIO SILVER PLATING CO.

The Ontario Silver Plating Co. began business at Thorold ten years ago, but in December, 1890, the plant was removed to Humberstone, the inducement being an offer by the Mutual Gas Co. to furnish free gas for fuel for a term of ten years.

A 75 h. p. boiler supplies steam to drive the machinery and heat the building, and gas is the only fuel used for generating the steam. Gas is also used for annealing, and the estimated daily consumption is 50,000 cubic feet in winter and 25,000 to 30,000 in summer. This is equivalent to two tons of soft coal per day.

THE WAINFLEET DISTRICT.

In 1869 Mr. John Reeb purchased 20 acres of lot 6 in the first concession of Wainfleet, on the line of the Grand Trunk Railway three miles west of Port Colborne, and began to manufacture lime.

Until February, 1890, the fuel used at these works consisted of a mixture of coal and wood, which cost about $4,000 a year.

In November, 1889, Mr. Reeb began to bore on the property for gas, and the well was finished in February of the following year at a depth of 854 feet. Sulphur gas was found at 456 feet which yielded enough to run one kiln, and pockets of gas were struck all the way down to the white Medina sandstone at 823 feet. The greatest flow was obtained at 685 feet, in Clinton limestone.

The capacity of the well has not been measured, but it is sufficient to furnish fuel for two kilns with a producing capacity of 720 bushels of lime per day, and for three boilers which drive a hoisting engine, drills, pump, etc., besides light and fuel for six dwelling houses; and the well pressure with all fires running is 230 lb.

With wood and coal fuel 75 bushels of lime per kiln were drawn three times in the day of 24 hours, whereas with gas fuel 90 bushels per kiln are drawn four times in the day. The daily production has therefore been increased by 270 bushels, and this advantage is secured at an expenditure of $1,900 for drilling, casing and completing the well.

But in computing the economy effected with the use of gas fuel account has also to be taken of the labor of handling wood and coal, which is now dispensed with; so that while the efficiency of the works has been increased by 80,000 bushels a year the cost of labor and fuel has been reduced by not less than $4,500.

As an offset to this economy however there is the increased duty on lime under the McKinley tariff, for almost all the lime produced at these kilns is shipped to Buffalo. Before that tariff went into operation the duty on a carload of lime was $4; now it is $15.

Following is the record of this well as furnished by the contractor, Mr. S. E. Humphrey:

		Thickness.	Depth.
Drift	feet	2	2
Corniferous limestone		16	18
Lower Helderberg limestone, fair cement rock		5	23
" " cement rock and shale		7	30
Impure limestone with shale and gypsum (Onondaga)		390	420
Niagara limestone		185	605
Niagara shale		79	684
Clinton limestone and shale		30	714
Mottled Medina stone		46	760
Shaly Medina sandstone		40	800
White Medina sandstone		23	823
Medina shale		31	854

Gas was obtained at 430, 448 and 466 feet and salt water at 468 feet, in Niagara limestone; but the principal flow the contractor says was got in the Clinton limestone at 685 feet, and from the white Medina sandstone at 800 to 815 feet. The well was cased to 632 feet, in the Niagara shale.

The Provincial Natural Gas and Fuel Company.

The largest operations in the Haldimand and Welland field are being carried on by the Provincial Natural Gas and Fuel Company of Ontario. This company was organised in May, 1889, with a capital of $500,000, which has since been increased to $600,000, the leading mover in the enterprise being Mr. Eugene Coste of Amherstburg, formerly connected with the Geological Survey. Mr. Coste began to explore the county of Welland as soon as the company was organised, for which purpose leases were procured on a large number of farms in territory supposed to be gas-bearing.* He had the benefit of the

* The following lease is copied from a file in the Registry office of the county of Welland, and is one of the regular forms saving as to details of terms and conditions:

Memorandum of agreement and lease made and entered into this 17th day of September, A.D. 1891, by and between Edward T. Green, of the county of Welland, in the province of Ontario of the first part, and the Provincial Natural Gas and Fuel Company of Ontario (Limited) of the second part.

Witnesseth, That the party of the first part in consideration of one dollar in hand paid, the receipt of which is hereby acknowledged, and the covenants, rents and stipulations hereinafter contained, has granted, demised and let unto the said party of the second part the exclusive right of drilling and operating for petroleum, oil and gas, and taking and removing same therefrom upon all that certain tract of land situate in the township of Humberstone, county of Welland, province of Ontario, and bounded and described as follows: [Description of lot 6 in 5th concession, 87 acres.]

The party of the second part to have and to hold the right hereby granted peaceably and quietly for the said purposes only on the following conditions:

If petroleum oil be obtained or produced, the said party of the second part hereby agrees to give the party of the first part one-tenth part of all the oil obtained on the said premises or the cash value of same at the option of the party of the first part.

If gas be found the said party of the second part further agrees to give the party of the first part $100 per annum for each 3,000,000 feet of gas per day found on said land as long as said gas well may be utilised by the party of the second part, and the privilege of using free of charge enough gas in one house on the premises for ordinary household purposes.

It is further agreed that if after one year from the date of this agreement a well has not been drilled on the premises, the party of the second part to retain the right hereby granted will pay to the party of the first part a rental of $21.50 per annum until work is commenced.

The party of the first part grants to the party of the second part the right of using sufficient water for all necessary purposes from the premises hereby leased except from wells used by the party of the first part, the right of way through said premises, the exclusive right to lay pipes to convey oil and gas, and the right to bring upon said premises and erect or remove any machinery or fixtures required by the party of the second part: Provided that no well shall be drilled within 200 feet of a house or barn or in orchard experience of those parties who had bored at Port Colborne and its vicinity, and selected as the location of the company's first well lot 35 in the third concession of Bertie, about seven miles east of Port Colborne. The territory since explored by borings has an area of twenty-eight square miles, being four miles in breadth from north to south and seven miles in length from east to west. No. 1 well is midway between the north and south and a little east of the centre of the east and west limits. Its record as given by Mr. Coste is as follows :

		Thickness.	Depth.
Soil and Drift	feet	3	3
Corniferous limestone		77	80
Onondaga limestone and shale, with gypsum		345	425
Guelph and Niagara limestone		225	650
Niagara black shales		55	705
Clinton limestone, white and gray		30	735
Medina sandstone and shale		115	850

For 80 feet in the Medina formation the drill passed through red, followed by 15 or 20 feet of dark shale. Below this came 15 or 20 feet of white sandstone, in which at a depth of 846 feet the gas was struck.

In other wells deeper borings have been made into the Medina shale, but no gas has been found in it. In some wells gas has been found in the Clinton formation, but in all of them the greatest flow proceeds from the Medina sandstone.

Drilling operations were carried on by the company steadily in 1889, and five wells were finished before the end of that year. In 1890 the work continued, and by the first of October, 1891, eighteen wells had been drilled and six others were in progress. Three of the completed wells have however been abandoned, although a small quantity of gas was found in each of them.

In one locality a show of petroleum has been found in the Medina sandstone, the following account of which has been given to me by Mr. Eugene Coste under date of 30th December, 1891 :

In answer to your enquiry of December the 24th I would say that the report is correct about the discovery of petroleum in one of our wells north and west of Sherkston, on lot 10 in the third concession of Humberstone. This is our well No. 20, which we completed on the 24th of October last. The oil was struck in it at the depth of 770 feet, in the Medina sandstone. It is a beautiful light oil of 44 Beaumé ; its color is light green and amber, like the best Pennsylvania oils, and there is no sulphur in it, the smell being quite sweet. We have since struck another oil well (our No. 28) 1,500 feet west and north from the first, on lot 11 of the same concession. The quality of the oil from this second well is just the same as from the first.

Fresh water in large quantity is found in all the wells from a few feet in the rock to about 335 feet, but the depth varies a little in each well. A very strong magnesian salt water is met with at 550 feet, but by sinking a $5\frac{5}{8}$-inch casing to 600 feet the water is shut off. In some wells the Drift consists of 50 or 60 feet of clay, which is bored, and an 8 inch drive pipe is put down to the rock. The dip of the formations, as shown by the records of the wells, is found to be uniformly about 30 feet per mile to the south.

Small quantities of the gas yielded by the wells of this company are supplied to consumers in the locality, and at the village of Victoria on the Niagara river, but the great bulk of it is delivered through pipe lines to the Buffalo Natural Gas Fuel Co. This company was organised in 1886, and it has a pipe line 90 miles long from the Bethlehem

without the consent of the party of the first part, and that all pipes will be laid under grourd at a sufficient depth unless a special consent is obtained from the party of the first part, and so as not to interfere with cultivation.

In the event of any damage done to the crop or other produce on the land hereby demised by the party of the second part, it is further agreed that the party of the first part shall be compensated therefor at the rate of $25 per acre for each acre of crop or other produce so destroyed.

Failure on the part of the party of the second part to comply with the conditions or to pay the cash considerations herein mentioned, either to the party of the first part in person or to his credit at the Imperial Bank at Port Colborne, will render this lease null and void and not binding on either party.

It is further agreed between the parties to this agreement that all conditions between the parties hereto shall extend to their heirs, administrators, executors and assigns.

In witness whereof the said parties have hereunto set their hands and seals the day and year first above written.

field in Pennsylvania to the city of Buffalo. But owing to low pressure in that district, which has gradually been falling, the company turned its attention to the Ontario field, and a contract was made with the Provincial Natural Gas and Fuel Co. under which pipe connection was made with Buffalo in January, 1891, and now this is the chief source of that city's supply of natural gas. The Buffalo company charges consumers 25 cents per 1,000 cubic feet as indicated by house meters; and under the contract terms the Provincial Co. receives 50 per cent. of the rates, which has enabled it to pay one quarterly dividend of 6 per cent. on its capital stock of $600,000—and a portion of its capital is water.

An 8-inch delivery pipe has been laid down from the side-road between lots 8 and 9 of Humberstone along the road allowance between the first and second concessions to a point near the townline between Humberstone and Bertie. Thence it has been laid north-east in Bertie to the Bowen road, and east along that road to the Niagara river. Branch lines of 2 to 6 inch pipes collect the gas from the several wells of the company to the main pipe. These pipes are wrought iron of tested strength, and large sizes are laid a foot under ground; but pipes of 2 to 3 inches diameter are laid on the surface when alongside fences or elsewhere out of the way, as the flow of gas is affected only in a slight degree by conditions of heat or cold.

Drip tanks are placed near each well to receive sand or moisture which may be forced up; but the gas contains no tar or other foreign material, and if there are no leaks the gas flows freely in all kinds of weather.

The rock pressure varies in the wells, ranging from 500 to 550 lb., while the yield ranges from 300,000 to 12,500,000 cubic feet per day of 24 hours. The average of fifteen wells supplying the main pipe line is 2,500,000 cubic feet per day as measured in the open air, but it must be much less at the point of consumption, owing to the effect of friction. At Victoria the gas is delivered to consumers under a pressure of 4 to 5 oz.

The expansion of natural gas under pressure produces intense cold, and experiments made at Victoria station by S. P. Stiker of Buffalo showed that mercury was reduced to 40° below zero C. With an alcohol thermometer the temperature was reduced to 80° below zero F.

Carroll Bros. Limekilns and Gas Wells.

Carroll Bros. of Buffalo have been carrying on operations on the lake shore in Humberstone for six years, burning lime and quarrying limestone and sand for the Buffalo market. The dunes which rise here to the height of fifty feet above the lake, and which extend for many miles along the north shore of the lake west from the Niagara river, furnish an inexhaustible supply of sand of excellent quality for building and road-making purposes. In the construction of asphalt and stone pavements large quantities are used in Buffalo, the bulk of which is furnished by the Carroll Bros. So that operations might be carried on at all seasons a $1\frac{1}{4}$-mile railway was built four years ago from the Grand Trunk station at Sherkston to the lake shore, passing alongside the limekilns, and additional tracks have been laid down at the foot of the dunes along the beach for a distance of $2\frac{1}{2}$ miles. Extensive docks have also been built where vessels may be loaded with sand, lime and limestone during the season of navigation. About forty cords of limestone are shipped per day to Buffalo, where it is used in chemical works and for flux at the iron furnaces. The firm employs seventy-five men at their several works in the summer months, and their average for the year is fifty.

The limekilns and quarries are on lot 4 in the first concession of Humberstone, and have been worked for many years. When Carroll Bros. acquired the property they erected a new kiln with a capacity of 75 barrels (10 tons) per day. To produce this quantity of lime required a consumption of eight cords of wood, at a cost of $2 per cord.

In March, 1890, a well was bored near the kiln for gas, which yielded about 2,000,000 cubic feet per day. The firm had no assurance of striking gas here, as the first well bored by them was a failure, although located within a hundred yards of one sunk by the Provincial Co. which yielded 5,000,000 feet per day. But their second well only repeated for them the experience of many others, and while a large volume was wasted at first—

the well having been given free vent for six or seven days at a time—the pressure is still 500 lb. as against 560 lb. when first opened.

Four other producing wells have been drilled on this property, and in August of 1891 the firm united with the Erie County Gas Co. of Buffalo for further development of the territory and the supply of gas to that city. Three additional wells have been put down since, two of which are productive, and a pipe line has been laid down to convey gas to Buffalo.

Carroll Bros. have also erected a second limekiln with a capacity of 125 barrels per day, which has been in operation since the beginning of September. The gas used for fuel is reduced to a pressure of 3 oz. through two regulators, and is mixed with air in the furnace. With this cheap fuel they are enabled to sell lime in the Buffalo market at 80 cents per barrel, although the duty has been increased under the new tariff from 4 to 15 cents per barrel.

Bertie Natural Gas Company.

The Bertie Natural Gas Company was organised February 21, 1891, with a capital of $2,000, afterwards increased to $8,000, and with headquarters at the village of Ridgeway, on the Buffalo and Goderich line of the Grand Trunk Railway. B. M. Disher is president, H. N. Hibbard managing director, and A. H. Kilman secretary-treasurer. A contract to drill for gas on a lot selected in the village was let in March to Carmody Bros. Work was commenced April 15, and the well was finished June 8. Following is the record of boring:

	Thickness.	Depth.
Flinty limestone .... feet	60	60
Shale and gypsum	90	150
Hard shale	5	155
Shaly rock	30	185
Slate and gypsum	15	200
Slate and shale	230	430
Limestone	115	545
Silicious limestone, salt water	15	560
Hard limestone	110	670
Slate	50	720
Clinton limestone	10	730
Shale	10	740
Red Medina sandstone	70	810
Sandstone, salt water	5	815
Light colored sandstone	5	820
Dark shale	20	840
White Medina sandstone	12	852
Red shale	18	870

Water was struck at 100 feet, and was met with at intervals to 250 feet, and it was shut off with a $5\frac{5}{8}$-inch casing at a depth of 660 feet. A bed of rock salt it is said was met with near the bottom of the boring.

The first gas was found in Clinton limestone at 725 feet; the second in red Medina sandstone at 785 feet; but the best flow was obtained at the level of 840 to 850 feet in the white Medina. A 3-inch pipe has been put down to the bottom of the well, through which the gas from the second and third horizons is delivered to the service pipe. The gas from the Clinton limestone is delivered separately through the casing pipe.

Gas was supplied to cottages at Crystal Beach, east of Point Abino, during the summer, and on the 27th September it began to be supplied to village consumers, the number of applicants being sixty, and the rate $25 a year for a cooking stove, heater and two jets. The receipts of the company to the end of the year were $479.57.

The rock pressure is estimated at 500 lb., but it is reduced by two Fulton & Chapman regulators to 5 oz. at the consuming point.

Niagara Falls Gas Fuel and Light Co.

The Niagara Falls Natural Gas Fuel and Light Co. was organised under an Ontario charter in the spring of 1889 with an authorised capital of $30,000, whereof $8,000 was subscribed. A well was bored the same year on the farm of Mr. L. McLashan, on the west side of Drummondville, to a depth of 1,080 feet. A small quantity of sulphur gas was found at a depth of 202 feet and boring was discontinued in red shale.

A second well was drilled on J. G. Cadham's farm, three-quarters of a mile south of the village, to a depth of 1,260 or 1,280 feet. Gas was got in white Medina sandstone at 300 feet, but the bed was only two feet in thickness and the yield was light. The well was cased off at that depth, but nothing was found below it—not even water.

In the spring of 1891 the operations of the company were renewed in the township of Humberstone, it having been financially strengthened in the meantime and the stock increased to $50,000. Leases were obtained on 500 acres in the southern part of the township.

The first well was drilled on the Barass farm in the first concession, just west of Carroll Bros.' limekilns. Its total depth is 917 feet, and gas was found in a bed of sandstone 21 feet thick at a depth of 860 feet. The yield of gas was not measured, but it was estimated to be 1,000,000 cubic feet per day; the rock pressure was 590 lb.

The company's second well is on David Michell's farm east of Sherkston, on the first concession of Humberstone, and was finished on the 3rd of October. The gas was found in the sandstone here also, and it is claimed that the capacity is 5,000,000 to 6,000,000 cubic feet per day.

The Welland District.

In 1891 two companies were formed to prospect for gas in the vicinity of the town of Welland, the first with $2,000 and the second with $3,000 capital. Two wells were bored during the summer and fall by the Carmody Bros. and the results in both cases were nearly the same.

The first well was located on Alexander Asher's farm, a quarter of a mile southeast of the village, and was let under contract to drill to a depth of 800 feet. The following record has been furnished by the drillers:

	Thickness.	Depth.
Drift ....feet	113	113
Soft slate	107	220
Hard limestone	210	430
Slate or shale	50	480
Clinton limestone	20	500
Red Medina sandstone	52	552
Slate or shale	25	577
White Medina sandstone	20	597
Red shale	115	712

Eighty-five feet of the Drift consisted of clay and quicksand. Water was met with at the surface of the rock and again at a depth of 300 feet, and was cased off at the bottom of the hard limestone (430 feet). A light flow of gas was struck in the red Medina sandstone at 512 feet, which continued without apparent abatement.

The second well is on the farm of Mr. Leitch, half a mile south of the first, and half a mile northeast of the Welland station of the Canada Southern Railway. Here the rock was struck at 112 feet, the Drift being composed of clay, quicksand and gravel. Following is the record of boring:

	Thickness.	Depth.
Drift ....feet	112	112
Slate or shale	118	230
Limestone	240	470
Slate or shale	50	520
Clinton limestone	13	533
Red Medina sandstone	45	578
Slate or shale	25	603
White Medina sandstone	20	623
Red shale	82	705

In this well about four times as much gas was found as in the other, but it was in the Clinton formation and continued only two days, when it diminished almost to the vanishing point.

The contract for the first well was let at $1.70 per foot and for the second at $1.50, the company furnishing for the latter the drive and casing pipe; the same persons were for the most part shareholders in both companies.

THE DUNNVILLE DISTRICT.

In April of last year a company was organised at Dunnville to bore for natural gas, known as the Dunnville Natural Gas Company, with F. J. Ramsay as president, L. A. Congdon secretary and John Taylor treasurer. At first the capital was $5,000, but after the discovery of gas it was increased to $20,000.

A contract to bore a well was let to Carmody Bros. to a depth of 800 feet, at $1.65 per foot, the contractors to furnish casing and drive pipe, and work was begun on the 22nd of June. The place selected is at the eastern end of the village, on the north side of the Welland canal feeder. Here the Drift was found to be 76 feet deep, 4 feet of the surface being yellow loam and 72 feet below it blue clay. The log of the well is as follows:

	Thickness.	Depth.
Drift ... feet	76	76
Brown limestone and thin layers of gypsum	74	150
Hard shale, with gypsum	205	355
Hard Niagara limestone	210	565
Soft shale or slate	47	612
Clinton limestone	24	636
Slate or shale	4	640
Red Medina sandstone	45	685
Hard shale or slate	40	725
White Medina sandstone and shale	15	740
White Medina sandstone	12	752
Red shale	20	772

Sulphur water was struck at 85 feet, and weak brine at 500 feet. The well was cased to the bottom of the Niagara limestone at 565 feet.

The first show of gas was found in the Clinton formation at 612 feet, and this bed yields about one-fifth of the total flow. The second show was obtained in the white Medina sandstone between 740 and 752 feet, but the strongest flow came from 747 feet. The boring was continued into the red shale below this bed so that it might serve as a drain or pocket to receive any fragment of sand or other rock which might fall into it.

The well was finished on the 22nd of August, when the gas showed a pressure of 375 lb., and the yield was estimated at 150,000 to 200,000 cubic feet per day, measured with an open flow.

A second well was commenced immediately after the first was finished, on the left bank of the Grand river and distant about a mile from the first, which was bored to a depth of 780 feet. Following is the record:

	Thickness.	Depth.
Drift ... feet	70	70
Limestone	80	150
Shale and slate	190	340
Hard limestone	227	567
Shale or slate	45	612
Clinton limestone	22	634
Shale or slate	1	635
Red Medina sandstone	45	680
Slate and shale	50	730
White Medina sandstone	20	750
Reddish shale	30	780

A third well put down by the same company gave the same record as the second, and the average flow of each of the three wells is 150,000 cubic feet per day. The maximum pressure is 335 lb., but during supply it falls to 200 lb. The daily consumption is about 100,000 cubic feet.

The second and third wells were shot with 30 quarts of nitro-glycerine each, which had the effect of doubling their flow of gas.

THE CAYUGA DISTRICT.

In the fall of 1891 steps were taken to explore the country in the vicinity of Cayuga for gas, and on the 25th of November Carmody Bros. began to bore a well on the left bank of the Grand river, within the village bounds. On the 16th of January of the present year the boring was finished in the Medina shale at a depth of 710 feet, with the following record :

		Thickness.	Depth.
Drift, clay	feet	23	23
Limestone		120	143
Shale		132	275
Hard limestone		232	507
Slate or shale		41	548
Clinton limestone		15	563
Slate or shale		5	568
Red Medina sandstone		35	603
Shale		62	665
White Medina sandstone		15	680
Red shale		30	710

The well was cased to a depth of 508 feet with 5⅝-inch casing, and gas was found at three levels, viz.: in the Clinton limestone, in the red Medina and in the white Medina sandstones. The daily yield is estimated to be 210,000 cubic feet.

THE NEW TORONTO FIELD.

Perhaps the most important fact connected with the discovery of natural gas in New Toronto is, that natural gas has been discovered there at all. But in the opinion of the best authorities on the subject gas in greater or less quantity may be found in all the sedimentary rocks, so that there is no certainty of its being obtained in paying quantity in every field where its existence has been proved. On the other hand, there is a possibility of its being found in great abundance ; but there is only one way of determining the matter, and that consists in making a full and possibly a costly exploration of the ground by deep borings.

THE ASYLUM WELL.

New Toronto is one of those speculative suburbs of Toronto which have recently been called into being by real estate men, and is situated in the township of Etobicoke on the western side of the village of Mimico. The new cottages for the insane, known as the Mimico asylum, are on the lake shore west of Mimico, and here in 1889 a deep well was bored with the object of procuring a supply of water for the institution. The depth of this well is 1,061 feet, and near the bottom of it a vein of bitter water was struck which rose in the bore 350 feet No fresh water was found, and the boring was therefore discontinued. But small flows of gas were met with which encouraged the hope that a supply of this valuable mineral might be procured which could be utilised to give the institution light and fuel. Inspector Christie thereupon sought expert opinion on the matter, and first consulted Dr. Bell of the Geological Survey, who replied as follows under date of August 20, 1889 :

You probably struck the Utica formation at 575 feet and passed quite through it in the next 150 feet. The gas you got at 725 feet would indicate that you had then entered the Trenton formation, which is somewhat jointed and open and allows the passage of gas through it, while the Utica probably would not.

At 1.000 feet you would likely be 275 feet into the Trenton, and at 1,061 feet 336 feet, or more than half way through that formation.

I don't think your chances of a strong gas well would be much improved by boring deeper, although there is always a possibility of finding more gas till you are quite through the Trenton, as a comparatively thin layer of impervious shale or clay under great pressure is sufficient to hold down gas. We do not know the exact thickness of the Trenton group (including the Black River and Birdseye) under Toronto, but it may amount to 500 or 550 feet.

Before sinking any deeper I think it would be well to try the effect of a dynamite cartridge.

Mr. Christie next consulted Mr. Eugene Coste, manager of the Provincial Natural Gas and Fuel Company, who examined the well and made the following report upon it under date of September 14, 1889 :

In accordance with the desire expressed in your letters of the 31st August and 5th of this month *re* the deep well sunk by the Government at the Mimico cottages in which natural gas was struck, I examined the well on the 11th inst., and after a careful consideration of the matter I now beg to report as follows:

The flow of natural gas struck at the Mimico cottages well, though burning with a nice little flame, is very small and has no commercial value even though it is so near the cottages.

Indeed even when made to flow from one-inch pipe it does not give any measurable flowing pressure on a water gauge, thus indicating a quantity of gas equal only to two or three thousand cubic feet a day of 24 hours.

This, I understand from the record kept of the boring, was struck at three different depths, viz.: 425, 575 and 1,052 feet, indicating of course the flow of each vein to be smaller again.

It may be said with certainty that no good vein of gas was encountered in the descent, though there is no doubt from the depths given above that the gas was struck in the Trenton limestone, below the Hudson River and Utica black shales, which were the first strata traversed in boring.

From the fact of the gas being found at Mimico in the Trenton limestone, the great famous reservoir of oil and gas in Ohio and Indiana, most geologists would conclude that the chances for augmenting the flow by the firing of a torpedo or for obtaining large quantities in other wells sunk in the neighborhood are good; but in my opinion this is not the case, and I have no hesitation in saying that it would be entirely useless (though it could be done without the least danger to the cottages) to shoot the well, or to sink it deeper, or to sink other wells near by in the hope of getting large quantities of gas.

Notwithstanding the generally admitted idea among geologists, the fossiliferous matter of the Trenton limestone (either animal or vegetable) has nothing to do with the production of natural gas, no more than the organic matter of any other strata.

In my opinion natural gas and petroleum have been originated by an entirely different action than the decomposition of organic remains.

This action only took place in certain districts, and according to my studies on the subject it did not take place at Mimico or around Mimico.

My conclusion is, then, that it is entirely useless to look there for more than what little escape was found, which escape may come from districts miles and miles away.

No accurate record of the boring was preserved, saving that the total depth was 1,061 feet, that salt or bitter water was found near the bottom which rose in the bore to a height of 350 feet, and that small flows of gas were supposed to have been met with at 550, 725 and 1,000 feet; but there is no certainty on these latter depths. However the discovery of gas in a second well in the vicinity in the early months of this year suggested to the Inspector the propriety of shooting the well with cartridges of nitro-glycerine. This was done, but without resulting in any apparent increase of the flow.

The formation at Mimico is Hudson River shale, which has a probable thickness of 700 feet, and there is little doubt that the boring entered the Trenton limestone.

The Syndicate Well.

The syndicate of real estate men who founded the town of New Toronto were induced by a knowledge of the showing at the asylum well to test their own property, being impressed by the great possibilities of natural gas as a factor in promoting a new town. Accordingly steps were taken late in 1891 to put down a deep well, and experienced drillers were brought over from Pennsylvania to undertake the work.

The boring penetrated the Hudson River shales and all the underlying formations to the Laurentian rocks, to a depth of 1,312 feet, when it was concluded that the quest was hopeless. A moderate flow of gas was found, according to the report of one of the drillers, at 780, 885 and 1,089 feet, with signs of oil at the second level. At 1,250 to 1,260 feet bitter water was struck which rose 600 feet in the well.

After the boring ceased the well was plugged at 1,200 feet, and it was shot at three different levels, with the result of increasing the flow of gas quite perceptibly. The capacity has not been measured, but it is understood that the pressure as indicated by a steam gauge was only 45 pounds.

Here as at the asylum well there is some doubt of the depths at which gas was found, and it is not absolutely certain that it had more than one source.

No samples of the borings were kept, but samples of rock thrown out by the lowest shot leave no doubt that they came from the Trenton limestone.

The syndicate proposes to sink one or more wells in the locality, feeling confident that a good supply of gas may be found there in spite of the views of some of the scientific experts whose opinions have been obtained.

THE MANITOULIN FIELD.

It has already been stated that the Cincinnati arch is believed to extend northward across the island of Manitoulin, and it is well known that petroleum exists in the Trenton limestone there. It also appears that natural gas has been struck in several wells, and the following memorandum on the subject has been given to me by Mr. F. A. Fenton of this city, who spent some time in exploring La Cloche island and other districts near Manitoulin for minerals last year.

GAS AT LITTLE CURRENT.

In the fall of 1890, about 1½ miles from the town of Little Current, a well was sunk on the farm of Robert Morphet, which at a depth of 120 feet yielded and still yields a steady flow of gas. A well was also drilled on the property of Mr. John Lynch at Little Current, in which there was a small showing of gas. During the summer of 1891 another well was put down on a farm about 4 miles southwest of the town to a depth of about 260 feet, at which depth drilling ceased because of the pressure of gas. It was with great difficulty that the last mentioned hole was plugged and at the present time a large amount of gas escapes daily, so much indeed that it is dangerous to light a match within 25 or 30 feet of the hole. As in Ohio, the gas and oil bearing rock of Manitoulin island is in the Trenton limestone, which there underlies the Clinton and Niagara limestones and Utica shales.

I am informed by Dr. Bell that none of the wells referred to by Mr. Fenton are likely to be good producers, as they have been bored in the valleys or synclinals. If natural gas exists in large quantity in that locality Dr. B. thinks it will be found near one or other of the arches or uplifts which cross the island along north and south lines.

ON THE ORIGIN, OCCURRENCE AND VALUE OF NATURAL GAS.

Our experience of natural gas in Ontario is confined to two localities, and does not date farther back than three years. Accordingly we cannot pretend to know much about it from our own observation, and if we would avoid mistakes which may cost us dear the reasonable course to pursue is to aim at being guided by the experience and observation of others. It has therefore occurred to me that in treating of the origin, occurrence and value of natural gas I could not do better than present the views of the best authorities in the gas and petroleum regions of the United States, in the hope that persons in our own country who are interested in the search for and production of natural gas, as well as all who may be interested in the uses to which it is applied, may be guided into the best course alike for producers, consumers and the whole community. It will be observed that on some scientific aspects there are sharply defined lines of dissagreement between scientific men, especially on the occurrence of gas and petroleum. But upon the utilitarian side there is no division of opinion; every one recognizes the economic value of natural gas, and the folly of wasting it.

ORIGIN OF NATURAL GAS.

Various theories have been put forward by scientific men to account for the mode of origin of petroleum and natural gas, all of which have been stated and considered by Prof. Peckham in the tenth volume of the census of the United States, 1880, and discussed by other authorities since. Those theories may be divided into two classes, viz: (1) the chemical theory, which refers the origin of bitumens to an inorganic source—a result of chemical affinity upon mineral matter; and (2) the geological theory, which regards bitumens as the result of a decomposition of animal or vegetable substances which have been stored in the rocks. The extracts which follow present for the most part the latter theory, which is generally entertained by American geologists.*

Petroleum and natural gas, which for the moment play so distinguished a *role* in the history of the Pittsburgh region, are merely supplemental to its prosperity—a temporary, a fugitive condition to its wealth; and, although inseparable from the main features of the carboniferous geology, yet to be treated entirely apart from coal in our forecast of the future. They make indeed a most important chapter in our description of the geology of the region; but that chapter will be seen in course of time to be merely an appendix to the book. They go together into the chapter; for oil and gas are but two aspects of one and the same substance, originally united and still in combination; the one a product of the other; but neither of them holding any natural relationship to coal. The oil and gas obtained from cannel coal and the coal shales are not the same as the oil and gas which spouts and roars from the bore-holes. The cannel coal and coal shales are themselves of a different nature from embedded bituminous coal, having been produced in a different way originally, and having a different internal constitution.

Moreover, although the Dunkard creek oil and gas come from one of the rocks of the coal measures, the oil and gas product of western Pennsylvania at large comes from a great formation underlying all our coal measures, one in which no coal bed has ever been seen; and therefore, even if the oil and gas of that subcarboniferous formation were not generated in the formation itself, and have ascended from a greater depth, they are still further removed from any relation to the coal measures.†

As is known, the wells which in Ohio have been sunk to the vicinity of the Huron shale have very generally yielded oil, but only in small quantity. The difference in the productiveness of this oil horizon in Ohio and Pennsylvania has caused considerable surprise and disappointment. It seems to me however easy of explanation. On Oil creek the strata which underlie the surface are: First, the argillaceous shales of the Waverly group and Upper Chemung, which form the sides and bottom of the valley; below these, several beds of sandstone, interstratified with shale which belong to the Upper Chemung and Lower Portage groups; still lower, the black shales of the Portage and Genesee having a thickness of several hundred feet. These strata have all felt the disturb-

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* The principal advocates of the chemical theory are Berthelot, a French chemist, and Dr. Mendeleeff of St. Petersburg. The views of the latter are shown in the following extract from a paper read by Mr. William Anderson before the British Association in 1889, published in Science, vol. XIV p. 230:

"It is generally admitted that the crust of the earth is very thin in comparison with the diameter of the latter, and that this crust encloses soft or fluid substances, among which the carbides of iron and of other metals find a place. When in consequence of cooling or some other cause a fissure takes place through which a mountain range is protruded, the crust of the earth is bent, and at the foot of the hills fissures are formed; or, at any rate, the continuity of the rocky layers is disturbed and they are rendered more or less porous, so that surface waters are able to make their way deep into the bowels of the earth, and to reach occasionally the heated deposits of metallic carbides, which may exist either in a separated condition or blended with other matter. Under such circumstances it is easy to see what must take place. Iron, or whatever other metal may be present, forms an oxide with the oxygen of the water. Hydrogen is either set free or combined with the carbon which was associated with the metal, and becomes a volatile substance; that is, naphtha. The water which had penetrated down to the incandescent mass was changed into steam, a portion of which found its way through the porous substances with which the fissures were filled, and carried with it the vapors of the newly formed hydrocarbons, and this mixture of vapors was condensed wholly or in part as soon as it reached the cooler strata. The chemical composition of the hydrocarbons produced will depend upon the conditions of temperature and pressure under which they are formed. It is obvious that these may vary between very wide limits; and hence it is that mineral oils, mineral pitch, ozokerite and similar products differ so greatly from each other in the relative proportions of hydrogen and carbon. I may mention that artificial petroleum has been frequently prepared by a process analogous to that described above.

"Such is the theory of the distinguished philosopher, who has framed it not alone upon his wide chemical knowledge, but also upon the practical experience derived from visiting officially the principal oil-producing districts of Europe and America, from discussing the subject with able men deeply interested in the oil industry, and from collecting all the available literature on the subject. It is needless to remark that Dr. Mendeleeff's views are not shared by every competent authority; nevertheless the remarkable permanence of oil wells, the apparently inexhaustible evolution of hydrocarbon gases in certain regions, almost forces one to believe that the hydrocarbon products must be forming as fast as they are consumed, that there is little danger of the demand ever exceeding the supply, and that there is every prospect of oil being found in almost every portion of the surface of the earth, especially in the vicinity of great geological disturbances. Improved methods of boring wells will enable greater depths to be reached; and it should be remembered that apart from the cost of sinking a deep well there is no extra expense in working at great depths, because the oil generally rises to the surface or near it. The extraordinary pressures, amounting to three hundred pounds per square inch, which have been measured in some wells, seem to me to yield conclusive evidence of the impermeability of the strata from under which the oil has been forced up, and tend to confirm the view that it must have been formed in regions far below any which could have contained organic remains.

† J. P. Lesley, State Geologist of Pennsylvania, in Transactions of the American Institute of Mining Engineers, vol. XIV. p. 620.

ing influence of the forces which raised the Alleghany mountains. Here then we have a peculiar geological substructure, such as is specially favorable to the production and accumulation of petroleum, and such as must be more or less perfectly paralleled elsewhere to make productive, or at least flowing wells possible. . . .

The influences that control the escape of carburetted hydrogen from the bituminous strata seem to be the same as those which regulate the flow of petroleum. The origin of the two hydrocarbons is the same. and they are evolved simultaneously by the spontaneous distillation of carbonaceous rocks. The source of the petroleum and the abundant flow of gas with which it is associated on Oil creek, the gas and less abundant petroleum of Erie and other points on the lake shore, is undoubtedly the Huron shale; and we must look to the physical condition of this and the associated strata for an explanation of the great variation in productiveness which they exhibit in different localities. . . . Where the oil and gas producing rocks and those overlying them are solid and compact, decomposition of the organic matter they contain takes place very slowly, and the escape of the resulting hydrocarbons is almost impossible. Where they are more or less shaken up decomposition takes place more rapidly; reservoirs are opened to receive the oil and gas, and fissures are produced which serve for their escape to the surface. Near the Alleghanies all the rocky strata are more or less disturbed, and here along certain lines the liquid and gaseous hydrocarbons are evolved in enormous quantities. As we come westward however we find the rocks more undisturbed, and the escape of oil and gas through natural or artificial orifices gradually diminished.*

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1. In the first place, all forms of bitumen must be considered together. They constitute a definite and well graded series throughout. There is no question, for example, as to mineral tar being derived from petroleum. Mineral tar *is* partially oxidized petroleum, and it is obvious therefore that this element needs no separate theory as to its origin.

In like manner no line can be drawn between mineral tar and asphalt. Asphalt is simply petroleum still further oxidized, and we are therefore absolved from the necessity of providing a theory for the origin of asphalt in addition to the origin of petroleum.

When petroleum so called is considered a great many varieties of crude oil are found to be included under the term, depending partly upon the chances for oxidation that the products have had. Natural oils range in gravity from below 20 degrees to above 50 degrees, Beaumé, the former so thick that they can scarcely be poured, the latter light enough to be burned in common lamps in the crude state.

If a line were to be drawn anywhere in the series it would be between gas and oil. The former as we know originates under many conditions in which petroleum does not appear, but on the other side petroleum is never found free from inflammable gas, and in a large way all the facts and the occurrences of both so exactly correspond that it is impossible to separate them in respect to their origin.

Which of these is the original substance? The question has been already answered. Petroleum is the parent product. From it all the varieties of the series are directly derived. Our task then is a simple one to this extent We are to inquire how rock oil originates in nature. When we can answer this question, we know that we understand as well how mineral tar and asphalt, and natural gas also, originated.

2. In the second place we need to bear in mind that the various members of the bituminous series are abundantly and almost universally distributed among the unaltered sedimentary rocks of the earth's crust. The valuable accumulations of these substances are rare, it is true, but one can scarcely go amiss of petroleum, asphalt or gas, at least in small quantities, among the stratified rocks that retain their original structure. In particular, the rocks of the entire Ohio valley can be said to be charged with petroleum. A well cannot be drilled at any point in the valley for even a few hundred feet in which careful examination will not reveal the presence of some representative of this bituminous series. The aggregate of this disseminated petroleum is often found to be very large. A fifth of one per cent. of petroleum, if distributed through a thousand feet of rock, would make a total to the acre or square mile far beyond any production that has ever been realized from the richest oil field, and percentages of this amount are not only not rare to find, but are even hard to miss.

It is a popular impression that oil and gas are unusual substances in nature. The object of this paragraph is to show that this impression is entirely unfounded, and that we must free our minds from it if we would consider in proper light the questions as to the origin of rock oil.†

In the same report from which the foregoing extract is quoted Prof. Orton sums up the two main views on the origin of petroleum held by American geologists as follows:

1. Petroleum is produced by the primary decomposition of organic matter, and mainly

* T. S. Newberry in Geology of Ohio, vol. I. pp. 160 and 192.

† Prof. Edward Orton in the Geological Survey of Kentucky, 1891, pp. 29-30.

in the rocks that contained the organic matter. Of this view Hunt is one of the chief advocates.*

2. Petroleum results from the distillation of organic hydrocarbons contained in the rocks, and has generally been transferred to strata higher than those in which it was formed. Newberry and Peckham have been quoted at length in support of this general theory. Newberry holds that a slow and constant distillation is in progress at low temperatures. Peckham refers the distillation of the petroleum of the great American fields to the heat connected with the elevation and metomorphism of the Appalachian mountain system.†

And in his general summing up on the subject Prof. Orton puts the various views of geologists in the form of the following propositions:

1. Petroleum is derived from organic matter.
2. Petroleum of the Pennsylvania type is derived from the organic matter of bituminous shales, and is probably of vegetable origin.
3. Petroleum of the Canada type is derived from limestones, and is probably of animal origin.
4. Petroleum has been produced at normal rock temperatures (in American fields) and is not a product of destructive distillation of bituminous shales.
5. The stock of petroleum in the rocks is already practically complete.‡

I have been favored by Mr. W. J. McGee of the Geological Survey of the United States with advance sheets of a report he has prepared for the Survey in which the subject of Rock Gas and Related Bitumens is very ably dealt with. To Mr. McGee's mind the hypotheses suggested by observations in Indiana, by the phenomena of the bitumen fields of the world, by common manufacturing processes, by the results of laboratory experimentation, and by observations upon a well known natural process, are as follows:

1. Rock gas is a simple product of slow primary decomposition at low temperature of organic matter (animal and vegetal) contained in natural sediments.
2. Petroleum is a simple product of primary decomposition of organic tissues imbedded in sediments when the process is long continued or accelerated by rise of temperature, increase of pressure, or orogenic movement.
3. The heavier bitumens may be products of primary decomposition of organic matter contained in sedimentary strata when the process of decomposition is exceedingly long continued or greatly intensified by heat, pressure or structural deformation; but most of them are doubtless residual, left after evaporation of the lighter members of the series.
4. In recent deposits gas alone may be generated, but in older deposits gas and oil are commonly generated simultaneously in proportions varying with the rate of the process and the extent to which it has been carried; or in brief,
5. Rock gas, petroleum and the heavier bitumens are simple products of natural processes of decomposition of the organic matter contained in sediments; and their weight and other attributes depend upon the conditions under which decomposition takes place.

A popular impression exists that the gas is being continually produced, but this is not a fact in a commercial sense as far as the natural gas deposits of the Appalachian region are concerned. "Natural gas and petroleum are intimately associated with one another. In all gas reservoirs it is possible to find petroleum, sometimes however in such infinitesimal quantities that it is of no commercial value, and can only be found by a very careful examination of the gas-producing rock. Natural gas is also always to be found in the rocks which produce petroleum, although in the latter case the amount is so small as not to be practically valuable.§

* In writing of the oil fields of Canada in the American Journal of Science Dr. Sterry Hunt said: "The facts observed in this locality appear to show that the petroleum, or the substance which has given rise to it, was deposited in the bed in which it is now found at the formation of the rock. We may suppose in these oil-bearing beds an accumulation of organic matters whose decomposition in the midst of a calcareous deposit has resulted in their complete transformation into petroleum, which has found a lodgment in the cavities of the shells and corals immediately near. Its absence from the unfilled cells of corals in the adjacent and interstratified beds forbids the idea of the introduction of the oil into these strata either by distillation or by infiltration. The same observations apply to the Trenton limestone, and if it shall be hereafter shown that the source of petroleum (as distinguished from asphalt) in other regions is to be found in marine fossiliferous limestones, a step will have been made toward a knowledge of the chemical conditions necessary to its formation."

† *Ib.* p. 42. ‡ *Ib.* p. 60. § Charles A. Ashburner in Trans. Am. Inst. M. E., vol. xviii. p. 291.

In the same paper (p. 290) Mr. Ashburner says:

By gas in commercial quantities I mean gas in such quantity that, if utilized with proper care and economy, it would generate steam at a cost below the cost at which the same duty could be obtained from the use of coal or wood at current prices, and that the net revenue from the use of the gas would be such as to give a reasonable profit on the capital invested in the drilling of the well and the piping of the gas to the consumer, and at the same time provide for a sinking fund to replace this invested capital within the time when it might be considered that the gas-producing rock would become absolutely exhausted. It is important in this connection to bear in mind that natural gas, like all other mineral deposits, can be exhausted. In a commercial sense a gas-reservoir is not unlike a coal-bed. For every cubic foot of gas taken out of a gas-reservoir there is just one cubic foot less remaining.

The close and invariable proximity of limestone to the wells has been noticed by all writers, but they have been most impressed by its being "fossiliferous" or shell limestone, and have drawn the erroneous inference that the animal matter once contained in those shells originated petroleum, but no fish oil ever contained *paraffin*. On the other hand the fossil shells are carbonate of lime, and as such capable of producing petroleum under circumstances such as many limestone beds have been subjected to. All limestone rocks were formed under water and are mainly composed of calcareous shells, corals encrinites and foraminifera, the latter similar to the foraminifera of "Atlantic ooze" and of English chalk beds. Everywhere under the microscope its organic origin is conspicuous. Limestone is the most widely diffused of all rocks, and contains 12 per cent. of carbon. Petroleum consists largely of carbon, and there is a far larger accummulation of carbon in the limestone rocks of the United Kingdom than in all the Coal measures the world contains. A range of limestone 100 miles in length by 10 miles in width and 1,000 yards in depth would contain 743,000 million tons of carbon, or sufficient to provide carbon for 875,000 million tons of petroleum. Deposits of bituminous shale have also limestone close at hand; *e.g.* coral-rag underlies the Kimmeridge clay, which is more or less saturated throughout with petroleum, and it also underlies the famous black shale in Kentucky which is extraordinarily rich in oil.*

OCCURRENCE OF NATURAL GAS.

Among American geologists there is little difference as to the manner in which natural gas occurs. Their testimony is that gas is found invariably in a porous or a fissured rock; in sandstone of more or less open composition; in pebbly beds which formed shore lines in the ancient seas; in limestone which has become porous by conversion into dolomite; or in limestone of a cavernous character or which is broken with jointings; and that the gas is confined within its reservoir by an impervious cover of shale or other rock. But as to whether it occurs in arched rocks invariably, either in anticlines or monoclines, or in synclines and level beds as well as in the others, there are very pronounced differences of opinion; as also on the causes which produce gas pressure. The views of the two opposing schools are presented in the following extracts:

It is difficult to prescribe any fixed limits in the geological scale to the occurrence of natural gas and petroleum. Every known rock, except the eruptive rocks, contains the remains of organic matter, animal and vegetable; and since it is quite certain that both oil and gas result from the decomposition of organic remains, it is quite possible to find oil and gas in rocks of any geological age, subsequent to the Archæan or rocks without life: in some rocks in commercial quantities, and in other rocks in quantities so small as to be only of scientific interest to the geologist and mineralogist.

Next to the necessity of having a sedimentary bed, such as sandstone, shale or slate, in which animal or vegetable remains of past geological ages have been buried, or a limestone bed made from water shells, the presence of natural gas is dependent upon the existence of a porous or cavernous rock to serve as a reservoir to hold the gas, and of an overlying impervious rock-roof to confine the gas The other necessary conditions for the occurrence of gas are more dependent upon the forces to which the strata have been subjected and the resulting geological structure than upon the age of the rocks themselves.†

Mr. J. P. Lesley, state geologist of Pennsylvania, has given the following short statement of principles involved in the answer to the question so often asked, Shall I bore for gas at my works?

1. There can be no gas stored up in the oldest rocks.

* The Origin of Petroleum by O. C. D. Ross, Report of the British Association for 1891, p. 640.
† C. A. Ashburner in Trans. Am. Inst. M. E., vol. xv. p. 507.

2. There can be no gas left underground where the old rocks have been turned up on edge and overturned, fractured and recemented, faulted and disturbed in a thousand ways. If there ever was any, it has long since found innumerable ways of escape into the atmosphere.

3. Where the rock formations lie pretty flat and have remained nearly undisturbed over extensive areas, there is always a chance of finding gas (if not oil) at some depth beneath the surface.

4. Wherever rock oil has been found, there and in the surrounding region rock gas is sure to exist.*

Two conditions dominate the gas production of the Trenton limestone of Indiana as of Ohio ; one chemical in its origin and nature, and one physical. The first condition is concerned with the porosity of the rock and the consequent possibility of storage of gas, oil and salt water in it, the latter state being probably essential to all vigorous production of either oil or gas. The second condition is concerned with the relief of the surface of the gas rock, and upon this also Nature inexorably insists in all gas and oil production. . . . The gas rock of Indiana as well as that of Ohio is a true and tolerably pure dolomite or magnesian limestone in the only cases in which chemical examination of it has been made. . . The analysis of the Trenton limestone outside the limits of production are equally valuable and significant. They show at a glance the cause of the barrenness of the rock southward. The stratum there becomes unproductive because it loses its porosity, or, to put the facts in a more natural order, the stratum becomes productive only when the dolomotic change has been accomplished in it. The mass of the Trenton limestone throughout the country at large, ninety-nine hundredths of it probably is a non-porous rock. . . That the Trenton limestone must be a porous rock to be an oil or gas rock goes without saying. As just shown, the highest degree of porosity in it is associated with a dolomitic composition, but its porosity ensures only the result that the rock shall be filled with one of three substances, gas, oil or salt water, almost invariably associated in all petroleum fields. Which of the three will be found occupying any particular portion of the porous part of the rock depends altogether on the relations of this particular portion to adjacent parts of the same stratum in the matter of elevation : in other words, on the local relief of the stratum. In every field in which oil or the gas derived from it is accumulated, certain comparatively small portions of the porous rock, always distinguished from the rest by relatively higher elevation, will be found assigned as it were to the storage of these desired substances, while the salt water holds possession of the bulk of the stratum on all sides.†

Referring again to the condition of "relief" or "uplift" in the rock, Prof. Orton explains that it

Results from some slight warping of these ancient strata in the course of their history, whereby the common contents of the porous portions of the Trenton limestone have been differentiated by gravity, the gas and oil seeking the highest levels and the salt water maintaining a lower but definite elevation in every field. The salt water level is necessarily the dead line of oil and gas production in the several sub-divisions of the productive territory. . . .

The influence of the remarkable discovery of oil and gas in the new horizon of Ohio and Indiana has been felt far and wide. Drilling directed specifically to the Trenton limestone has been undertaken on the strength of this discovery in many states and in localities 1,000 miles distant from the regions in which it was first found profitable. . . It is sufficient to say that there is nothing in the new experience to make it safe to count the Trenton limestone an oil rock or a gas rock in any locality unless it can be shown to have undergone the *dolomitic replacement* by which its porosity is assured. Even in case it has undergone this transformation it will not be found a reservoir of oil or gas in an important sense unless, in the accidents of its history, some parts of its deeply-buried surface have acquired the *relief* that is essential to a due separation of its liquid and gaseous contents. It is not known, nor has it been rendered even probable, that the limestone meets these two inexorable conditions anywhere in its wide extent except in regions that are now undergoing development, as the gas fields and oil fields of Ohio and Indiana. In other words, there is a strong presumption that the Trenton limestone will not prove an oil rock or a gas rock in any new field.‡

The general conditions upon which the occurrence of natural gas seems to depend, from a consideration of the facts at present at our command are: (*a*) the porosity and homogeneousness of the sandstone which serves as a reservoir to hold the gas ; (*b*) the extent to which the strata above or below the gas-sand are cracked ; (*c*) the dip of the gas-sand and the position of the anticlines and synclines ; (*d*) the relative proportion of

*Annual Report of the Geological Survey of Pennsylvania for 1885, pp. 679-80.
†Prof. Edward Orton in the report of the U. S. Geological Survey for 1886-87, pp. 641-2-3. ‡*Ib.* pp. 653-62.

water, oil and gas contained in the gas-sand; and (*e*) the pressure under which the gas exists before being tapped by wells. Other conditions may still be discovered which will have as important a bearing upon the problem as those which I have stated. . . .

It would appear that the gas is closely related to petroleum, and that their origin is due largely to the same cause—the decomposition of animal and vegetable life. It is believed that the gas is not indigenous to the sand-rock from which it is obtained, but comes from the decomposition of life-forms which were entrapped in underlying strata. If this be so the amount of gas contained in any one sand depends first upon the extent to which the rocks are cracked between the horizons of such organic remains and the gas-sand reservoir in order to permit the gas to flow into the sand; and second upon the extent to which the rocks are cracked above the gas-sand which would permit the gas to escape into the atmosphere and totally disappear. . . .

The first necessary condition for the presence of gas however is dependent upon the existence of a porous rock to serve as a reservoir to hold it. A number of wells have been drilled which have found gas, but, if the drillers' records are to be credited, have not pierced sand-beds; in these cases the gas has been unquestionably obtained from a crack in the strata which serves as a conduit to convey the gas from its sand-bed reservoir to the well. Although the dip of the gas-sand and position of the anticlines and synclines have an important bearing upon the occurrence of gas (in many cases this would seem to be the most important consideration), yet it is not believed that natural gas wells can be located on what has been formulated as the 'anticlinal theory,' since all great gas wells are not found along anticlinal axes, although some of the largest and most important wells in Pennsylvania have been found in such positions. A great many wells have been drilled in synclines which have found gas. These two statements are of great importance, since a large amount of money is now being expended in drilling wells which have been located on the basis of the anticlinal theory, so-called. . . .

The relative proportion of water, oil and gas in a sand-bed, and the pressure under which the gas exists have an important hearing upon its occurrence, when considered in conjunction with the dip of the sand and the position of anticlines. If nothing but gas existed in a given homongeneous sand-bed having only the ordinary dip of the strata in the oil region from which the gas could not escape by cracks into overlying strata, and the quantity of confined gas being such that it should fill all portions of the rock with gas under a great pressure, it must be apparent that, no matter where the gas-sand was pierced by a well, the same quantity of gas would be obtained excepting so far as it might be influenced by the force of gravity. If petroleum, water and gas should all exist in the same sand-bed the pressure on each would necessarily be approximately the same if there was an open connection throughout the whole extent of the rock in which they occurred; but the water would seek the lowest level of the sand-bed, the oil the next, and the gas would be found in the highest portions. The same condition of affairs would exist where either water or oil existed in the sand with the gas to the exclusion of the other.

A careful study of these facts makes it apparent that under special conditions the anticlinal theory alone may account for the existence of gas: but when however it is known that large gas wells have been found in synclines under conditions differing from those which obtain in the vicinity of gas wells on anticlines, it is quite certain that the occurrence of natural gas in Pennsylvania and New York regions cannot be explained but by a careful consideration of all the geological and physical conditions under which it is procured.

The facts relating to the geology of natural gas now in the possession of any one geologist are not sufficiently numerous or connected to permit the acceptance of any ultimate theory; and it is only possible for the present to deduce special geotectonic conditions under which natural gas has so far been exploited. Some of these conditions are so varying and apparently antagonistic that it is only possible to arrive at any general law controlling the occurrence of natural gas by a comparison of the individual facts obtained from innumerable well-drillings.*

THE ANTICLINAL THEORY.

The anticlinal theory that gas wells should always be located on anticlinals and not on synclinals, because gas is lighter than water or oil and should seek the highest reservoirs—premises a permeable sand rock containing water, oil and gas, or only water and gas, in such proportions and under such conditions that the fluids may stratify themselves as freely and completely as they would do in an open tank under air, the water and oil at the lower levels and gas at the higher.

There is nothing new in the theory, as many suppose, for it has been long ago discussed and illustrated in text-books on geology and in nearly every book published relating to the production of petroleum. Well-locators however gave it but little attention until developments intended exclusively for natural gas commenced.

* C. A. Ashburner in Trans. Am. Inst. M. E. vol. XIV. pp. 430-33-34-37-38.

Wherever the proper conditions exist there seems to be no objection to accepting an anticlinal as one of the factors in locating gas wells ; but in most cases it is being too inconsiderately used without giving due thought to other and much more important considerations.

First, it is proven by the experiences of over 25 years that no profitable oil or gas well can be obtained in the Upper Devonian strata and rocks of later ages in the Pennsylvania oil fields unless a good sand-rock reservoir is found. Second, it is a generally accepted conclusion that the oil and gas making material was deposited before—and perhaps in some cases with—the producing sand-rock, not after it ; that the tendency of gas and oil when generated is upward not downward. Therefore the two primary conditions to be sought are gas-producing materials and sand-rock reservoirs to hold the products. All others are secondary, for without these no profitable oil or gas wells can be had.

Now what has an anticlinal to do with these indispensable qualifications? Evidently nothing in a primary sense, for it had no existence when they were being prepared. Nevertheless I have heard experienced operators self-confident in their geological acquirements, assert that certain oil fields could not extend beyond fixed limits on account of anticlinals which interrupted the deposition of the oil sands when they were forming.

It is well known that all our oil rocks are sedimentary; that they are composed of materials derived from older rocks, the disintegrated particles of which have been sifted, assorted and deposited in stratified layers by the action of water. These rocks are known to be several thousand feet in thickness, and untold ages elapsed while they were forming. For the purposes of this discussion we need go no further back in the eons of the past than the time when the Murraysville gas-sand (taking a definite stratum to avoid confusion) was completed by those changes of conditions (whatever they were) which terminated the sand deposits at that spot and commenced to lay down the overlying shales. At that date the two most important requisites for a future gas field had been provided. The gas making material had been deposited ; the receiving tank, so to speak, put in place and the impervious cover was being put on. But the sedimentary deposits were not yet completed. Other carbonaceous shales, other sandrocks, alternating with beds of coal, slates, fireclays and limestones were yet to be superimposed to a height of 3,000 feet or more. These all were deposited in the course of time in regularly stratified layers, showing that no deep-seated unequal or local disturbance had occurred up to the date of their completion. Subsequently some great change took place. The whole region was lifted above ocean level, the Alleghany mountains rose in crested ridges, and the Murraysville anticlinal with other comparatively minor flexures was formed. Now what effect could these anticlinal movements have had upon the gas producing capabilities of the rocks at Murraysville, whereas we have seen the gas materials and the reservoirs had been provided ages before? Had the hydrocarbons stored in the shales lain dormant all these ages, awaiting some awakening energy to set them free, which could only be furnished by the crush and pressure accompanying anticlinal movements? This can hardly be admitted, for oil and gas are plentifully found in regions where the rocks have not been so affected. Did the anticlinal movement open up crevices below the gas-sand leading down to some deep-seated storehouse of gas beneath the sedimentary rocks? This question is open to the same objection as the former one; and furthermore is it not reasonable to suppose that the side thrust and pressure which caused these anticlinals to rise would have a tendency to consolidate the basal shales confined under a heavy mass of incumbent strata, and to fracture and loosen the rocks near the surface if anywhere? Is it probable that gas after forcing its way up through thousands of feet of clay-shales and slates, such as have been penetrated by wells to the depth of at least 1,800 feet without encountering any noticeable leads, would stop in the gas-sand only checked by a covering of a few feet of clay-shale overlaid mostly by sand-stone to the surface?

If then anticlinals had no part in depositing the gas making materials, and sand-bed reservoirs were not the special agents that caused the generation of gas to commence and did not open crevices to deep-seated sources of unlimited supplies, what other favorable conditions could they have been instrumental in originating to make them more prolific in gas now than any other locality? I can imagine but one, which is this : When the anticlinal uplift tilted and warped the previously horizontal strata, destroying the equilibrium of the fluids in them a new adjustment of their positions in the sand-beds followed. This readjustment, in cases where all the conditions were favorable, probably resulted in storing larger quantities of gas in the anticlinals than elsewhere; but we have no assurance that all the arches were thus fortunately circumstanced, or that the conditions making one part of an arch productive would be equally efficient in another part.

The drill has demonstrated that the permeable sand rocks lie in beds so inclosed in impervious shales that each bed practically forms a reservoir itself. In certain horizons these sand beds are numerous and persistent, as for instance in the Venango-Butler group. But each individual bed has its *locus* and its characteristic fluids. In the same well one may produce water, another oil, another gas, another a mixture of all three, and only a few feet of shale intervene between the different layers of sandstone. All these rocks were equally affected by the general uplift and now lie dipping to the southwest at an average rate of from 18 to 22 feet per mile.

If the sand rocks were continuous instead of being in chains of beds or pools, and sufficiently porous to allow fluids to circulate through long distances,—say, for instance, from the southerly part of the Butler oil belt at Herman station to Murraysville—then according to the principles upon which the anticlinal theory is founded the Murraysville rock should now be deluged by water while the Herman station rock should be stored with gas, for the monoclinal slope of 22′± to the mile would submerge the anticlinal at Murraysville where the gas sand on the crown of the arch is more than 200 feet lower than it is at Herman station.

In applying the anticlinal theory to locating gas wells, this great monoclinal slope has in most cases been lost sight of by those who do not understand the geological structure of the country. Knowing the tendency of gas to seek the higher levels, and only stopping to learn that an anticlinal is an arch in the rocks, they procure a geological report, trace out the anticlinal referred to, secure leases upon it, as they suppose, and drill wells. If no gas is obtained, the Survey is charged with not having located the anticlinals correctly. They overlook the fact that the crests of anticlinals slope with the progressive dips of all the rocks towards the southwest, and that this has an important bearing upon the question of anticlinal reservoirs. For example, the Brady's Bend arch is 450′± lower at the Ohio river than it is at Lardintown, Butler county; the Murraysville axis is 250± lower where it crosses the Pennsylvania railroad than at Murraysville. Now if the whole county between Lardintown and the Ohio is underlaid by a permeable sandstone containing water and gas, and which produces gas at Lardintown on the crown of the arch and water on its flanks (in the synclinal) say 225 feet below its crest, then if the fluids are free to seek natural levels water would cross the anticlinal's crest half way between Lardintown and the Ohio (for there the crest has fallen 225 feet, which puts it on a level with the watered synclinal at Lardintown). and going southwesterly from that point the anticlinal must be as thoroughly water-logged as the synclinals. Hence this universally prevailing monoclinal dip is quite as important a factor in locating gas wells as the anticlinals are; for while the former affects the whole country, the latter only favorably affect local areas.

This persistent southwesterly dip has been referred to time and again in our geological reports. From the oil fields of New York to the gas fields of Pittsburgh it may be noticed that the southwesterly ends of productive pools frequently contain more water than the higher slopes. The Brady's Bend axis has been found full of water up to a certain point going northeast; so has the Murraysville; so has the Bull creek or Tarentun. In fact if the anticlinal theory is worth anything this phase of it requires to be specially studied. As before stated the productive sand rocks of the oil regions are generally deposited in elongated beds, stretching out in a northeast and southwest direction. One of these containing water and gas might lie between two anticlinals scarcely affected by either; in which case, according to the anticlinal theory, the elevated northeastern end should be good gas territory, although it might lie exactly in a syncline. Another bed might trend down from the unwarped regions at the north and have its southerly end uplifted by an anticlinal. Say it is ten miles long—nine miles on the monoclinal slope carries it down about 200 feet and if it rises 100 feet in the next mile to the crown of the anticlinal it is there level with a point in the same stratum four and a half miles from its northerly end; and should the sand bed contain a little more water than gas, or its southerly end have less storage capacity than its northerly end, the sand on the anticlinal would be as completely water-logged as in the synclinal north of it. Carrying the illustration still farther, if a sand rock at a higher or lower geological level commences under this anticlinal and extends southwardly, it should be gas-bearing not only on the anticlinal but also in the syncline towards the south, unless it has but little length or is uplifted by another anticlinal a short distance south.

The effects produced by an anticlinal are further modified no doubt by the partial or complete porosity of the sand beds, the relative proportions and qualities of the fluids contained in them, and the different degrees of pressure under which they are confined.

These may be called fanciful suppositions, but they are neither impossible nor improbable, and knowing that such heterogeneous physical conditions may exist we should be warned that no theory based on *one idea*, however plausible it may appear, is worthy of acceptance. Yet locators with such theories are most in popular favor, even with many who very well knew (if they will but pause to consider) that no man in any age, whatever his pretensions may have been, ever discovered an infallible rule for unerringly locating ore beds or oil and gas wells. And we may confidently add that the diversified conditions under which all minerals exist make it absolutely certain that no such rule ever will be discovered. The oil regions are strewn with financial wrecks caused by an overweaning confidence in one-idea theories delusively formulated upon accidental successes and often having no foundation whatever in fact.*

Within the last few years, since natural gas has attained such prominence in Pitts-

*John F. Carll in Geological Survey Report of Pennsylvania, 1885, pp. 45-51.

burgh, its sources and the conditions of its occurrence have been studied anew with sharpened inspection by both geologists and practical men, and some real advance seems to have been made in our search for it. The anticlinal theory has been revived and extended, and has been used successfully in the location of many productive wells. For the new statement we are indebted to Professor I. C. White of the University of West Virginia, and recently of the Pennsylvania Geological Survey. Professor White in turn gives credit to Mr. W. A. Earsenian, an oil operator of many years' experience, who had noticed in 1882-3 "That the principal gas wells then known in western Pennsylvania were situated close to where the anticlinal axes were drawn on the geological maps. From this he inferred there must be some connection between the gas wells and the anticlines." Professor White goes on to say:

"After visiting all the great gas wells that had been struck in western Pennsylvania and West Virginia, and carefully examining the geological surroundings of each, I found that every one of them was situated either directly on or near the crown of an anticlinal axis, while wells that had been bored in the synclines on either side furnished little or no gas, but in many cases large quantities of salt water. Further observation showed that the gas wells were confined to a narrow belt, only one-fourth to one mile wide, along the crests of the anticlinal folds. These facts seemed to connect gas territory unmistakably with the disturbance in the rocks caused by their upheaval into arches, but the crucial test was yet to be made in the actual location of good gas territory on this theory. During the last two years I have submitted it to all manner of tests, both in locating and condemning gas territory, and the general result has been to confirm the anticlinal theory beyond a reasonable doubt.

"But while we can state with confidence that all great gas wells are found on the anticlinal axes, the converse of this is not true, viz., that great gas wells may be found on all anticlinals. In a theory of this kind the limitations become quite as important as, or even more so than, the theory itself; and hence, I have given considerable thought to this side of the question, having formulated them into three or four general rules, (which include practically all the limitations known to me up to the present time that should be placed on the statement that large gas wells may be obtained on anticlinal folds) as follows:

"(*a*) The arch in the rocks must be one of considerable magnitude. (*b*) A coarse or porous sandstone of considerable thickness, or, if a fine-grained rock, one that would have extensive fissures, and thus in either case rendered capable of acting as a reservoir for the gas must underlie the surface at a depth of several hundred feet (five hundred to two thousand five hundred feet). (*c*) Probably very few or none of the grand arches along mountain ranges will be found holding gas in large quantity, since in such cases the disturbance of the stratification has been so profound that all the natural gas generated in the past would long ago have escaped into the air through fissures that traverse all the beds. Another limitation might possibly be added, which would confine the area where great gas flows may be obtained to those underlaid by a considerable thickness of bituminous shale.

"Very fair gas wells may also be obtained for a considerable distance down the slope from the crest of the anticlinals provided the dip be sufficiently rapid, and especially if it be irregular or interrupted with slight crumples. And even in regions where there are no well marked anticlinalls, if the dip be somewhat rapid and irregular, rather large gas wells may occasionally be found if all other conditions are favorable." *

To the qualifications already made Professor White would probably add, at this time, one to the effect that gas wells shall be located on the domes of the axis rather than its depressions, recognizing the same line of facts in regard to them that Minshall had already established in the case of the White Oak anticlinal of Ohio and West Virginia, to which reference has previously been made.

The facts cited by Professor White as to the gas supply of Pittsburgh are conclusive. Every foot of it comes from anticlines, but not from them because it has been sought nowhere else, but because, if found in other stations it is speedily overcome and extinguished by salt water. Where anticlines of the type here referred to traverse an oil-bearing series it may be considered demonstrated that they exert a decided effect on the accumulations of oil and gas in this series. So rational is such a conclusion, so directly does it result from the facts already stated, that it is hard to see on what grounds it can be called in question.†

The whole community interested in the subject of natural gas has been carried away by a theory. Practical men and theorists have apparently changed sides; the so-called theorists maintaining a conservative attitude; the so-called practical men becoming wild theorists. And the theory to which I allude is the anticlinal theory of gas.

Stated in a few words, it is a theory that oil, being lighter than water, must rise to higher levels. If the application of this theory was confined to bottles no one would dispute it; the water in a bottle must collect at the bottom, the oil in the middle, and th

* Science, vol. v, p. 522. † Prof. Orton in the Geological Survey of Kentucky, 1891, pp. 78-80.

gas on top. But the earth is not a bottle, It has no great caverns in it. More than that, the arrangement takes place naturally under the pressure of only one atmosphere; while any arrangement of water, gas and oil made at depths of a thousand or two thousand feet must be made under pressures of from 100 to 400 pounds to the square inch.

Mr. Carll recites a case where gas escapes at a pressure of 450 pounds to the square inch. It is impossible therefore that any arrangement of water, oil and gas can occur in the deep oil rocks such as occurs in a bottle. If the anticlinals at Pittsburgh were like those in middle Pennsylvania, where the rocks instead of lying nearly flat are turned up nearly vertical, the water, oil and gas at great depths, if they could exist at all, would remain practically mixed like the carbonic acid gas in a soda water fountain. It therefore seems to me irrational to assign any importance whatever to the extremely gentle anticlinals of the gas-oil region. To this I add the important consideration that the movements of oil and water have been shown by actual practice to be governed entirely by the character of the rock in which they take place, and that they are effectually stopped at fixed geographical lines where porous rock changes into sandstones and sandstones into shales. And these changes of character in the rock itself have no fixed relation whatever to the anticlinal waves, which on the contrary cross them transversely or diagonally.

Finally, sufficient instances can be adduced to refute the popular assertion that great gas wells are struck only on anticlinal lines: for some of them deliver gas from the bottom of basins. And on the other hand holes sunk on well known anticlinal lines, and not far from good gas wells, have yielded little or no gas at all.*

THE THEORY OF HYDROSTATIC PRESSURE.

The question of how far the hydraulic head may account for the gas well pressure (on purely artesian principles) deserves and is receiving attention. But those who especially favor this theory must not ignore, as they are probably well aware, the *unknown factors in the problem*, viz: the distances and methods of connection with the surface; the rate at which the water-flow, and consequently the water-pressure, is transmitted down hill from the outcrop head to the well bottom in the deep; the stoppages of the water-way here and there by tight rock; the interposition of mud cracks across the water-way, etc. To get the observed pressure at Pittsburgh, for example, one must go for a high-head outcrop as far north as Venango county; but the porous oil rocks do not extend continuously that far; nor is any water-bearing stratum known to be continuous a sufficient distance to answer the requirements. Nor can a nearer local head be assumed with any confidence, because the water-flow in that case must be vertical.

Friction in a pipe line is estimated to reduce gas pressure at the rate of about 7 lb. per mile. In doing this it reduces the theoretical rate of velocity with which gas would deliver from the free mouth of any section of a pipe.†

It is generally understood that the strongest rock pressures obtain in the deepest wells; and the theory of *hydrostatic pressure* has been appealed to to account for the fact. No one however has yet been able to work out from actual observations of the phenomena presented by flowing oil and gas wells any absolute and uniform correspondence between increasing pressures and increasing depths, as compared with the immediately overlying surface, or with distant elevated outcrops of the producing strata.

If an oil well is simply an artesian well, should not its flow be constant while it lasts, and dependent upon the rapidity with which the impelling water invades the oil rock reservoir; and after displacing the oil ought not water to follow into the well and rise to the surface, or at least to the level indicated by the strength of its initial oil flow?

But oil and gas wells do not act in this way. The output decreases gradually and sometimes rapidly from the start; and after production has settled almost to its minimum the wells may be pumped for years and even subjected to the drafts of gas pumps without being flooded with water, provided the abandoned wells in the pool have been effectively plugged above the oil and gas rock.

It is a well known fact that the oil sand in the celebrated Triumph district, which has been under the drill and pump for over 22 years, and produced on the aggregate fully 5,000-000 barrels of oil accompanied by large volumes of gas, is now so voided by the use of gas pumps that a vacuum gauge at any of the well heads registers a downward pressure of 12 to 13 lb. per square inch. This has been the situation for many years, as gas pumps have constantly been in operation in that district since 1869. New wells are occasionally drilled in this exhausted belt, and it invariably happens that when the oil sand is pierced a current of air commences to whistle down the hole, nor can any oil be obtained till the well mouth is closed and a gas pump put in operation. After a few days testing oil begins to appear and the production frequently runs up to 15 to 20 barrels

*J. P. Lesley in Trans. Am. Inst. M. E. vol. xiv. pp. 654-5.

† J. P. Lesley in Annual Report of the Geological Survey of Pennsylvania for 1885, p. 664. Elsewhere in the same report he says, "Evidently the gas must in some way produce its own pressure; like gas generated by chemical reaction in a closed vessel." p. 661.

per day. Then, as the slight excess of fluid in the immediate vicinity of the well drains and an equilibrium is established, the output gradually shrinks to the level of the old wells in the pool.

The wells at Triumph are from 600 to 800 feet deep, and usually have only from 200 to 250 feet of casing in them, consequently some four or five hundred of the bore hole is bare rock, equally exposed to the draft of the pump as the oil rock itself. In this uncased portion of the well are the first and second sands, which also outcrop in the river hills within two miles of the exhausted pool; and one member of the second sand forms a part of the river bed a mile farther north, and yet no surface water or air finds access to the wells through these sources.

Many other proofs of the impermeability of the strata above the oil rocks and of the fallacy of the hydrostatic theory could be adduced were it necessary. In a practical experience of twenty-three years in the oil regions I have never witnessed nor heard of a single circumstance to support it. The theory as applied to Pennsylvania oil and gas wells is delusive and untenable, and the cause of the great rock pressure witnessed must therefore be sought for in some other direction. *

The cause of the rock pressure of gas and oil wells is a subject upon which our best authorities have not been in haste to commit themselves by offering definite and comprehensive theories to account for the facts. Three causes have been suggested as adequate to explain the results :

1. The gas produces its own pressure. Solid or liquid matters in the rocks are there converted into the gaseous form, and the gas thus formed repuires larger space than the solid bodies from which it was derived. In seeking this larger space it exerts the pressure noted.

2. The weight of the cverlying rock produces the pressure of the gas. According to this view the gas is in the rock and the weight of the earth above it exerts a constant pressure upon it, and forces it out with the velocity observed whenever an exit is made for it.

3. The pressure is due to a water column that is behind the gas and oil. The porous stratum that makes the reservoir of gas and oil and salt water, and which always has an impervious roof, somewhere rises to the surface. Water entering at its outcrops will exert its pressure through all the flexures of the stratum upon the salt water that it contains, and thus upon the accumulations of oil or gas that are held within the arches and terraces of the stratum. This explanation makes the flow of gas and oil depend upon precisely the same cause that occasions the flow of water from artesian wells, viz : a water head of greater or less elevation, at a greater or less remove.†

Commenting on these theories Mr. Orton believes that the first has some element of truth, and for the pressure of shale gas he can see no other cause. But he argues that the facts in regard to the great gas and oil rocks require a cause more energetic and more variable than the expansive power of gas could furnish, for if gas originates its own pressure it would be difficult to account for the extreme range of pressure that we find in the same stratum, all the gas of which has essentially the same composition.

As to the second theory, Mr. Orton is of opinion that Mr. Lesley has demonstrated its invalidity by showing that the rock can exert no pressure on the gas unless its particles are free to move upon one another. This implies that the rock is in a crushed state, but no force can be found adequate to crush the rock at the depths at which the gas occurs. The driller finds it intact, and samples of Trenton limestone procured after a well is shot are seen to be full of pores in which the gas finds storage.

The third theory finds a more ready acceptance, since all observation shows that in oil fields the driller finds gas in the higher levels of productive rock, at a lower level he finds the stocks of oil (if any) with which the reservoir is charged, and at a still lower level he reaches salt water that sometimes fills the well entirely. "Every oil or gas field has a margin of salt water surrounding its productive portion, in whole or in part. The influx of this salt water is one of the most common evidences of total failure in wells drilled for oil or gas. The moment this fatal flood is reached all hope departs." The gas it may be is confined to narrow streaks on the crests of anticlines and occupies a few feet at most in the upper portion of the rock, while the salt water stretches out for scores of miles on every side and through great depths in the rock. "We have no reason to believe that all the accumulations of petroleum contained in the crust of the globe would exceed a few cubic miles in volume, but the salt water contained there would make a sea."

* John F. Carll in Geological Survey of Pennsylvania, 1890, vol. I 5, pp. 12-13.

† Prof. Edward Orton in the report of the United States Geological Survey for 1886-87 p. 594.

When an opening is made in the rock the gas, oil and salt water rise as water rises in an artesian well, and the height to which the gas rock rises at its nearest outcrop will determine the height to which the salt water will rise in the well. This is the factor which controls the so-called "rock" pressure of the gas, but obviously it is "water" pressure instead. The "rock pressure" phrase came in with the second theory. Mr. Orton draws the following inferences from the acceptance of the hydrostatic theory :

1. The definite limitation of all supplies of gas and oil stored in rock reservoirs is emphasized by this view of the origin of rock pressure. If salt water is the moving force all speculations of a constantly renewed supply of either gas or oil are vain and idle.
2. Other things being equal, the pressure will be greatest in the deepest wells.
3. The rock pressure of gas may perhaps be continued with little abatement of force until the end of the production of a field is near. The maintenance of pressure is no proof whatever of a maintenance of supply. The last thousand feet of gas come out from the gas holder with as much force as the first thousand feet.
4. In a field that combines both oil and gas, but in which the reservoirs of these substances are differentiated, the first sign of approaching failure will be the invasion of either level by the contents of the division next below it.*

The third of these inferences may require some modification, in view of the observed fact that pressure in all gas districts is found to diminish gradually after one or more wells have been flowing steadily for some time. For when the gas in reservoirs is released by the drill it is not only forced to the surface by the pressure of water behind it but by its own elasticity also ; and as the water cannot occupy the space left by the gas as fast as the latter escapes, having to flow through rock of less or greater density as well as to overcome the dilating energy of the gas which remains in the reservoir, the pressure must of necessity be gradually reduced.

Presence of Salt Water in Oil and Gas Rocks.

Oil rocks and gas rocks have been shown to be porous rocks, covered with impervious shales, and in some way connected with underlying sources of petroleum. Are there any porous strata that are entirely and exclusively devoted to the storage of these fossil hydrocarbons? None such are known. All the gas rocks and oil rocks that have ever been worked have, without exception, contained in some part of their extent water, and in the great majority of instances salt water. When the rock lies at comparatively small depth, as for example less than 500 feet, it often contains fresh water, but generally at greater depths and sometimes at less as well, it is for the most part occupied with salt water in all portions of it that are not filled with oil and gas. Even when occupied with fresh water at shallow depths the same stratum when followed to a greater depth generally becomes a salt-water rock. This association of salt water and oil has been conspicuous from the first. It will be remembered that the original discovery of oil and gas in deep wells came from drilling that was undertaken in the search for salt water. It is certainly true that all the strata which have yielded brine for salt manufacture have, in some portion of their extent, yielded gas and oil also. It is not only true that all gas and oil rocks are salt water rocks, but the converse has but very few exceptions ; namely, all salt water rocks carry gas and oil as well.

What is the source of the salt water that the oil rocks contain? No other source than the sea in which they grew need be looked for. It is not necessary to find beds of rock salt at great depth to account for the enormous supplies of salt water with which all porous rocks are generally filled. They have been charged with this from the date of their formation.

These deep brines sometimes vary widely in composition. Hunt has suggested that the Silurian brines may represent the composition of the sea water of an earlier day, and notably different from the composition of salt water at the present time. An important fact in this connection is, that the quality of the brines varies with the rock from which they are derived. Limestone, for example, carries sulphurous and otherwise impure brines. The best brines are derived from sandstones.

Do these rocks reach the surface at any point? Certainly they do. They form constituent parts of the general series, and share all its fortunes. When found in outcrop they necessarily receive their portion of the rainfall of the regions to which they belong. This fresh water follows the stratum downward through its various flexures, blending at length with the salt water that fills the great mass of the rock.

When the porous rock in its salt water areas is penetrated at considerable depths by the drill, the brine invariably rises a greater or less distance in the well. Sometimes it overflows, but in other cases it falls short of reaching the surface by 50, 100 or 500 feet.

* U. S. Geological Survey Report for 1886-87, p. 598.

The elevation that it reaches in one well it is likely to reach in others drilled near, indicating a common source and common pressure for all. What causes the salt water to rise in the wells? The answer is plain. The water is simply responding to artesian pressure, and thus is governed by the elevation of the outcrop of the porous stratum. The latter may be carried in mountain folds to considerable elevations, and thus give high pressure even when the wells are not excessively deep. But this porous stratum that we are considering has a small amount of oil and gas distributed through it; and it must be remembered that the rock never lies horizontal for any great distance, but has been variously flexed by the accidents of its geological history. Numerous folds, greater or less, are sure to be found in it. Where shall we look for the stocks of gas and oil above referred to? Under such circumstances as we have supposed, gravitation would have been sure to effect a separation of substances that differ as greatly in weight as the three that together fill the pores of this reservoir rock. Gravity in other words will drive forward the gas to the highest point or arch of the stratum. The oil will take its place next below, while to the salt water the remainder of the rock, or in reality almost its entire volume will be surrendered. All the low-lying regions of th porous stratum in particular will be flooded with salt water.

If now a well be drilled to the stratum along one of these lines where all three substances are located in close proximity to each other, it is plain to see that any one of the three substances, gas, oil or salt water, may be yielded to the drill, according to the location of the drill hole. If we drill into a trough of the rock we find the salt water following the drill as soon as the reservoir is reached, and very likely it will overflow the well. The cause of this ascent of the salt water we have already seen, and we must keep it clearly in mind. It is an artesian flow. But if the drill descends into the oil space, what is the result? The oil may rise and overflow the well with great force. Gas is sure to be mingled with it in such a case. Let us make one more supposition. Suppose the drill reach the gas area of the porous rock upon the summit of one of the unbroken arches we have already described. What are we to find now?

The phenomena of a high pressure gas well are among the most striking in the whole range of mining enterprise. The gas issues from the well-head with a velocity twice as great as that of a ball when it leaves a Minnie rifle. The noise with which it escapes is literally deafening. Exposure to it often results in loss of hearing on the part of those engaged about the well.

What is it that originates this indescribable force? What else do we need but the force we have just left, acting on the salt water which lies it may be but a few rods away from the gas well, and but a score or two of feet below in absolute depth?

It seems impossible to escape the conclusion that the pressure of the water column contained in the rock is responsible for all the effects of the outflows of gas and oil. Natural gas is compressed in the arch of the reservoir rock under the pressure of a water column just as artificial gas is compressed in the gas-holder of the city works.

What other explanations of these remarkable facts have been offered? But two have been put forward that deserve special consideration. Both will be briefly stated here.

One of them teaches that the rock pressure of gas is derived from its expansive nature. Solid or liquid materials in the reservoir are supposed to be converted into gas as water is converted into steam. The resulting gas occupies many times more space than the bodies from which it was derived, and in seeking to obtain the space demanded by the change through which it has passed it exerts the pressure which we note.

This view has no doubt elements of truth in it, even though it fails to furnish a full explanation. For the pressure of shale gas, it may be that no other force is required. But the theory is incapable of verification, and we are not able to advance a great way beyond the statement of it. Some objections to it will also appear in connection with facts that have been already stated.

The second of these explanations is without doubt more generally accepted than any other by those who have begun to think upon the question at all. It is to the effect that the weight of the superincumbent rocks is the cause of the high pressure of gas in the reservoirs. In other words, the term rock pressure is co sidered to be descriptive of a cause as well as of a fact. That a column of rock 1,000 or 1,500 feet deep has great weight is obvious. It is assumed that this weight, whatever it is, is available in driving accumulations of gas out of rocks that contain them whenever communication is opened between the deeply buried reservoir and the surface.

Is this assumption valid? Can the weight of the overlying rock work in this way?

Not unless there is freedom of motion on the part of the constituents of the rock, or, in other words, unless the rock has lost its cohesion, and is in a crushed state. If the rock retains its solidity, as Professor Lesley has shown, it can exert no more pressure on the gas that is held in the spaces between the grains than the walls of a cavern would exert on a stream of water flowing through it. The distinguished geologist named above has discussed this theory at some length, and has shown its entirely untenable character. (Annual report Penna. Survey, 1885.)

The claim that the Trenton limestone for example, where it is an oil or gas rock, exists in a crushed or comminuted state, is negatived by every fact that we can obtain that bears upon the subject. The claim is in fact entirely inadmissable and preposterous. but without this condition the theory fails.

Neither of these explanations of the rock pressure of gas and oil is found to be valid when subjected to any adequate examination, and we are left therefore to rely altogether upon the theory first stated, viz., that the flow of gas and oil depends upon the pressure of a water column, or in other words, every flowing gas well or oil well is in reality an artesian well. With the principles involved in ordinary artesian wells all intelligent persons are familiar, and it will therefore be easy for such to extend the applications of these laws to the cases now under consideration. An artesian water well obtains its supply from the syncline or trough of a folded section of rocks. Gas and oil on the contrary must come from the anticlines of the same or similar series.

DEMONSTRATION OF THE ARTESIAN THEORY.

The facts recently accumulated in the great gas-fields of northwestern Ohio and central Indiana afford a demonstration of the truth of the artesian theory of the rock pressure of natural gas, so far as these fields are concerned, and at the same time they render it probable that the cause which is found present here is equally operative in all other gas-fields as well.

The facts that enter into the demonstration come under the following heads, viz.: (*a*) the height to which the salt water rises in wet wells; (*b*) the density of the salt water; (*c*) the depth below the surface at which the water is found in drilling the wells; (*d*) the initial rock pressure of the gas when it is reached by the drill.

(*a*) As to the height to which the salt water rises in wet wells, there is not as much *exact* information as could be asked. A salt water well is by its very nature a failure. and the driller loses all interest in it from the time that its real character is made apparent; but we can sometimes obtain from his statements some clue as to the height to which the water ascends. The level at which the casing stands is an important point in the record of every well. When therefore the salt water is reported as rising 100. 200 or 300 feet in the casing, we can learn from such a record its approximate absolute height. The casings in the Findlay district are set at an elevation of 300 to 400 feet above tide. Salt water that ascends 100 or 200 feet into the casing is thus seen to have an absolute elevation of 400 to 600 feet above tide. When the surface of the ground in which the well is drilled is lower than in the field last named it becomes easier to get accurate figures. Along the shore of lake Erie in Ohio and in the Wabash valley of Indiana we obtain our most reliable data. The salt water rises nearly to the surface in the former district, and flows out in true artesian fashion from wells drilled in the last-named region, the surface of the valley being lower than that of the shore of Lake Erie.

As a result of all the observations made it can be stated that the strong and free flow of salt water from the Trenton limestone in the new gas-fields rises to approximately the same height in all wells, viz., to a level of about 600 feet above tide, whatever the elevation of the surface, or the depth below the surface at which the gas or oil is found.

This rise of the salt water must represent the height of some outcrop of the Trenton limestone in its porous condition. Such an outcrop is found on the shores of lakes Huron and Superior, and at approximately the same elevation as that to which the salt water rises in the new gas-fields, viz., 600 feet above tide. Fresh water finds access to the limestone in these outcrops; but its influence, while available for pressure, would not go far towards changing the character of the peculiar bitterns or brines that occupy this great sheet in its subterranean expansion.

(*b*) The specific gravity of the salt water of the Trenton limestone is high. Several determinations show a gravity of 1.1, and some samples are even higher. A column of fresh water one foot high and having a one square inch for the section weighs .43285 lb. avoirdupois. The weight of such a column of average sea-water is .445 lb; but twelve cubic inches of the Trenton brine counted at 1.1 weigh .476 lb. The weight may go as high even as .5 lb.

(*c*) The depth at which the gas or oil is found is the one element in the calculation that can as a rule be definitely ascertained. Coming as they do from the surface or near the surface of the Trenton limestone, the depth at which this great stratum is reached is a fact of universal interest and record in all the subdivisions of the fields.

(*d*) The remaining inquiry, that, namely, pertaining to the original rock pressure of the wells does not admit as a rule of determination or observation at the present time; and to learn the facts we must go back to the records of the earliest wells drilled in each portion of the productive territory. The pressure of a gas-field is reduced, and generally promptly, as soon as wells are multiplied to any considerable extent in it, and when we inquire for the facts of the pressure at the opening of the fields we frequently find more or less uncertainty. Gauges are not always reliable, and more than that they are not always promptly applied. Exaggeration also finds place in these early records to some extent.

In the list of early pressures, reported from the different portions of the gas-fields, the following figures are counted fairly trustworthy and fairly representative to the districts to which they belong.

Tiffin, Ohio	lb 650*
Upper Sandusky, Ohio	515
Bloom township, Ohio	465
Findlay, Ohio	450
St. Mary's Ohio	390
St. Henry's, Ohio	375
Kokomo, Indiana	328
Marion, Indiana	323
Muncie, Indiana	300†

These figures will now be combined with other data from the respective wells, and to them will be added for comparison a column containing calculations of the pressure that should result from the following factors, viz., (*a*) an assumed ascent of the salt water to 600 feet above tide; (*b*) an assumed specific gravity of 1.1 for the salt water, which gives .476 lb to the foot in pressure. If the gas rock is found below tide, the figures representing this depth must be added to the 600 feet above tide to which the water rises. These sums will represent the effective water column. The rock pressure should be, according to theory, the product of the numbers thus resulting, and the weight of a column of Trenton limestone brine, one foot in height and one inch in section, which is .476 lb.

Location of wells.	Depth to gas. (feet.)	Relation of gas rock to sea level (feet below tide.)	Original pressure (lb.)	Calculated pressure (lb.) ‡
Tiffin, O.	1,500	747	650	1347 × .476=641
Upper Sandusky, O	1,280	478	515	1078 × .476=513
Bloom township, O	1,145	395	465	995 × .476=476
Findlay, O	1,120	336	450	936 × .476=445
St. Mary's, O	1,159	238	390	838 × .476=399
St. Henry's, O	1,156	200	375	800 × .476=380
Kokomo, Indiana	936	98	328	698 × .476=332
Marion, Indiana	870	78	323	678 × .476=323
Muncie, Indiana	900	0§	300	600 × .476=286

The agreement between the last two columns of the table affords a demonstration of the principal cause of the rock pressure of Trenton limestone gas. It is due to the weight of the salt water that occupies the porous rock jointly with itself, though by a very unequal partnership, and the water pressure in turn is unmistakably of artesian origin.

A few obvious conclusions that follow the acceptance of the artesian theory will find appropriate place at this point and will conclude the discussion of this particular subject.

1. The supplies of gas and oil are seen to be definitely limited by this theory of rock pressure. If a salt water column is the propelling force, it is idle to speculate on constantly renewed supplies. The water advances as the gas or oil is withdrawn, and the closing stage of the oil rock is, as already pointed out, a salt water rock.

2. Other things being equal, the rock pressure will be greatest in the deepest wells. The deeper the well the longer the water column.

3. Other things being equal, the rock pressure will be greatest in districts the gas or oil rock of which rises highest above the sea in its outcrops. The 800 pounds of rock pressure in Pennsylvania gas wells, as contrasted with the 400 pounds pressure of Findlay wells, can be accounted for on this principle.

4. Where both oil and gas are found in a single field, the first sign of approaching failure will be the invasion of the gas rock by oil, or of the oil rock by salt water. Salt water follows the gas directly however in a great many fields without the intervention of an oil horizon.

5. This explanation shows the lack of all foundation for the views advanced from time to time by sciolists, wrongly called scientists, as to imminent dangers that are to result from air entering the gas rock, and there forming an explosive mixture, or from extensive subsidence of the regions from under which the gas has been withdrawn. Such notions whenever advanced are sure to obtain wide currency through the newspapers, but they are utterly foolish, and so far as they disquiet the minds of the ignorant are mischievous.‖

* The gauge used in this well read only to 600 lb., but the index indicated an excess of 50 lb.
† Reported as "less than 300 lb."
‡ At tide level. §Add 600 to figures in third column, and multiply by .476 lb.
‖ Prof. Orton in the Geological Survey of Kentucky, 1891, pp. 83-91.

Reference has already been made to the fold or uplift which crosses the county of Essex in a north and south course in the vicinity of the Kingsville gas field. But in considering the relation of this arch to the presence of gas we should take account of the opposing fact, that all the Silurian formations in southern Ontario dip in a southwesterly direction, and that they rise again on the other side of lake Erie; whence it follows that they form a great synclinal fold having an east and west axis, but the line of which has not yet been located. Now the borings in Essex are not sufficiently numerous nor the records of them sufficiently exact to make one sure of his ground in estimating the value of opposing theories of occurrence. The synclinalists and the anticlinalists may wage war indefinitely on this field, or at all events until the formations have been more carefully and thoroughly explored by the drill, although at present the anticlinal theory would seem to be in the greater favor.

In the Niagara peninsula, on the other hand, circumstances are more favorable to the synclinal theory, or perhaps the monoclinal, for there the gas-producing rocks have a uniform dip southward, without sign of an arch fold so far as known. From the outcropping of the Medina, Clinton and Niagara formations along the face of the Niagara escarpment to the line of borings along the shore of lake Erie the dip is computed to be about 25 feet per mile, although there is no absolute agreement found in the records. At Port Colborne, near the lake shore, the Corniferous formation has a depth of 13 feet, and 705 feet below it the Medina is reached, which is the principal gas rock of the district.* At Black Rock near Buffalo the Corniferous is 625 feet above the level of the sea; at Fredonia, 38 miles to the southwest, it is 315 feet below; while at Conway, in Pennsylvania, 81 miles southwest of Fredonia, it is 2,900 feet below, the average dip of this section being 32 feet per mile. At the town of Erie, on the south shore of lake Erie and 44 miles west of Fredonia, the Corniferous formation is 725 feet below the sea, the average dip being only 9 feet. But at Wheatland, 64 miles south of Erie, it is 2,517 feet below tide, the average southern dip being 28 feet per mile. Wheatland is 32 miles west of Conway, so that the formation rises in that section at the rate of 12 feet per mile. At Akron in Ohio, 54 miles west of Wheatland, the Corniferous is 925 feet below the sea, showing an average rise in this section of 30 feet per mile; and at Wellington, 37 miles west of Akron, it is only 174 feet below, showing an average ascent of 20 feet per mile for this section. But at Columbus, the capital of Ohio, the formation rises to 630 feet above tide, or 5 feet higher than at Black Rock. At Pittsburgh, about 60 miles south of Conway, a well was bored to the depth of 3,733 feet below sea level without reaching the Corniferous formation, and assuming that it does not thin out and disappear before reaching that point the dip from Black Rock to Pittsburgh, a distance of about 180 miles, is not less than 4,358 feet.†

The Medina formation, much thinned out, is found to lie up against the eastern slope of the Cincinnati arch in Ohio, and therefore there is no reason to doubt that it underlies the Corniferous in that direction for its whole extent, dipping southward at the same angle and rising with it westward. But it is also found to crop out in the mountain chains of southeastern Pennsylvania (where the Corniferous is wanting), and with a thickness of 1,500 to 1,900 feet forms there a succession of folds which rise in some ranges to 2,600 feet above the sea.‡ Southward it is found to rise to the surface in the mountains of Tennessee. The Medina formation is thus shown to be a great synclinal trough, whose deepest part must be nearly if not fully a mile below the gas-producing horizon of it in the county of Welland, and whose highest fold or outcropping must be 2,800 feet above that horizon.

How then can the anticlinal theory or the theory of hydrostatic pressure apply under such conditions to the existence of natural gas or oil in the Medina formation along the north shore of lake Erie, within 18 miles of its outcropping along the Niagara escarpment? And how is the barren belt between that outcropping and the line of producing wells to be accounted for? These questions may possibly be answered after the Niagara peninsula has been more thoroughly explored by the drill and when accurate records of the wells

* McRae's record of drilling: see *ante* pp. 129-130.
† Geological Survey of Pennsylvania, Carll's report, 1890.
‡ *Ib.* 1 3, the Geology of Huntingdon County.

have been obtained. Or more likely a solution of the problem may be found in a study of the conditions which existed before the occurrence of the disturbances which produced the foldings, subsidences and other alterations of level which now exist in the gas-yielding strata, and ages before the Silurian escarpment had an existence, when the Niagara, Clinton and Medina beds still extended northward over a large portion of the area now covered by the waters of lake Ontario, and when their area southward was a wide and level plain. At what time the Clinton limestones and the Medina sandstones became reservoirs of gas, and how the changes of level which took place before and at the time the Appalachian mountains were raised affected those reservoirs, can be at best only subjects of ingenious speculation.

THE ECONOMIC VALUE OF NATURAL GAS.

The many uses to which natural gas has been applied in the United States prove it to possess a high economic value; but obviously enough producers and consumers have gone upon the assumption that the supply was not only abundant and cheap, but inexhaustible also. As an article of fuel it possesses for many purposes great advantages over coal or wood, notably as regards cheapness, application and cleanliness. It has therefore been in great demand wherever supplies have been obtained, and in some instances pipe lines have been laid to convey it to distances of 70 and even 100 miles. It has also been very wastefully used in rolling mills, brick yards and other places, with the result that many wells which a few years ago yielded millions of cubic feet per day are already very greatly reduced in capacity, and in almost all of them there is a noticeable decrease in pressure. The following extracts will show how American authorities regard the economic aspect of natural gas.

One pound of coal weighs 25 cubic feet of gas.

One pound of coal has a fuel value of 7½ cubic feet of gas.

In 1885 300 miles of gas mains to the factories and dwellings of and around Pittsburgh furnished heating power equal to 2,000,000 bushels of coal per month=1,000,000 tons of coal per annum.

Before the end of 1885 one gas company in Pittsburgh reported 335 miles of pipe of all sizes, displacing the use of about 10,000 tons of coal per day, or 3,650,000 tons per annum, the consumption growing rapidly.

Probably 5,000 men will be dispensed with.

The waste at the wells being at first enormous, there was no economy at the works; but of late precautions have been taken to economize the supply.

The gas is odorless, because free from sulphur, etc.

This purity must be taken into account in estimating its value as a fuel. It makes better iron, steel and glass than can be made with coal gas or coal.

It makes steam more regularly, because there is no opening or shutting of doors, and no blank spaces left on grate bars for the entrance of cold air. When properly arranged its flow regulates the steam pressure, leaving the engine man nothing to do but watch the steam gauge.

Boilers last longer and fewer explosions result from unequal expansion and contraction when cold air strikes hot plates.

The *theoretical value* of gas as compared with coals is stated in the report of S. A. Ford, chief chemist of the Edgar Thomson steel works, 210,069,604 *heat units* in 1,000 *cubic feet of gas* weighing 38 pounds avoirdupois, while the same weight of carbon contains 139,398,896.

Therefore 1,000 cubic feet of gas,=57.25 pounds carbon, or
Coke, (at 90 per cent carbon) 62.97 pounds, or
Bituminous coal, 54.4 pounds, or
Anthracite coal, 58.4 pounds.*

I take this opportunity to express my opinion in the strongest terms, that the amazing exhibition of oil and gas which has characterized the last twenty years, and will probably characterize the next ten or twenty years, is nevertheless not only geologically but historically a temporary and vanishing phenomenon—one which young men will live to see come to its natural end. And this opinion I do not entertain in any loose or unreasonable form; it is the result of both an active and a thoughtful acquaintance with the subject. From the time that Colonel Drake sunk the first well on the plains of Titusville, I have professionally participated in the history of the oil and gas developments, and be-

* J. P. Lesley, State Geologist of Pennsylvania, in Trans. Am. Inst. M. E. vol. xv. pp. 527-8.

lieve myself to be familiar with whatever has been said and done in the premises; and there does not remain upon my mind a shadow of doubt respecting the practical extinction, in the comparatively near future, of that great commerce in oil of which the people of Pennsylvania have taken so little advantage when they might have accumulated from its sale in all quarters of the world a provision of moneyed wealth unheard of in the history of our race. The opportunity is indeed still offered; but it is steadily diminishing, and in a few years it will entirely pass away never to return again. For I am no geologist if it be true that the manufacture of oil in the laboratory of nature is still going on at the hundredth or the thousandth part of the rate of its exhaustion. And the science of geology may as well be abandoned as a guide if events prove that such a production of oil in western Pennsylvania as our statistics exhibit can continue for successive generations. It cannot be; there is a limited amount. Our children will merely, and with difficulty, drain the dregs.

I hold the same opinion respecting gas, and for the same reasons; with the difference merely that the end will certainly come sooner, and be all the more hastened by the multiplication of the gas wells, and of the fire boxes and furnaces to which it is led.*

Natural gas in the favored regions has been a great boon to the open-hearth-steel manager; he no longer has to spend a very valuable portion of his time "poking the gas-man to poke his fires." The gas is carried to the furnace in an even flow through a three-inch gas pipe, which branches off to both ends of the furnace in two-inch pipes. The delivery and reversing of the gas are regulated by ordinary globe gas-valves placed in the circuit. The ends of the pipe are encased in the brick work, and open into the flats of each end of the furnace from the opposite side walls by leaving out the space of a header in the fire-brick at the ends of the pipe. This gaseous fuel is not diluted to fully 60 per cent. of its entire bulk with inert nitrogen, as is Siemens gas, which has to be conducted in pipes of four feet diameter to one of the gas-regenerators to be pre-heated. Natural gas is conducted directly to the ports of the furnace, as it was found that pre-heating decomposed it and soon filled the checker-work of the gas-regenerators with deposited carbon. The use of cold gas is much more than compensated for in the heat produced by the combustion of the concentrated fuel, and by avoiding the large amount of nitrogen which is present in Siemens gas. Natural gas melting furnaces are now built so that both of the regenerators at each end of the furnace are connected with the air-inlet valve, or they are built with only one regenerator at each end of the furnace for pre-heating the air. In this case the air-valve and air-regenerators are built larger, with 60 per cent. greater capacity than when using Siemens gas. Natural gas is supplied in the service-mains to melting furnaces in the vicinity of Pittsburgh with a pressure of about eight ounces; and this pressure is adjusted in the service-pipes by regulators, ordinarily furnished to the plants by the natural gas companies, and placed with their connection to their mains at some suitable point about the plant. The pressure, as regulated by the valves at the large lash furnaces, is at present only about one ounce or an inch and a half of water pressure, as the gas goes into the melting furnace. The lighter the pressure, so long as the flow is kept uniform and steady, the better the combustion and the more intense the heat. The steady uniform flow of natural gas has made it peculiarly applicable as a fuel for melting in open-hearth furnaces and has been a very potent cause of the growing reputation for regularity and uniformity, as well as for superiority in other ways, of the open-hearth steel made in the natural gas districts. †

Postulating that every gas pool contains a fixed quantity of gas already stored and awaiting liberation, it is evident that the life of a pool does not depend so much upon the quantity of gas accumulated as upon the comparative rapidity with which it is allowed to escape. Given two deposits of equal capacities and pressures—if A suffers depletion by 10 wells in five years B ought to be equally depleted by 50 wells in one year. In fact B should be most exhausted; for having five times as many vents as A the gas need travel but a short distance in the rock to reach an outlet, and hence suffering less retardation from friction would escape more rapidly. . . .

It is *not claimed* in any part of this report (nor indeed in any previous one) that the oil and gas fields of Pennsylvania *are exhausted*, nor that they will be completely drained in *a very few years*, although speaking comparatively and with reference to geologic time, the latter expression might be allowable. But it *is* claimed that they have been excessively and wastefully depleted, that all the fully developed pools are surely on the decline, that every pool depleted lessens by just so much the area to be profitably drilled, and every year's unsuccessful prospecting outside of the productive belts and of deep drilling within them makes the outlook for the discovery of new oil horizons less hopeful, that from this time forward we have no reasonable ground for expecting or even hoping that these oil fields will continue to supply the world with cheap light as they have in the past, and that therefore it is wise to pause and consider how best to husband our remaining resources and make the most of them.

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* J. P. Lesley, State Geologist of Pennsylvania, in Trans. Am. Inst. M. E., vol. XIV, pp. 621.

† Alfred E. Hunt of Pittsburgh in Trans. Am. Inst. M. E., vol. XVI, p. 696.

And when we remember that the piping of natural gas on a large scale is now only in its fifth year; that the demands for daily consumption have grown to over 500,000,000 cubic feet per day, and are still increasing; that nearly all the gas pools now in sight show evidences of gradual failure; and that a large proportion of the available gas territory in the state has already been more or less thoroughly prospected, we are forced to the conclusion that the continuance of gas supplies is even less certainly assured than the continuance of oil supplies. At any rate the time has evidently come when the natural gas companies should insist upon a fair compensation for the gas delivered and enforce economy in using it, for it is too valuable a product and too evanescent to be recklessly wasted and consumed as it has been in the past.*

In the manufacture of glass, of which there is an immense quantity made in Pittsburgh, I am informed that gas is worth much more than the cost of coal and its handling, because it improves the quality of the product. One firm in Pittsburgh is already making plate-glass of the largest sizes equal to the best imported French glass, and is enabled to do so by this fuel. In the manufacture of iron, and especially in that of steel, the quality is also improved by the pure new fuel. In our steel rail mills we have not used a pound of coal for more than a year, nor in our iron mills for nearly the same period. The change is a startling one. Where we formerly had ninety firemen at work in one boiler-house, and were using 400 tons of coal per day, a visitor now walks along the long row of boilers and sees but one man in attendance. The house being whitewashed, not a sign of the dirty fuel of former days is to be seen, nor do the stacks emit smoke. In the Union Iron Mills our puddlers have whitewashed the coal bunkers belonging to their furnaces. Most of the principal iron and glass establishments in the city either are to-day using this gas as fuel or are making preparations to do so. The cost of coal is not only saved, but the great cost of firing and handling it; while the repairs to boilers and grate-bars are much less.†

In his last report on the geology of Ohio Prof. Orton devotes a chapter to the utilization of natural gas in that state, and some of the conclusions to which the facts and discussions he presents would lead are summarized as follows:

1. Natural gas finds its highest and most valuable use as domestic fuel. It is here that it does the greatest good to the greatest number. In all our dealings with it this fact should be kept constantly in view. To maintain it for the longest period for this service is our highest interest in relation to it.

2. If there is any use for which gas should be sold below the price of the fuel which it supplants, it is its use in cooking stoves. The less fortunate members of the communities should be the favored ones in this regard. For the gas used in heating there is no occasion to mark the price below the cost of coal; neither is there any justifiable demand for a discount on gas bills increasing according to the number of fires supplied. If a sliding scale is introduced it might perhaps better be made to slide the other way, charging consumption beyond the average at a higher rate.

3. An advance in price on the part of municipal corporations for all the uses that they undertake to supply is their proper policy. The price at which they have furnished it hitherto leads to undervaluing and wasting the gas. The supply will do the towns more good by serving them longer if they are required to pay a higher price for the gas.

4. All gas should be sold by measured volume. Meters and gauges ought to be introduced everywhere. No adequate motive to economy can be brought to bear on many consumers until they are obliged to pay at a proper rate for what they use.

5. Next to domestic use the use of gas in the production of steam power is to be counted the most suitable application of it. Comparatively small amounts of it are required for this purpose, and great convenience and economy result therefrom. The most skilful use of it will find a rate of fifty feet to 1-horse-power sufficient, but a use of more than eighty feet to 1-horse-power should not be allowed, even if the user is willing to pay for it.

6. Of the various manufacturing uses in which the gas is applied as fuel proper, glass-making has probably the best rights. It contributes larger returns to the community in the shape of wages than other like industries. While its introduction into northern Ohio has been greatly overdone, and while much of it has been accomplished by the exercise of a mistaken policy, it should be maintained as long as possible. To this end economy should be everywhere enforced. The window-glass works might perhaps be required to introduce coal into their furnaces for melting at an early day, reserving gas for the stages of blowing and flattening.

7. From certain uses to which gas is now largely applied it should be at once entirely withdrawn. It is a great wrong to the community to allow it to be used in burning common building brick and in calcining limestone. These processes consume large quantities

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* John F. Carll in Geological Survey of Pennsylvania, vol. 15. pp. 11 and 23.

† Andrew Carnegie in Macmillan's Magazine January, 1885, p. 212.

of gas and make no returns except to their owners. For these uses wood and coal are good enough. The industry that consumes gas in by far the largest amount is iron working. It is a grievous mistake on the part of any community or company to allow a rolling mill access to its gas field. An ordinary mill uses as much gas every day as several thousands of families would consume, and the returns to the common good by such an application are small compared with any other ways of using the gas. Even though a rolling-mill stands ready to pay as much per thousand feet as the small consumers pay, it ought not to be supplied. If it is willing to do this it shows that there is not enough charged for the gas. It may be to the interest of the gas company to get its money back rapidly, it is true, but the community has interests, if not rights as well, that should not be overlooked in relation to this supply. The state interferes when an oil well is left without being plugged, or when a gas well is allowed to blow into the air without use. Why? Because these precious stocks of mobile power are fitted to do good to great numbers of the people, and no man has a right to take any action by which they shall be needlessly wasted. A like reason could perhaps be found for forbidding entirely the use of gas for the rough work that has been named above.

8. If economy is everywhere insisted on and practised, the last days of natural gas in Ohio may be its best days. If, on the other hand, the wasteful policy that is now so largely in force should be maintained, there is sure to be, and at no very distant day, great disappointment and reaction in the communities that have obtained it and that have been stimulated by its acquisition to what may prove an unhealthful activity.

9. Natural gas is merely a transient phase of the stored power of the earth. It is folly to talk of its taking anything like a permanent place in the work of the world. The claim that it can do so springs only from enthusiasm or sciolism. There is in reality but little of it, and this little is found in but very limited regions and cannot last long whenever its utilization is undertaken by the eager and masterful activities of our day.

10. Natural gas has a very important work to do. It should prepare the world for something much better than itself. It is giving an object lesson to great communities as to the advantage of gaseous fuel, and it can hardly be that this lesson will be given in vain. The exemption from the soot and dust inseparable from the burning of bituminous coal in our cities and the positive addition that gaseous fuel makes to the comfort and convenience of the entire community when used as domestic fuel and as a source of steam power are results in themselves too valuable to be abandoned when these small and treacherous stocks of buried power are exhausted. The conversion of the coal now burned in a large city into gas before being used would result in an immense economy in fuel, besides affording the incidental advantages alluded to above, and this economy of stored power is an object to which the civilized world will soon be obliged to address itself good earnest.*

We in Ontario should be able to learn some valuable lessons from the experiences of our neighbors as to the uses and economies of so important a mineral as natural gas. In Essex and the Niagara peninsula there is good reason to believe that we possess a large supply of it, and in the absence of any other mineral fuel which might be utilized in manufactures as well as for domestic purposes the wasteful or economic use of it is a matter of no little importance. In Essex the bulk of the gas supplies light and heat for the villagers, and in the Niagara peninsula it renders a like service to a small extent. But by far the greater part of the product of wells in the latter district is conveyed across the river to supply a cheap fuel to the citizens of Buffalo. This is a questionable policy in so far as the interests of Ontario are concerned. It is parting with a valuable asset in an extravagant way, and when it is gone there is an end of it.

Expert Opinion on the Niagara Peninsula.

Mr. C. A. Ashburner of the Pennsylvania Geological Survey was consulted by citizens of St. Catharines as to the possibility of obtaining gas in the vicinity of that city in sufficient quantities to permit of its profitable distribution through the city for manufacturing purposes. The following account of the results obtained there is taken from a paper read by Mr. A. before the American Institute of Mining Engineers.

Immediately subsequent to the erection of the Thorold well derrick, and before drilling had been commenced, I ventured an opinion that the geological structure of the strata at Thorold absolutely precluded the existence of gas there in commercial quantity, and that the drilling of this well would not settle the question conclusively, because even if a gas pool did exist in the Trenton strata under the eastern portion of the Ontario peninsula there was no hope of encountering it in the Thorold well.

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* Prof. Orton in the Geological Survey of Ohio, 1890, pp. 278-80.

The St Catharines well was located at a point where there was apparently a very low but perceptible dome in the strata, caused by the intersection of two broad and comparatively flat anticlinals, one having a general north-northeast and south-southwest direction, and the other having a general northwest and southeast direction.* After setting the drive-pipe in this well in the alluvium clay, drilling was commenced in the upper portion of the Medina sandstone strata 130 feet vertically below the top of the Medina formation. The upper part of the Medina is boldly exposed at several points southeast of St Catharines.

The St. Catharines well was drilled to a total depth of 2,200 feet. The geological horizon separating the Medina sandstone from the underlying Hudson River shales was pierced at a depth of 720 feet. The Trenton limestone was struck at a depth of 1,505 feet. The bottom horizon of the Trenton† was passed through at a depth of 2,182 feet, drilling being stopped at a depth of 2,200 feet after 18 feet of the Calciferous sandstone had been pierced.

Combining the sections of the Port Colborne and Buffalo wells with that of the St. Catharines well, the following is a general section of the strata:

		Thickness.	Depth.
	Devonian.		
No. VIII.	Corniferous limestone	25 feet	to 25 feet
No. VII.	Oriskany sandstone		Wanting.
	Silurian.		
No. VI.	Lower Helderberg limestone		Wanting.
	Water lime		Wanting.
	(The Buffalo cement-bed is one of the top strata of the Salina, and does not belong to the water-lime group, as popularly supposed.) Salina or Onondaga limestone and shales	500 feet	to 525 feet.
	Niagara limestone	155	" 680 "
	Niagara shales	70	" 750 "
No. V.	Clinton limestone and shales	50	" 800 "
No. IV.	Medina sandstone and shales	850	" 1650 "
	Oneida sandstone and conglomerate		Wanting
	Silurio-Cambrian and Cambrian.		
No. III.	Cincinnati { Hudson River shales; Utica shales and slates }	785 feet	to 2,435 feet.
No. II.	Trenton limestone; Black River limestone; Birdseye limestone; Chazy limestone; Quebec limestone	677	" 3,112 "
	Calciferous sandstone	18	" 3,130 "

The upper 930 feet of this section has been compiled from facts obtained from the Buffalo, Getzville and Port Colborne wells, and from a study of the strata along the Niagara river gorge from lake Erie to lake Ontario . . . .

The lower 2,200 feet of the above section were classified from over 200 specimens of the drillings of the St. Catharines well and from a number of general facts reported of the strata pierced by the Thorold well.

In the St. Catharines well several small pockets of gas were found at a number of places in the Medina, Hudson, Utica and Trenton strata, and about 500 feet below the top of the Trenton limestone, at a point more than 1,500 feet below ocean level. a pool of gas was pierced which produced on an average about 100,000 cubic feet of gas per day for several days, but was soon exhausted.

A careful mineralogical and chemical examination of the drillings from the Trenton limestone pierced by the St Catharines well does not give promise of the existence of gas in commercial quantities in the Trenton limestone anywhere under the eastern portion of the Ontario peninsula, unless the character of the rock changes very materially from that found in the St Catharines well.

This section of the eastern portion of the Ontario peninsula, which is now published for the first time, is not only of great importance as bearing upon the occurrence of natural gas in the district, but one of the most important sections relating to American geology. since it conclusively settles the stratigraphical structure of the Niagara region, whose geology has been studied by more geologists and for a longer period than that of any dis-

* "There are no such things as *cross anticlinals*, any more than there are *cross billows* on the surface of the ocean during a storm, the whole system of billows being arranged in one direction in nearly parallel lines, but each billow being composed of a multitude of waves arranged along a line." J. P. Lesley in the Report of the Pennsylvania State Geologist for 1885, p. xxix.

† No attempt has been made to subdivide the limestone strata between the Utica shales and the Calciferous sandstone into the Trenton, Black River, Birdseye, Chazy and Quebec; the drillings between the Utica and Calciferous being so nearly alike, the entire 677 feet of limestones have been grouped for convenience under the name of Trenton.

trict on the continent. On account of the low southern dip of the strata (an average of 35 feet per mile), the lack of good exposures, except from the falls north to the mouth of the Niagara river, and the fact that lake Ontario cuts off the opportunity of observing the basset edges of the strata north of the river, it was impossible to determine absolutely the thickness of most of the strata from the Corniferous limestone down to the Trenton limestone except by drilling of wells; the records of the Buffalo, Getzville, Port Colborne, Thorold and St. Catharines wells, studied independently and conjointly, have afforded for the first time this favorable opportunity.

Upon the facts contained here and in my Duluth and Buffalo papers already referred to, the following conclusions bearing upon the occurrence of natural gas in the eastern Ontario peninsula are based:

CONCLUSIONS.

1. The gas in the Buffalo wells, in quantities sufficiently great to be profitably utilized, comes from the lime shales occurring from 15 to 60 feet above the bottom of the Salina formation. Small amounts of gas, but not in commercial quantities, were also found in the Niagara limestones from 45 to 80 feet below the top of the Niagara formation.

2. The top of the Trenton limestone under the city of Buffalo should be encountered by a well drilled in the vicinity of the Buffalo Cement Company's present wells, at a depth of 2,400 feet, more or less.

3. Little hope can be entertained of finding gas in commercial quantities in the Trenton limestone under the eastern Ontario peninsula.

4. In the southern portion of the Ontario peninsula, east of a line from Hamilton to Port Dover, natural gas, in quantities sufficiently great to be profitably utilized near the wells can be expected to be found in special localities where the local geological structure is favorable to its existence, in the following geological horizons: (1) From 15 to 75 feet above the bottom of the Salina formation. (2) In parts of the Niagara limestone and shales; notably in the upper part of the Niagara limestone. (3) In the upper part of the Medina sandstone. (4) In the Hudson River and Utica shales and sandstones. The most promising horizons are those in the upper part of the Medina and lower part of the Salina formations.

5. It cannot be expected that gas would exist in any of the strata in commercial quantity unless the gas-reservoir stratum is covered by at least 400 feet of superincumbent strata; nor can it be expected that gas will be found in any two or three different strata in the same well.*

Yet the accounts of recent borings show that gas has been found in two or three different strata in the same well in the Niagara peninsula.

In volume XVII. of the Transactions of the American Institute, p. 401, the same authority furnishes the following data on the thickness of formations in the Niagara peninsula:

THICKNESS OF THE FORMATIONS.

I have recently made a careful geological examination of the Ontario peninsula between lakes Erie and Ontario; and the facts obtained during this survey, studied in connection with the records of the three wells recently drilled at Port Colborne (at the southern end of the Welland canal, 17 miles west of Buffalo), enable me to determine the thickness of the Salina strata.

The third well at Port Colborne was drilled 1,500 feet. Carefully collected specimens of the strata passed through were kept by Mr. O. C. Richardson, from whom duplicate specimens were obtained. From these specimens I have gathered sufficient facts to enable me to construct a detail section of the well, of which the following is a summary:

			Thickness.	Depth.
	Erie Clay	feet	12	12
No. VI.	Salina limestone and shales		473	485
	Niagara limestone		155	640
	Niagara shales		70	710
No. V.	Clinton limestone and shales		50	760
No. IV.	Medina sandstone and shales		740	1,500

The top of this well is 587 feet above tide level; the top of the Medina sandstone was struck at a depth of 760 feet; and, judging from the character of the strata passed through near the bottom of the well, I do not believe the drill stopped very far above the geological horizon between the bottom of the Medina shales and the top of the Hudson River shales, so that the thickness of the Medina formation is probably not far from 900 feet.

The Clinton limestones and shales are exposed in the Government quarry back of the Riordan paper mills at Merritton, 9 miles west of Lewiston. Immediately overlying the Clinton rocks in this quarry is an exposure of the Niagara shales, the bottom of which

* Trans. Am. Inst. M. E. vol. XVIII. pp. 300-3.

is 490 feet above tide. The same geological plane (that between the Clinton and Niagara formations) in the Port Colborne well No. 3 is 123 feet below tide; hence the average southern dip of the strata from Merritton to Port Colborne (17½ miles) is 35 feet per mile.

This result, considered in conjunction with the scattered geological data collected on either side of the Niagara river between Buffalo and Lewiston, and with the records of the Buffalo wells, leads to the conclusion that the bottom of the Niagara shales was pierced by the drill in the Buffalo deep well at a depth of 710 feet, and that the top of the Medina sandstone was struck at a depth of 760 feet, so that the drill in this well was stopped in the Medina formation 545 feet below its upper limit. In this well I would assign a thickness of about 475 feet to the Salina, about 235 feet to the Niagara (both limestone and shales), and 50 feet to the Clinton.

VALUE OF RECORDS OF BORINGS.

On the value of accurate records of borings John F. Carll of the Pennsylvania Geological Survey says:

Every land-owner should make it a point to preserve at least one complete and reliable record of the drillings on his farm, giving the depth, thickness and character of each stratum from the top to the bottom of the deepest well. This record should be kept from actual measurements, made wherever a change of rock occurs and recorded on the spot at the time in a book kept for that purpose; and not be written up, as is too often the case, when the well is completed, when it is made to conform to some general formula which the driller has worked out from his experiences on other wells.*

Whoever has tried to get a record from drillers or the owners or managers of wells knows how hard it is to procure a satisfactory one. In most cases the record is given from memory, and all the figures are "about it and about," like the Persian poet's description of great argument between doctor and saint. Besides accurate figures, samples of the drilling should be kept in glass bottles provided for the purpose, each sample to be labeled with the depth from which it has been taken. But then there is such a thing as doctoring the record in the interest of the contractor, that he may get another contract; and there is such a thing as concealing it, so that other operators may not profit by the information which it could supply.

AN ACT TO PREVENT THE WASTING OF NATURAL GAS.

Approved by the Lieutenant-Governor, April 14, 1892.

Her Majesty, by and with the advice and consent of the Legislative Assembly of the Province of Ontario, enacts as follows:

Natural gas not be allowed to escape from unused wells.

1. From and after the passing of this Act any person or corporation, and each and every of them in possession, whether as owner, lessee, agent or manager, of any well in which natural gas has been found, shall, unless said gas is sooner utilized, within a reasonable time, not, however, exceeding two months from the completion of said well, in order to prevent the said gas wasting by escape, shut in and confine the same in said well until such time as it shall be utilized; provided, however, that this section shall not apply to any well while it is being operated as an oil well.

Plugging abandoned wells.

2. Whenever any well shall have been put down for the purpose of drilling or exploring for gas, upon abandoning or ceasing to operate the same, the person or corporation in possession as aforesaid shall, for the purpose of excluding all water from the gas-bearing rock, and before drawing the casing, fill up the well with sand or rock sediment to a depth of at least twenty feet above the gas-bearing rock, and drive a round seasoned wooden plug, at least three feet in length, equal in diameter to the diameter of the well below the casing, to a point at least five feet below the bottom of the casing, and immediately after drawing the casing shall drive a round, seasoned wooden plug at a point just below where the lower end of the casing rested, which plug shall be at least three feet in length, tapering in form, and of the same diameter at the distance of eighteen inches from the smaller end as the diameter of the hole below the point at which it is to be driven. After the plug has been properly driven there shall be filled on top of the same sand or rock sediment to the depth of at least five feet.

Penalties for contravention of Act.

3. Any person or corporation contravening any of the provisions of the first or second sections of this Act shall be liable to a penalty not exceeding $100 for each and every violation thereof, and to the further penalty of $25 for

* Annual Report for 1885, p. 77.

each thirty days during which said violation shall continue; and all such penalties shall be recovered, with costs of suit, in a civil action or actions in the name of any person or persons who may sue for the same.

Entry on lands to close wells.

4. Whenever any person or corporation in possession of any well in which gas has been found shall fail to comply with the provisions of the first section of this Act within the time therein set forth, any person or corporation lawfully in possession of lands on which the well is bored, or of lands situate, adjacent to or in the neighbourhood of said well, may after ten days' notice in writing to the owner of the well or his lessee, agent or manager, enter upon the lands upon which said well is situated and take possession of said well from which gas is allowed to escape or waste, in violation of said first section, and tube and pack said well and shut in said gas, and may maintain a civil action in any court of this Province against the owner, lessee, agent or manager of said well, and each and every of them, jointly and severally, to recover the cost thereof, in addition to the penalties provided by section 3 of this Act.

Power to take possession of well and plug same.

5. Whenever any person or corporation shall abandon any gas well and shall fail to comply with the second section of this Act, any person or corporation lawfully in possession of lands adjacent to or in the neighbourhood of said well may after ten days' notice in writing to the owner or his lessee, agent or manager, enter upon the land upon which said well is situated and take possession of said well and plug the same in the manner provided by the second section of this Act, and may maintain a civil action in any court of this Province against the owner or person abandoning said well, and every of them, jointly and severally, to recover the cost thereof, in addition to the penalties provided by the third section of this Act.

Commencement of Act.

6. This Act shall take effect on, from and after the first day of May, 1892.

THE MINERALS OF ONTARIO.

An Address to the Students of Upper Canada College, May 6, 1892.

It is about thirty years since in a country school section in one of the Lake Erie counties I gave my last talk to boys and girls. Never much gifted in that way, I feared to trust myself to make an oral address in a room of College boys, and especially upon a subject that demands care in the statement of facts. Therefore I have thought it wise to speak to you from paper.

Thirty years is a long time in the life of a man, as the life of man goes; a long time to be spent in well or ill doing. In that school section where I taught a generation ago I am reminded that there were forty-eight or fifty persons each of whom had then reached my present time of life, or over. They were men and women in the vigor of their days and strength, who had cut for themselves homes out of forests of oak and maple and walnut and chestnut, and a hardier or healthier lot of men and women you could not find in the whole of broad America. Where are they to-day? The answer is the old, old story. Of all but two of their number it has now to be said that there are other toiling hands where theirs have ceased from their labors, and there are other weary feet where theirs have completed their journey. It is the old, old story. "One generation goeth, and another generation cometh; and the earth abideth forever."

You have read of Waterloo, an event of seventy-seven years ago. You recall the brilliant cavalry attacks of Marshal Ney upon Wellington's fifth brigade, and Wellington's unleashing order at sunset when arose that stern and appalling shout which the British soldier is wont to give upon the edge of battle, and which no enemy ever heard unmoved. In that fifth brigade which withstood and repulsed the charges of Marshal Ney's horse, and joined in the shout when the order to advance was given, was an Irish soldier, Maurice Shea, one of the 24,000 of English, Irish and Scotch who shared in the glory of that fateful day. Maurice Shea was the last survivor of the 24,000, and his death at the age of 97 took place a few weeks ago in the town of Sherbrooke, in the province of Quebec*. A few days later there died in France the last survivor of the marines who fought and lost under Villeneuve off cape Trafalgar. Eighty-seven years—nay seventy-seven years—is a long time in the life of a man, and such last survivors as those of Waterloo and Trafalgar are not often met with in human annals, so fleeting is our stay upon this world's stage.

In his book on Nineveh and its Remains Layard observes that a deep mystery hangs over Assyria, Babylonia and Chaldea. With these names, he says, are linked great nations and great cities dimly shadowed forth in history; mighty ruins in the midst of deserts, defying by their very desolation and lack of definite form the description of the traveller; the remnants of mighty races still roving over the land; the fulfilling and fulfilment of prophecies; the plains to which the Jew and the Gentile alike look as the cradle of their race. For six centuries Nineveh was one of the great cities of the

*Since this was written I have seen a letter by A. B. Powell in the London Free Press which tells of another last survivor of Waterloo—William Chambers of Dresden, in the county of Kent—who not only fought at Waterloo but went through the whole of the Peninsular war. Mr. Powell says that Mr. Chambers was born in the county of Antrim, Ireland, on the 12th of September, 1787, and is therefore in the 105th year of his age. "He can carry on a conversation with much strength and intelligence, and gives a most vivid description of his life in the army." He came to Canada in 1831. Dr. Samson of Blenheim also writes to me concerning him: "The old man Chambers has been an intimate friend of my father for sixty years, and no doubt stands alone today as the most remarkable man of his age in the world. He spent a day with me last week and seems as bright and clear as ever in referring to many of the incidents of his life. His description of the times of the Irish Rebellion of '97 seemed like a chapter from ancient history. To have seen George the Third on his throne for thirty-three years and all of the events that have occurred since is certainly to have seen an immense part of the history of all mankind. A master of elegant English, an ardent reader, and something of a philosopher for nearly a century, it was a treat to spend a day with him. He said to me the other day that he had recently sent an invitation to a widow whom he had heard of in her hundredth year to accept his escort to the Exposition next year!"

East, or perhaps it might more accurately be described as a group of cities. It was the capital of a great empire, in which a series of palaces surrounded by great and high walls had been built by successive kings. It was a city of three days' journey according to the prophet Jonah, or of sixty miles circumference according to the old geographer Diodorus; and it had a population computed to be not less than 600,000. Nineveh perished with the last Assyrian king 2,500 years ago, and from that time until the explorations of Botta and Layard were commenced fifty years ago its place on the world's map was blotted out. Having been abandoned by man, its palaces and walls were gradually buried under the fine yellow dust which in the course of centuries the winds had drifted over them. Xenophon, who commanded the Retreat of the Ten Thousand, encamped upon the site of the city without knowing its name. When the battle between the Romans and the Persians was fought within sight of the mounds in the seventh century of our era "the city and even the ruins of the city had long since disappeared," as we are told by Gibbon. And about a hundred and twenty-five years ago the traveler Niebuhr, father of the historian, passed over Nineveh without perceiving it; he mistook for a ridge of hills the dust-covered rampart of brick and earth.*

Then there is Troy, the old Troy of your Homer if you read old Homer here. That city was taken and burnt by the Greeks more than 3,000 years ago, and its place on the map has been a subject of contention with scholars down to a period of less than

*The following account of ancient Babylon is taken from a paper by Prof. Hermann v. Hilprecht of the University of Pennsylvania in the Sunday School Times of May 14, 1892:

"Between the Euphrates and the Tigris—where the drama of the childhood of man was enacted, where the waves of the flood roared, and where the unity of the race of man found an early grave in shrill discord—we behold also the seat of the most ancient empire. And in Ur of the Chaldees the world's history takes a new beginning,—not built on the might of an Asiatic despotism, but firmly established up n the living faith of that man who forsook his country and kindred in order to serve the God of gods in a distant land.

"Some two thousand years before Abraham made his famous journey there existed on the banks of the Euphrates, farther to the north, a primeval sacred spot,—ancient Babylon. This was centuries before Ur came into prominence as the city of the moon-god cult, and, as the seat of mighty dynasties, made its influence felt in the history of Babylonia. About a two days' journey to the southwest of the present Bagdad lay the city, situated on a veritable lowland cut up by thousands of smaller and larger canals. It was in its commanding and central position, which later engaged the attention of Alexander the Great, that the unique and long-recognised significance of the city more particularly lay. The ample watering of the rich alluvial ground, especially in the neighborhood of the Euphrates and Tigris, under the ingenious schemes for irrigation invented by the inhabitants, produced a marvelous vegetation unequalled in the whole world. As late as B. C. 500 the fields of the comparatively little country of Babylonia brought unto king Darius a tribute of grain equivalent in amount to one-third of the entire produce of the broad domains of Persia. Then the country was 'an inexhaustible storehouse, and abounding at the same time in palm-groves even unto the borders of the sea.' To this fact testify the thousands of the cuneiform tablets in museums in London, Paris and Philadelphia. . . .

"To-day there is little left of the proverbial glory of this early seat of civilization. Palm-groves of extraordinary beauty indeed still line the sluggish waters of the Euphrates; but otherwise the neighborhood of Babylon is an arid, burning wilderness. The ancient canals which traversed the whole region and dispensed fertility have dried up, and the winds of winter have often buried them under the drifting sands. And in striking harmony with the Persian caravans of the dead, whose mouldering and offensive corpses every year infest the routes from Bagdad to Kerbela and Meshed Ali, the far-stretching ruin heaps of ancient Babylon, as watchers of the grave, tender to them a heart-sore welcome. For several miles the city of the dead stretches along both banks of the river, with its ruins of walls and terraces and the shattered homes of its former inhabitants. At the northeastern point encompassed still by deep trenches and massive brick walls, as of a prison, there rise upon the massive substructure the ruins of Nebuchadrezzar's palace, with its spacious chambers and its now empty halls.

"Far away in the southwest, still to the height of a hundred and eighty feet toward the brazen heavens, rise the vitrified ruins which some scholars believe to be the remains of the 'Tower of Babel.' When I had climbed laboriously to the highest point of this monument of human ambition I leaned for a moment against the walls of the old tower, which have stood for millenniums, and my eye glanced longingly beyond the sand-flats and morasses of the Babylon of today, to seek the life which filled the streets of the Babylon that was. But where once the temples of Bel and Nebo shone like the sun, and, sparkling like jewels, attracted throngs of worshippers to make their offerings; where once the hanging gardens o a Semiramis delighted the eye as a world's wonder; where once the Median princess Amytis, walking to take the air in the shadow of rare trees and fragrant shrubs, dreamed of the mountain ranges and leafy woods of her home,—there rises now a chaotic mass, broken by heights and hollows, from the lonely plains of Babylon. Turn whithersoever we may, our glance is everywhere met with scattered fragments of the storied piles, with the high-sounding inscription, 'Nebuchadrezzar, king of Babylon, adorner of the temples Esagila and Ezida, first-born son of Nabopolasser, king of Babylon, am I.' The proud speech of the self-conscious monarch, before whose scepter the peoples of Asia as far as the Nile stream bowed, sounds like a hollow mockery in the face of Isaiah's grewsome words, 'How art thou fallen from heaven, O day star, son of the morning! how art thou cut down to the ground, which didst lay low the nations!' If I ever had doubted the exact fulfilment of Old Testament prophecy such a doubt must have vanished under the impression I received from these striking facts among those cheerless solitudes full of ruins and graves, full of death and decay."

ten years ago. "The question is now decided for ever," Dr. Schuchhardt tells us. "On the hill of Hissarlik Dr. Schliemann has uncovered the ancient palaces of Troy, has laid bare its colossal fortifications, and brought to light its treasures of gold and silver. Moreover, in the country round about, his unwearying exertions have proved the accuracy of many details, which show a coincidence, astonishing even to the most credulous, between the picture unfolded in Homer and the one preserved to this day."* The mound of Hissarlik is shown by Dr. Schliemann to be the remains of seven successive cities, one built over the ruins of another, and the second of which was the Troy of Homer. The first lies on the virgin rock, 115 feet above the sea, while the full height of the hill at the beginning of the excavations was 162 feet. The second is separated from the first by a layer of debris eight feet in thickness, covered by a layer of soil nearly two feet in depth, which proves that the site had been deserted and not built upon for a long time. The walls, the towers, the palace, the pottery, and the gold and silver cups and bowls and vases and ornaments uncovered in the second city are remarkable evidences of its strength and civilization, and fully justify the observation of Dr. Schliemann in his last report that only after he had cleared the walls and excavated beneath them was he able to clearly understand how long the duration of this settlement had been and for what centuries its golden era must have lasted. He was able to verify in many particulars the accounts of Troy given by Homer, as traced in the records of the ruins, not the least important of which is the fact so curtly told in our primers that "Troy—was—burnt," the proof of which he found in the charred beams and the vitrified brick of its walls. And he was able also to establish this further fact, to quote Schuchhardt again, that "there existed on the site of Hissarlik, at a period far anterior to any we know of on Greek soil, a proud and royal city, mistress of sea and land; and the singers of the Trojan war, just as they were familiar with Ida and Skamander, with the Hellespont and the Isle of Tenedos, knew also of this city, knew of its golden age and of its mighty downfall."†

I have said this much by way of preface in the hope of giving you some idea of the lapse of time as we find it in the annals of human events. What it means when we come to consider the history of the earth itself, how we measure the time of geologic events, we can hardly conceive, much less determine. The brick in the walls of this building was made out of the brown clay of the Drift age, the Saugeen clay of the geologists, which you find extending over a wide area of the province, underlying the humus or vegetable mould and perhaps a few feet of gravel or sand. It is as old as the glacial era, or the closing period of that era, and doubtless older than our great lakes as these now exist, and very much older than our forests. But after all it is only the product of older rocks, of the granites and clay slates of the Huronian and Laurentian areas, ground to dust by glaciers, or decomposed by the action of water and weather, or dissolved by carbonic acid in a moist atmosphere. Much older is the lime in the plaster of the walls, the material of which we get at the nearest point from the Niagara group of rocks, whose aggregate thickness in places is not less than 150 feet. Whether built up by the encrinites whose forms are so plentiful in the upper beds, or by the deposition of calcareous matter chemically separated from the primary rocks in the ancient seas, or, as seems most likely, by both these agencies working together, the process must have occupied thousands of years. Still more ancient is the brown sandstone used in the foundation of your building, taken from the upper beds of the Medina formation, near the base of the Niagara escarpment. Where this stone is quarried at the Forks of the Credit the Niagara limestones overlie it to a height of nearly 200 feet; and this sandstone, like the limestone and the clay, is material reworked from the primaries. Very much older than the clay or lime or sandstone are the slates on the roof. The slates we use here are obtained for the most part from the province of Quebec or the state of Vermont, where they occur in the so-called Quebec group of rocks in the Lower Silurian system, but which is probably of pre-Cambrian or Huronian age. We know that the best slates are found among ancient lavas and rocks which have been faulted and tilted, and we have reason to believe that they have been formed under the influence of great

*Schliemann's Excavations, an Archæological and Historical Study, by Dr. C. Schuchhardt, p. 18.
†*Ib.* p. 92.

pressure and heat. In this province if slates of good quality and cleavage exist at all they will no doubt be found in the Archæan formations of the north, and explorers report their discovery there. On Temagami lake and the Matabechawan river there is said to be enough to supply the continent,—but the stories of explorers must be received with a grain of salt.*

But if the sandstones, limestones and clays out of which the walls of this college building have been constructed are old, what is to be thought of the age of those primary rocks out of whose ruins they were brought, and worked over grain by grain, and slowly laid down again by the waters of the sea in new beds removed by hundreds of miles in distance and by eons of years in time from the parent bodies? And what is the life of man compared with those primary rocks, or those still order and formless rocks whence the primaries had their origin? To think on those themes or seek to answer those queries is only to bring up afresh the questioning which came to Job out of the storm.

> Who is this that darkeneth counsel
> By words without knowledge?
> Gird up now thy loins like a man;
> For I will demand of thee, and declare thou unto me.
> Where wast thou when I laid the foundations of the earth?
> Declare, if thou hast understanding.
> Who determined the measures thereof, if thou knowest?
> Or who stretched the line upon it?
> Whereupon were the foundations thereof fastened?
> Or who laid the corner stone thereof;
> When the morning stars sang together,
> And all the sons of God shouted for joy?
> Or who shut up the sea with doors,
> When it brake forth, as if it had issued out of the womb:
> When I made the cloud the garment thereof,
> And thick darkness a swaddling band for it,
> And prescribed for it my decree,
> And set bars and doors,
> And said, Hitherto shalt thou come, but no further;
> And here shall thy proud waves be stayed?

We are appalled by the story of our earth's creation; yet it is befitting that we study it, and speculate upon it, and strive to understand it. Even in things too large for finite comprehension it is profitable to speculate and enquire if we do so in a spirit of reverence and of loyalty to truth, for the mind expands by the contemplation of the universe about us.—But let us get on to the practicable and the knowable.

The primary rocks, embracing the Cambrian, Huronian and Laurentian systems, together with the igneous rocks which sometimes overflow them as trap, but are oftener extruded through them as veins and dykes, are the source of almost all our minerals. Of the primary rocks we know something. They make up the surface of a very large portion of our country, and small regions of them have been explored and studied with more or less care for many years. They are indeed of vast extent and volume, covering an area in Ontario alone of not less than 150,000 square miles. In the Dominion they reach from the straits of Belle Isle on the Atlantic to Demarcation point on the Arctic ocean, and cover an area of 2,000,000 square miles. Their thickness has never been measured, and owing to foldings and tiltings it may be impossible to measure it, but one section of the Laurentian series north of the Ottawa river was computed by Logan to be 32,750 feet or a little over six miles. By others the depth of the upper division of this formation is estimated at 100,000 feet or nearly twenty miles. The Laurentian mountains, which extend in a V-shaped line from Labrador to the region west of Hudson bay, are the oldest in America; and upon both their northern and southern slopes in Ontario, but especially

*This reminds me that after the Mining Commission had taken the evidence of Sir James Grant at Ottawa the witness volunteered a piece of wholesome advice. "You must be very careful, Mr. B.," Sir James said in his deliberate Scotch way, "of what these mining men tell you; they are so prone to exaggerate." "Yes," I said, "I have no doubt David had them in his mind's eye when he made that hasty remark. You know David prepared a hundred thousand talents of gold, and a thousand thousand talents of silver, and brass and iron without weight for the building of the temple; and when he said in his haste that all men are liars I sometimes suspect that he had before him his experience with the mining men of his day." Sir James thought so too.

upon the latter, are stratified beds of successive ages which are no doubt the accumulations of sand and mud worn away by the action of ice and rains upon the mountain ranges during countless time.

"The destruction of the elevations in the Laurentian district," Prof. Shaler says, "is so complete that we cannot make out the original trend of the several ranges; as in an ancient city where the devastation wrought by time leaves nothing but a confused ruin which we only know to have been the dwelling-place of men by the nature of the materials, so this old mountain field can only be shown to have been at one period like the newer systems of the Cordilleras and the Appalachians, by the waste of its former structures."*

If you examine a fragment of Laurentian rock under a glass or even with the naked eye you will observe that as a rule it does not consist of one mineral or element, but of a variety of metallic and non-metallic substances which enter into almost endless combinations. Of the sixty or more minerals found in this Laurentian series and its enclosing veins there are twenty-three enumerated by Sterry Hunt which are constituents of the country rock as well as of the veins, including such important ores as apatite, serpentine, muscovite, quartz, magnetite, hematite, pyrite and graphite. Great limestone beds are interstratified with gneisses and quartzites in the formation, and disseminated through the limestone or arranged in parallel bands in it are grains of specular and magnetic oxides of iron, scales of mica and graphite, and crystals of iron pyrites and apatite, all of which are sometimes met with also in large accumulations either in veins or running with the stratification.†

In the Huronian and Cambrian systems the minerals are largely the same as in the Laurentian, from which they have been derived; but they also abound in dykes and are covered in places with extensive overflows of greenstone and basaltic trap, and are reticulated with mineral veins. They are pre-eminently the metal-carrying rocks of our province, and are for that reason of first importance from an economic point of view, or are by most persons so regarded. The Cambrian system is confined chiefly to the shores of lake Superior, embracing the Animikie, Nipigon and Potsdam formations; but there is also an outcropping of the Potsdam in the eastern part of the province, from the river St. Lawrence below Brockville to the town of Perth in Lanark. The Huronian is much more extensive, consisting of a number of belts or areas from the upper waters of the Ottawa river to Lake of the Woods. The system has not yet been accurately mapped, but the largest belt is no doubt that which extends from Georgian bay northeastward to the province line at lake Temiscaming, where it enters Quebec and continues to lake Mistassini. Other important belts lie between lake Superior and the western limit of the province, and these like the one north of Georgian bay have their greatest length in northeast and southwest lines. The most extensive remaining areas are those in the upper basin of the Moose river and its tributaries, and in the region north of lake Superior and east of lake Nipigon. The mineral-bearing district of which the northern part of the county of Hastings is the centre was at one time supposed to belong to the Laurentian system; but its rocks are now by some geologists classed with the Huronian, and by others with a later series, the Taconian.

Rocks of the Silurian and Devonian systems, which constitute all the more recent formations in Ontario, have hardly been disturbed at all since their first deposition, except as changes of elevation or subsidence may have occurred slowly and uniformly over wide areas. Veins carrying small quantities of galena, copper and some other metals cut through the lowest Silurian formations in the eastern parts of the province, where thin beds overlie the Laurentian rocks; but no dyke or vein has yet been discovered in the sandstones, shales and limestones which cover to great depths the country between the great lakes. Mineral veins are most frequent in districts where eruptive rocks are

* The Story of our Continent, p. 99.

† Prof. Coleman of the School of Practical Science informs me that he has observed the following minerals in our Archæan rocks in considerable amount, viz.: Essential and Secondary—Quartz, orthoclase, microcline, plagioclase (several species), muscovite, biotite, hornblende (several species), augite (several species), epidote, serpentine, calcite, eleolite, olivine, kaolin and dolomite. Accessory—Garnet (several species), tourmaline, zircon, apatite, magnetite, ilmenite, titanite, rutile, hematite, limonite, siderite, pyrite, pyrrhotite, chalcopyrite and graphite. Several other minerals he has observed in less amount.

abundant and are confined to certain areas of disturbance, and of these conditions the Silurian and Devonian rocks of western Ontario give no sign. Either they were laid down in a quiet period of the earth's history, or the region over which they extend was never seriously subject to the influence of disturbing agencies. It is a vast plain whose level is only broken by long and low anticlinals, and therefore there have been no great movements to divert pressure from one part of the earth's crust to another, to find out lines of weakness and develop volcanic excitement along lines of fracture.

I would not however have you assume that there are no minerals where there are no veins. Iron ore is sometimes found in large deposits in regions where no veins occur; and although it has not yet been discovered in the Silurian or Devonian systems of western Ontario, except as the local coloring matter of certain strata, no one can definitely say it does not exist there. Salt is found in great abundance in beds of the Onondaga formation, and above it in parts of the same formation are extensive beds of gypsum. Of limestones, sandstones and clays there are illimitable quantities, suitable for economic uses; and of all the minerals of those newer systems, salt, petroleum and natural gas excepted, the source is to be sought in the Archæan rocks of the north.

As far as known there are about 600 mineral substances in the crust of the earth which are made up of the 64 or more elements found in the earth and its atmosphere. These elements are classed as gases, metals of the alkalies, metals of the earths, metals proper and non-metallic substances; but many of them must be exceedingly rare, since it is estimated that eleven of the number make up 99 per cent. of the earth's crust. One of the gases, oxygen, forms one-half of the whole; silicon, a non-metallic substance, one-quarter; aluminium, a metal of the earths, one-tenth; calcium and magnesium, two other metals of the earths, 8 per cent. of the whole; sodium and potassium, metals of the alkalies, 3.6 per cent.; carbon, iron, sulphur and chlorine together, 2.4 per cent.; and all other bodies one per cent. Of the compound bodies silica constitutes 53 per cent. of the whole; alumina 19 per cent; and lime, magnesia, soda and potash, 17 per cent; leaving the combinations of oxygen with carbon, iron, sulphur and chlorine to make up 7.5 per cent., and with other bodies 3.5 per cent. It thus appears that the metals proper constitute only a very small part of what we know as minerals; and in no corner of the globe are they so generally diffused as to form any great bulk of it, although some areas are vastly richer in the metallic ores than others.

No one can undertake to give an exhaustive account of the minerals of our province, for the sufficient reason that only a small portion of it has been explored. Fifty years ago the work of the Geological Survey was begun by Sir William Logan, with a small staff; but the labors of the Survey were spread over the whole of Upper and Lower Canada. Twenty-five years later the area was extended by Confederation to the maritime provinces, and in five years more the country was taken in from ocean to ocean, embracing a land area of 3,315,000 square miles. Logan's survey of Ontario did not extend northward beyond the height of land, and indeed a very large part of the Ontario of our day northward and westward was not supposed to lie within its boundaries a quarter of a century ago. Since then other portions of the Dominion have demanded the attention of the Survey, and the result is that little has been added to our geological knowledge of Ontario since the publication of Logan's Geology of Canada in 1863. Small sections have been surveyed with more or less care. Hunt made a report on the Huron salt district, Vennor on the Hastings district, Lawson on the Lake of the Woods, Ingall on the silver-bearing rocks of lake Superior, and Bell on the Sudbury district. Other larger territories have been explored in a general way, but not so as to supply very definite or practical information on the character of their ores or minerals. Bell's report on the Hudson bay district will answer for illustration; an exhaustive report on so extensive a region could not be made on the observations of two short seasons of field work. His more recent report on the geology of the Sudbury mining district is based on the labors of three seasons, and embraces a tract 72 miles long by 48 broad, or 3,456 square miles. Now at 130 working days in the season a thorough survey would require the covering of nine square miles per day, which is far more than could be accomplished under the most favorable circumstances. But see what the difficulties were as described in the report.

Rocky ridges and boulder-covered slopes, alternating with swamps and small lakes, are the rule over the greater part of the area. In most parts the boulders are not only thickly scattered over the uneven rocky surface, but are often piled on top of one another without any finer materials between them. The trees which originally grew between and even on top of the boulders have generally been killed by forest fires, and their trunks have fallen over them in every direction. A second-growth thicket of small prickly spruces entangled with tough young birches has sprung up among the boulders and resists the explorer's progress like a continuous hedge. This, together with the uncertain footing, due to the boulders and the net-work of prostrate trunks, renders it very difficult to make one's way through these obstructions. Indeed it sometimes became impossible to do so until we had first chopped a passage through them.*

With such hindrances to exploration large portions of the field must have escaped notice, and so the report cannot be assumed to deal fully with the ores and minerals of the district. It is possible that there are many metalliferous veins and ranges in those two and a quarter millions of acres of his sheet which the geologist either passed over unobserved or did not cross at all. The late Alexander Murray spent a year in surveying the district between lake Wahnapitae and the mouth of Whitefish river on lake Huron, yet only the barest mention is made in his report of a sign of the nickel ore which within the last six years has made the name of Sudbury famous in America and Europe. Not one-tenth part of the province has been explored, we are told by the head of the Geological Survey, although the work has been carried on by the government for fifty years. Therefore we are forced to speak in a qualified way on the extent and value of its mineral resources. We know that they are considerable by the number and variety of discoveries which have been made and proven. They may be vastly greater, but that can be determined only when the whole area has been gone over, and 200,000 square miles is a very large territory to be scanned by the geologist's eye or sampled by his hammer. Fortunately his labours are being supplemented by the explorer, and in recent years the explorer has developed not a few of the qualities of an expert. Accordingly I feel sanguine that the ratio of progress in knowledge of the geology of our province will soon be increased, and that we shall not have to wait five hundred years for a completion of the survey.

I propose now to pass in review, as concisely as may be, some of the principal ores and minerals of the province, their places of occurrence, and the extent to which these resources of our natural wealth have been developed; and for convenience I shall group them under the following heads, viz: I. Metals and their Ores; II. Structural and Decorative Materials; III. Mineral Pigments; IV. Mineral Fertilizers; V. Refractory Materials; VI. Salt and Mineral Waters; and VII. Materials of Light and Heat.

I. Of the principal metals we have, in alphabetical order, aluminium, arsenic, copper, gold, iron, lead, nickel, silver and zinc, one or two of which are sometimes found in the native or metallic state, but all of them in chemical combination with other elements in the form of ores and earths. Often they occur in veins traversing the crystalline rocks and in the rocks themselves, frequently as deposits and impregnated beds, and sometimes, but very rarely, in alluvial clays, sands or gravels. How the metals came to occupy veins or the country rock, and whether they came as elements or compounds, no one can tell. We can speculate on their source, and there are many theories,—so many, in fact, as to suggest the story of the young candidate at a civil service examination. "How did you succeed my son?" his father asked. "O pretty well, father, I guess. I answered one question, I am sure." "And what was that?" "Well, they asked Why Charles I. was put to death? and I answered that I didn't know." As to the metalliferous veins there are theories of contemporaneous formation, of igneous injection, of electric currents, of aqueous deposition from above, of sublimation, of lateral secretion and of ascension. Prestwich says that by Werner and his school "They were supposed to have been introduced in a state of solution from above; by others they were supposed to have been injected simultaneously with the opening of the fissures from below; but

*Report on the Sudbury Mining District by Dr. Robert Bell, p. 7 F.

the more general opinion of geologists now is that they are the deposits formed during lengthened periods by thermal mineral waters or by sublimation." And again he observes that

Ordinary mineral veins were no doubt fissures in which there were cavities or spaces left open for a length of time, and in the interstices or on the sides of which were gradually deposited a variety of minerals and of metallic ores. The banded structure of some veins, and the fact that the minerals are such that could be deposited in water, tend to prove that their formation has been in most cases due to thermal waters, rather than to sublimations of gases and vapors such as are now discharged in the solfataras of volcanic districts. It is possible that in some instances such emanations may have contributed to a particular result, but in the majority of cases the phenomena agree better with the hypothesis of aqueous solution.*

Sir Archibald Geikie in discussing the various theories of origin says:

The structure and characteristic mineral combinations of metalliferous veins are precisely such as would be produced by deposition from aqueous solution. There can hardly be now any doubt that the contents of these veins have generally been deposited by water. But the source from which the metals were derived is not so obvious. The fact that the nature and amount of the minerals, and especially of the ores, in a vein so often vary with the nature of the surrounding rocks shows that these rocks have had an influence on the precipitation of mineral matter in the fissures passing through them, if they were not themselves the source from which the metals were obtained; for, as already remarked, the presence of the heavy metals has now been detected in rocks of almost every kind and age. On the other hand, in some volcanic districts at the present time various minerals, including silica, both crystalline and chalcedonic, metallic sulphides, and even metallic gold, are being deposited in fissures up which hot water rises. Each of these modes of origin may in different cases have occurred. It is almost certain, from what we now know of the diffusion of metallic substances, that there must be a decomposition of the rocks on either side of a fissure, perhaps to a great distance, and that a portion of the mineral matter abstracted will be laid down in another form along the fissure walls. If, on the other hand, the rocks on either side of the fissure are permeated for some distance by hot ascending waters, holding such metalliferous solutions as have been detected in the hot springs of California and Nevada, some of the dissolved mineral substances will doubtless be deposited in the fissure, and may even be introduced into the pores and cavities of the adjacent rocks.†

Sterry Hunt's theory is set forth as follows:

The metals .. seem to have been originally brought to the surface in watery solutions, from which we conceive them to have been separated by the reducing agency of organic matters in the form of sulphurets or in the native state, and mingled with the contemporaneous sediments, where they occur in beds, in disseminated grains forming fahlbands, or are the cementing material of conglomerates. During the subsequent metamorphism of the strata these metallic matters being taken into solution by alkaline carbonates or sulphurets, have been redeposited in fissures in the metalliferous strata, forming veins, or, ascending to higher beds, have given rise to metalliferous veins in strata not themselves metalliferous. Such we conceive to be, in a few words, the theory of metallic deposits; they belong to a period when the primal sediments were yet impregnated with metallic compounds which were soluble in the permeating waters. The metals of the sedimentary rocks are now however for the greater part in the form of insoluble sulphurets, so that we have only traces of them in a few mineral springs, which serve to show the agencies once at work in the sediments and waters of the earth's crust.‡

And Arthur Phillips, after demonstrating the almost universal presence of heavy metals in rocks belonging to every geological period, states his conclusions briefly in these words:

There can be no longer any doubt that the filling of veins has often been derived, in a state of chemical solution, from the surrounding country rock, and the theory of lateral secretion appears to explain more satisfactorily than any other certain phenomena not otherwise easily understood. It moreover not only accounts in a satisfactory way for the changes which take place in metalliferous veins when passing from one formation into another, but it also affords a reasonable explanation for the fact that shoots of ore usually follow the dip of the enclosing rocks.§

This relation of ore bodies to surrounding rock was illustrated in the Silver Islet mine, to which I shall again refer, and has long been familiar to miners. The famous

* Geology, Chemical, Physical and Stratigraphical, by Prof. Joseph Prestwich, vol. I pp. 334-5.
† Text Book of Geology, p. 590.
‡ Chemical and Geological Essays, 3rd ed., p. 220.
§ A Treatise on Ore Deposits, p. 85.

Dolcoath mine in Cornwall changed from copper to tin some forty years ago, and in both Cornwall and Devon it has been observed that some lodes yield tin where they cross granite, and copper where they traverse slate, changing from one metal to the other as they cross from the one rock into the other. In the north of England, again, the galena is most abundant in the limestones and scarcest in the shales, and Geikie mentions the fact that the veins in the Great Limestone, as it is called, which is 150 feet thick or less, have yielded as much lead as all the rest of a mass of 2,000 feet of strata put together.

The question of the origin of metals as found in veins and in the country rock has not been solved, but I thought it might interest you to be told what theories are held respecting it, as well as some peculiarities concerning the occurrence of metals and their ores.

As to aluminium, the first of my list, the theory of its origin is not a matter of so much doubt as that of most other metals. Yet it is never found in a free state in nature, and although by great odds the most abundant of all the metals—being estimated to make up a tenth of the earth's crust—it is one of the most modern in respect of discovery. A great French chemist, Lavoisier, suspected its existence about a century ago as the metallic base of alumina, but not until 1827 was it isolated for the first time. Then however it was obtained only as a metallic powder; the first ingot was cast in 1854. Alumina itself was not named until 1760, when it was obtained by calcining alum. We find it in many forms and combinations. It is the basis of all clays, and when crystallized in six-sided prisms it is called corundum, the clear and blue varieties of which constitute sapphire and the red varieties oriental ruby. Alumina is one of the chief components of felspar, which is a mineral generally of igneous origin, erupted from below the sedimentary strata. Felspar itself is one of the components of granite and syenite; but occasionally it is found separate and in large masses, as in parts of the counties of Frontenac, Leeds and Lanark. It is very generally diffused in rocks of the Laurentian system. Exposed to atmospheric influences the soda and potash felspars are altered to kaolin or china clay, but generally the admixture of lime, iron and other impurities on this side of the Laurentians has produced the common clays of our farmland. In localities on the other side of the Laurentians, especially on the Missinaibi and Abittibi rivers on the Hudson bay slope, there are extensive deposits of a very pure kaolin which, when reached by railway communication, will prove to possess great economic value. Doubtless you sometimes wonder at the lightness and strength of porcelain or chinaware, but wonder will cease when you know that it is made up largely of the metal aluminium. The sample of this metal before me, which is 8 inches long, 4⅝ inches wide, one inch in thickness and weighs only 3 pounds 8½ ounces, was smelted from a charge of kaolin in a crucible. As made by the first process thirty-eight years ago, aluminium cost its weight in gold. Six years later it was produced at a cost of $8 per pound and the selling price was $12, at which price it remained for twenty-five years. In 1885, by the application of electricity, the cost of production was reduced to $1 per pound; and by an improvement of the electrolytic preparation the cost in the following year was further reduced to fifty cents per pound, the selling price now being seventy-five to ninety cents per pound. By this last process it is claimed by Prof. Richards, instructor in metallurgy at Lehigh University, that "the electrolytic preparation of aluminium has reached its climax of simplicity." In an article in the January number of the Cosmopolitan Magazine Prof. Richards says:

> The electrolytic processes for pure aluminium will be developed, but not radically changed. Details will be improved, but in principle they have reached their maximum development. It is unlikely that by them aluminium will ever be made and sold at a fair profit much below its present selling price. It will be several years before this maximum development is reached, and then the aluminium industry, metallurgically speaking, will again be at a standstill. The next upheaval after this will be the discovery of a process using neither sodium nor electricity, a purely metallurgical one, simple, rapid and cheap, by which aluminium can be produced at a cost of five to ten cents a pound. The writer hardly looks for this within the next fifty years, but before the next century has run its length such a process will be in operation.*

* The Cosmopolitan Monthly Magazine, January, 1892, p. 28.

Well, the truth of an old adage finds here another illustration : It is never safe to prophesy unless you know. A purely metallurgical process has already been discovered, a sample of what it can accomplish is the block of aluminium before me, and I am assured that at a selling price of twenty-five cents per pound there is a fortune in it for the inventor and the producers. As to its uses in the arts, these will depend on its qualities. It is light, being only 2.6 times heavier than water, while iron and steel are 7.8 and gold 19.3 times heavier than water respectively. A cubic foot of aluminium weighs 163 lb., while a cubic foot of iron or steel weighs 487 lb. and of gold 1,206 lb. It is strong, the tensile strength per square inch being 26,800 lb., while that of cast iron is 16,500 lb., of wrought iron 50,000 lb. and of steel 78,000 lb. It is feebly magnetic, it has no sensible taste or odor, it may be forged or rolled like gold or silver, it is ductile, it is fusible, and it is almost non-corrodible, neither air nor water nor sulphureted hydrogen nor sulphuric acid having an appreciable effect upon it; besides which it has most valuable properties as an alloy with other metals. In his excellent work on Aluminium, published two years ago, Prof. Richards says :

Whatever its price, it can only replace gold or platinum because of its lightness ; it already replaces silver especially because of its resistance to sulphur, as well as for its lightness, besides being cheaper ; it can only replace the common metals, at its present price, for uses where its lightness is an extraordinary advantage. But when its price is down to that of these baser metals it will begin to replace them by virtue of its other superior qualities, chemical and physical : aside from its lightness it will win a large field simply in comparison with them on its merits as a metal. Thus there are wide applications now almost unthought of, because the high price has been a blank wall to stop its use, but as it cheapens more and more we hear every day of new uses brought to light. Thus its sphere will widen until, since its ores are as cheap as those of iron, it will approximate in utility to that universal metal. . . When aluminium becomes cheaper it will without doubt be used for culinary articles of many kinds, replacing copper and tin vessels, for it is attacked to a less degree by the acids and salts ordinarily found in food than either of those metals, and possesses the great superiority that if dissolved its salts are not poisonous like those of copper or tin, being, on the contrary, perfectly harmless. The sulphurous acid of the air or of the products of combustion likewise leave aluminium untouched, while they quickly blacken silver.*

And in the article in the Cosmopolitan from which I have already quoted the same authority says :

It has been discovered that many of the alloys of aluminium with other metals have very remarkable properties. For instance, five or ten per cent. of aluminium added to copper forms a beautiful bronze of a golden color and as strong as ordinary steel. A small portion of copper or titanium added to aluminium makes it much stronger without increasing its weight perceptibly. It is these alloys which may replace steel for many engineering purposes, for they approach steel in strength and yet are very little heavier than aluminium. Again, a very small amount of aluminium has a decidedly beneficial effect on cast iron, so that many founderies are using it, while for the difficult process of making steel castings aluminium is coming to be regarded as almost a necessity. Hundreds of pounds are being used weekly for this purpose.†

I have said so much on aluminium that I must necessarily be very brief in referring to other metals and their ores ; but I have done so (1) because this metal is less known than most of the others, (2) because it is a metal of great promise, and (3) because it appears likely that no other part of America is so rich in the ores or earths from which aluminium may be extracted as our own province.

Arsenic is not a metal of high commercial value, it is not consumed in large quantities, and our supply of it in Ontario in the form of the white oxide far exceeds the call of the market. It is one of the components of the mispickel ores in the county of Hastings, and I believe that a sufficient quantity was produced at the Deloro gold reduction works when these were in operation several years ago to meet all requirements to the present time.

* Aluminium : its History, Occurrence, Properties, etc., by Joseph W. Richards, M. A., 2nd edition, pp. 367-9.

† The Cosmopolitan Monthly Magazine, January, 1892, p. 286. The statement that these alloys are very little heavier than aluminium can hardly be correct, except in cases where the latter metal constitutes the principal part of the alloy.

Copper is found in various localities, on the north shore of lake Huron, on the east shore of lake Superior and elsewhere, generally as copper pyrites in quartz veins traversing greenstone or diorite, as at the Bruce and Wellington mines; but sometimes native and in sulphurets, in amygdaloidal trap, conglomerate and sandstone, as at Mamainse peninsula and Michipicoten island in lake Superior, and at points on the mainland along the north shore of this lake. It may be noticed here, and the fact has an important bearing, that microscopic observations made by the late Prof. Irving of the United States Geological Survey have established a complete identity between the Michipicoten island rocks and those of the typical copper-bearing districts of the south shore of lake Superior in which are situated some of the largest and richest copper mines in the world.* Copper ore is found in many other parts of the province besides those already mentioned, but perhaps in the greatest quantity in association with nickel in the Sudbury district. For thirty years, ending with 1875, copper mining on a large scale was carried on at the Bruce mines; and Mr. William Plummer, who had charge of the works for a number of years, has estimated the value of the product of these mines at between $6,000,000 and $7,000,000. Operations at these mines were discontinued owing to the low price of copper and have not since been resumed.

The ore of lead, galena, usually carries a small percentage of silver. It occurs in veins, the greater number if not all of which in this province are found in rocks of the Huronian and Cambrian systems. Mines have been opened in the counties of Lanark, Frontenac and Peterborough, and smelting works have been erected at Kingston and near Carleton Place, but owing to wasteful management in one case and to a limited supply of ore in the other these enterprises failed. There are rich veins near Garden river, in the district of Algoma, which were worked about ten years ago; and although considerable quantities of ore were raised, stamped and shipped, the lack of capital and markets led to the works being closed at the end of three or four years. On the north shore of lake Superior, near Black bay, a number of veins have been discovered, as also in the district of Nipissing, near lake Temagami.

We have gold-bearing ores in many localities, as in the Hastings region, in the Sudbury country, in the valleys of the Thessalon and Mississaga rivers north of lake Huron, on the north shore of lake Superior, near Lac-des-milles-lacs, and on the islands and mainland of Lake of the Woods. Gold occurs almost always in quartz veins, in rocks of Huronian age; but sometimes it is said to be found in bands of slate, as on a location near the Vermilion river, west of Sudbury. Gold mining in Ontario has never been a profitable business, although fine specimens showing free gold are often exhibited by prospectors and real estate miners; but locations now being worked on Lake of the Woods, in the county of Hastings and in the Sudbury district are claimed to be full of promise. Reduction works recently started in the two regions first named are likely to prove the value of the ores, which as a rule are hard to treat. As illustrating the deceptive qualities of veins supposed to be gold-bearing, I may mention that of 96 specimens examined by the chemist of the Geological Survey, particulars of which are given in the last report of the Survey, 46 contained neither gold nor silver, 13 showed traces of gold and 4 of silver, while of the remaining 33 there were 21 which contained gold and 18 silver, some specimens showing both metals. Yet of those 96 specimens 73 were collected by officers of the Survey, thus proving the truth of a saying common among miners that "A great many other things are mistaken for gold, but gold is never mistaken for anything else."

Ores of iron are abundant in the Laurentian and Huronian formations, chiefly as magnetite, but sometimes also as hematite and limonite. In the eastern part of the province there are large bodies of magnetic ores in the counties of Peterborough, Hastings, Frontenac and Lanark, some of which are of excellent quality; but sulphur is often present, and occasionally titanium, both of which are very objectionable substances in combination with iron. Yet it seems likely that methods will be found to get rid of both sulphur and

* The Copper-bearing Rocks of Lake Superior, by Roland Duer Irving, pp. 341-7.

titanium, or to greatly reduce their proportions in the ore, in which direction very marked progress has recently been made by a process which consists in crushing the ore and cleansing it at one operation with a flow of water and a magnetic separator. Limonite, the brown ore, is found in Peterborough, and hematite, the red, in Hastings and Lanark. Hematite ore also exists in what is believed to be large quantities on the north shore of lake Superior. Farther west, on the Mattawan river, a range containing specular and magnetic ores is found which is supposed to be a continuation of one or other of the great ranges of Minnesota—the Mesabi and Vermilion. Other ranges of magnetic ore, which are described as of vast extent, lie along the Atik-Okan river, a tributary of the Seine which flows into Rainy lake. These ranges have been traced a length of ten or twelve miles, rising in places 200 feet above the plain, and the ore is said to be very rich and clean. There are many other outcroppings of iron ore besides the ones I have mentioned; yet it has to be confessed that there is not a working mine in the province, for which the only consolation is that we have got the ore still, and that it may perhaps be more valuable in some day to come, when other great deposits in America are worked out.

Nickel is the most important of all our ores, and there are inexhaustible supplies of it in the country north of Georgian bay. Nearly fifty years ago nickel was found with copper on what is known as the Wallace location, near the mouth of Whitefish river. It was found also on Michipicoten island; but at neither place is it known to exist in workable quantities. The construction of the Canadian Pacific Railway led to the important discoveries that have been made in the district of which Sudbury is the centre. A railway-cutting through one of the rocky ranges exposed the ore, which at first was supposed to be copper pyrites, but which six years ago was ascertained to carry nickel as well as copper. Explorations and workings made since have resulted in proving that the Sudbury district is richer in nickel ore than any other known part of the world, and two engineers of the United States navy department have reported 650,000,000 tons of ore in sight. The data from which this estimate was computed may not have been absolutely trustworthy, but we know that other large and rich discoveries have been made since those engineers visited the district, and there can be no doubt of the vast extent of the ore. Eight mines are being worked, three large smelting plants are in operation, and as the demand is said to far exceed the supply the reports we hear of enlarged development of the mining and smelting industries of the Sudbury field will find ready acceptance. The value of nickel when united with steel, producing an alloy which combines hardness with strength and freedom from fracture under the strain of heavy blows, has been so amply demonstrated that the secretary of the United States navy department has decided to construct the armor plate of all his battle-ships with it; and the British admiralty has recently decided to use it largely for the same purpose, extensive orders having been placed for nickel-steel armor which forms the secondary defence of the battle-ships now in progress. There are various other objects for which this alloy is well suited, such as in the making of cannon, small arms, boilers and machinery, cutlery, etc., where strength, malleability, capacity to take a fine polish and freedom from rusting are valuable properties. Besides, there are many uses in the arts to which the pure metal may be applied when produced cheaply and in large quantity; so that we may look forward with confidence to great activity in the working of the nickel mines of this province, and, possibly as growing out of it in a natural way, to the awakening of our dormant iron mining industry also.

The silver-producing district of our province is confined almost exclusively to rocks of the Animikie series in the Cambrian system, lying to the north and west of Thunder bay in lake Superior. The veins which carry silver are found cutting ranges of table-topped hills or mountains whose summit is basaltic trap and whose base is black slate. Underlying the slate are beds of chert and jasper of extreme hardness which contain a percentage of iron, and it is found that the mineral veins in these beds are much leaner in silver than in the slates. The observation of this fact has depreciated to some extent the value of silver mines in the district, but recent accounts give rise to the hope that beneath the cherts the veins become enriched again. Silver Islet mine, which lies in lake Superior south of the Thunder Cape promontory, was one of the earliest discoveries in that region, and from its opening in 1870 to the suspension of work in 1884 the value of the silver output was $3,250,000, the total depth reached being 1,230 feet. Although the vein of this mine has been explored on the mainland for about a mile, no silver ore has been found; the only productive part of it is at the intersection of the dyke which constitutes the islet, and out of which the silver is supposed to have been deposited. Other mines in this district, the best known of which are the Beaver and the Badger, have yielded large quantities of ore during the last four or five years, but if they have been worked profitably the fact has been carefully concealed. It may require more capital and skill than have yet been employed to give them a thorough test.

There are other metalliferous ores in the province, but I shall refer only to one other, viz., blende or the sulphide of zinc. A large vein of it exists on the White Sand river about ten miles from the north shore of lake Superior. This was discovered eleven years ago, and it is claimed that the ore may be mined with great facility, but for want of a road it cannot be brought to market. A specimen analysed by the chemist of the Geological Survey gave 54½ per cent. of zinc. Another vein has been discovered a short distance from the head of Thunder bay.

II. In structural and decorative materials Ontario is richer than most countries, both as regards variety and quality. Sandstones, serpentines, marbles and granites abound in the northern districts, while in the south we have sandstones, limestones, clays and the materials for the manufacture of cement. Native cements are obtained from limestones in the Niagara formation at St. David's, Thorold and Limehouse, and in the Trenton at Napanee Mills. Portland cement is now being manufactured out of shell marl, large quantities of which are found deposited in shallow or extinct lakes, the marl being mixed with certain proportions of clay of a suitable quality, after which it is baked in a kiln and ground to a fine dust. Clay for common brick and tile is taken from deposits of the Saugeen and Erie clays; while for the manufacture of pressed brick and terra-cotta the shales of the Medina and Hudson River formations are used. The brown Medina shale, which crops out along the base of the Niagara escarpment at frequent points between the Niagara river and Owen Sound, has a depth ranging from 400 to 600 feet. The Hudson River shale crops out along the valleys of the Don and Humber rivers, and is probably of as great thickness as the Medina, although not so accessible. A few years ago all the pressed brick used in Ontario had to be imported from Ohio and Pennsylvania, but a better quality is now produced at home. Its introduction is bound to greatly improve the architecture of our towns and cities.

III. Mineral pigments or natural paints are obtained in a number of localities, and some of them are very abundant Sulphate of barytes is used as an adulterant with white lead. It is found in many of the veins on the north shore of lake Superior, and sometimes, as on McKellar's and Jarvis islands in lake Superior, makes up a large part of the vein. In the eastern part of the province, but especially in the county of Lanark, there are numerous veins of this mineral. Ochres are clays of various colors, such as red, yellow and green. At Limehouse on the Grand Trunk Railway a variety of colors is obtained, and pigments have been manufactured there for many years, as also at a point in the same formation farther south in the township of Nelson. Yellow ochre is a mixture of clay and limonite or the brown ore of iron, while red ochre is a mixture of clay with the specular or hematite ores of iron. Large deposits of the latter of fine qu lity are found in the counties of Lanark and Frontenac, one of which is 30 feet wide and three-quarters of a mile long; while another, which has a rich bronze hue, has been explored with a diamond drill to a depth of 65 feet.

IV. Mineral fertilizers exist as marls, gypsum, and apatite or phosphate of lime. The last named occurs as veinstone in the upper rocks of the Laurentian formation in various parts of the counties of Frontenac, Renfrew, Leeds and Lanark, but mining has been carried on chiefly in Frontenac and Lanark. The mineral is rich, but it is difficult to mine, and most of the deposits are remote from railway communication. During the past year the industry suffered partial collapse owing to the discovery and working of large surface deposits in Florida and the shipment of great quantities to the European markets. Gypsum is found over a large area in the Onondaga formation which underlies the counties of Brant and Haldimand, where mines have been worked for half a century. As plaster of Paris it has been largely used as a fertilizer for grass land, and when calcined it is used to finish and decorate walls. There are very extensive deposits also on the Moose river and its tributary the Missinaibi.

V. Mineral waters and rock salt are of limited occurrence in Ontario, but while the latter occupies one field the former are found in a number of localities and at points far distant from each other. Salt beds in the Onondaga formation extend over an area of 1,200 square miles in the counties of Bruce, Huron, Lambton and Kent. These beds no doubt were originally deposited at the bottom of inland seas as their waters gradually dried up. The total depth of the beds in Huron is about 100 feet, gradually thinning out to the edge of the basin; but a boring near the river Thames in Kent is reported to have gone through one bed of white salt 171 feet in thickness. The supply is sufficient to last our province for centuries; yet it is small when compared with some other known deposits of rock salt, such, for example, as the massive accumulations at Sperenberg, near Berlin, which have been bored through to a depth of 4,200 feet, or those of Wieliczka in Galicia which are more than 4,600 feet thick. The annual make of our Ontario wells ranges from 350,000 to 400,000 barrels, and owing to the restricted market this limit of production was reached nearly twenty years ago. Mineral waters impregnated with sulphur and salt are found very generally in the western part of the province, when deep borings are made in rocks of the Upper Silurian and Devonian systems; whereas in the eastern section of the province they are alkaline waters and are found to issue from rocks of the Lower Silurian system.

VI. Refractory minerals are such as require an extraordinary degree of heat to fuse them, or as are altogether infusible, among which may be named actinolite, asbestos, graphite, mica and talc or steatite. These are found in commercial quantities in the eastern counties of the province, in rocks of the Laurentian formation. They have not yet however been worked upon a large scale, with perhaps the exception of mica. This mineral, from its possessing good insulating properties, has recently come into extensive use in connection with electrical machinery, and last year 240 tons of it were mined in Ontario.

VII. Materials of a mineral character used in the production of light and heat are not of first class importance in Ontario, being limited to petroleum, natural gas, lignite and peat. They are all of organic origin; the two former derived from animal or vegetable fossils, and the two latter from vegetable only. Our petroleum area at one time extended over portions of Lambton and Kent, but the producing field is now wholly confined to a few thousand acres in Lambton. It is obtained from the Corniferous limestone, but the original source may have been in lower formations. Natural gas is a recent discovery, but reservoirs of good producing capacity have been struck by borings in the counties of Essex, Haldimand and Welland. In Essex the gas rises, it is supposed, from the Clinton formation, whereas in the two eastern counties it rises from the Medina sandstone. Extensive beds of lignite have been discovered interbedded with the drift in the basin of the Moose river and its tributaries, the Abittibi and the Missinaibi. But the peat deposits of the Hudson bay slope have a vastly greater area, and when the time comes, as doubtless it will come, that peat can be converted into good fuel at an economic price, a material of first class necessity will be obtainable for the people of Ontario in limitless quantity. Nor, when that time comes, will we be dependent on the peat bogs of the Moose river basin alone. There is hardly a county in the province which does not possess a supply; there are large beds between the Ottawa and St. Lawrence rivers; our lake country is full of it; and along the line of the Canadian Pacific Railway from the Ottawa river to Lake of the Woods there is more of it than would replace the coal fields of Pennsylvania. And it is with some confidence I express the belief that in a process which I had an opportunity of looking into a few days ago the problem of the conversion of peat into fuel has already been solved in a simple, practical and economic way.

So I come to the end. The subject is very far from being exhausted, but I know that I must have wearied your patience if I have not exhausted your forbearance. Let me however express the hope that something has been said which may serve to arouse in your minds a higher opinion of this great Ontario of ours—the first commonwealth of America in the extent and variety of its resources, in the commanding opportunity of its situation, in the excellence of its institutions and the sterling qualities of its men. If I was to give a word of counsel concerning your relations to this commonwealth, the duty you owe to it and the sphere you should aspire to occupy in it when you also become men, it would be only in the words of the Spartan mother when her son was leaving farewell on going out to meet the enemy of his country and might not evermore return:

SPARTA IS YOUR PORTION, she said—DO YOUR BEST FOR SPARTA!

PEAT, ITS USE AND VALUE FOR FUEL.

Nature, which has dealt of her mineral treasures to our province with no niggard hand, has denied her the gift of coal. The Carboniferous series has no place in the geology of Ontario, nor have the Cretaceous areas of the Northwest Territories and British Columbia with their important and extensive coal deposits their counterparts here. It cannot be contended that this gap in the geological record is a matter of little consequence. In the bracing atmosphere of our northern winters personal health and comfort require a generous consumption of fuel, the cost of which forms no small share of the householder's annual expenditure. Time was when the hardwood forests which covered a great part of Ontario could be drawn upon for what seemed endless supplies of fuel, and with first-class cordwood at very little more than the cost of cutting and hauling, the question of fuel was not one to give any concern to the early settler, or his sons who succeeded him. Rather did they zealously strive in season and out of season to get rid of this magnificent supply of timber, until we who live in these latter days are inclined to think they succeeded but too well. To a large part of the population of the province wood has ceased to be the chief fuel and has given place to coal, almost entirely the product of the mines of Pennsylvania and Ohio. The long vessel and railway carriage and consequently heavy freight charges to which the coal we use is subject makes it impossible that the price should be otherwise than high, and the cost of coal both for domestic and industrial use is a heavy tax upon the productive energies of our country.

SUPPLY AND COST OF FUEL.

Statistics of the quantity or value of the fuel annually consumed in Ontario are not to be had, yet an approximation may be made which will show how largely this item bulks in the expenditure of the country at large.

The number of families in the province may be taken as 400,000, averaging five persons in each. A moderate estimate will allow ten cords (of 128 cubic feet) of wood or six tons of coal to each family per year, not taking into account the very large quantities of both wood and coal consumed by the railways and industrial establishments of the province. At the present time hardwood retails in Toronto at $5.50 per cord and anthracite coal at $6 00 per ton, and in other large towns and cities the prices are much the same. In country towns and villages in well settled districts the best hardwood costs $3 50 and $4.00 a cord, in more remote sections not so much, while the cost of coal is enhanced the farther it is taken inland from the border line between Ontario and the United States. The price of wood and coal varies also for the several varieties of each, but if it may be assumed that the cost to the consumer all over the province is three dollars per cord for wood and five dollars per ton for coal, we arrive at a yearly outlay per family for fuel of $30, or an annual expenditure for the province at large of $12,000,000 for fuel for domestic use alone. The annual cost per family for fuel from 1885 to 1889 is given in the report of the Bureau of Industries for 1889 as $40.12, which would give a yearly expenditure for the province of upwards of $16,000,000; the figures however have reference to the artisan classes in cities and towns only, and do not include the farmers or dwellers in rural districts who are much more numerous than the working classes (so-called) and whose fuel costs much less. It is therefore probable that $40.12 is in excess of the average expenditure per family for fuel throughout the whole of the province.

To the annual value of the fuel consumed for domestic use must be added the cost of fuel used by the railways, the steamboats and the thousands of manufacturing establishments throughout the province. This sum must be a large one. The total imports of coal into Ontario for the year ended 30th June, 1891, were, bituminous 1,510,411 tons, valued at $4,708,343 (including duty), and anthracite 931,463 tons, valued at $3,516,041 ; a total of 2,441,874 tons, valued at $8,224,384. If we suppose that one-half of this quantity is consumed for transport and industrial use, we get a total expenditure for fuel for all purposes of not less than $16,000,000 a year.

Dependent on a Foreign Country.

The forests and woodlands still supply a large share of this fuel, particularly of that part used in country districts both for domestic and industrial purposes, and will probably continue to do so for some time to come, but for the remainder we are dependent upon a foreign country.

Combines of coal-mine owners or railway companies, strikes or lock-outs of miners or railway employés, financial or other disturbances, all occurring in another country and entirely beyond the control of our own people, are causes which may at any time bring about a scarcity of coal and an advance in its price.

These are no imaginary dangers. A recent amalgamation of railway and coal-mining companies in the United States has placed the control of the coal product in the hands of a few owners, and the inevitable result has been the "stiffening of coal values," otherwise a rise in the price of coal. The cost has gone up to consumers in this city fifty cents per ton, with the prospect of further increases during the season; and the unpleasant truth has been forcibly brought home to the coal users of the province that they are delivered over to the tender mercies of a coal ring which has the power and apparently the intention of squeezing every cent it can out of the market. Were such combinations formed in Ontario, Canadian legislation might perhaps be brought to bear upon them ; but they are beyond the reach of our lawmakers, and not having coal within their own borders the people of this province, unpalatable though the thought may be, are doubly harnessed to the car of one of the most odious of monopolies—a monopoly in a prime necessary of life.

Our national pride cannot reasonably take offence at the decree of nature which obliges us to import our coal from the United States, yet surely, in addition to the considerations mentioned above, it may and ought to furnish a stimulus to the examination of our own resources in the hope of obtaining an article therefrom which would be to some extent at least a substitute for coal, and which would create a new industry and provide new employment for the labor and enterprise of our citizens.

Iron without Coal.

Abundant supplies of good coal and iron are at the foundation of England's prosperity and her industrial and commercial supremacy. Iron alone would have been of comparatively little avail had she not had the coal with which to smelt it, nor would the coal alone have served her had she not had vast stores of ironstone close by out of which to win the raw material for her ships, her guns and her machinery. Similar in kind, if not in degree, have been the results wherever stores of these minerals have been confided to the hands of a people who knew how to make use of them. The amazing progress in all the arts of peace and industry made by the United States, which threaten to eclipse even that of the mother country herself, the rapid strides in the same direction made by France, Germany, Belgium and other European nations have all depended to a very large degree upon the possession by these countries of beds of iron and coal.

Here in Ontario we have iron ; iron of the best quality and in immense quantity. It is found in the east, in the north and in the west, and there is every likelihood that in the many unexplored parts of the province future prospectors will bring fresh deposits to our knowledge. But we cannot hope, however diligently our prospectors may search, that their efforts will be rewarded by finding workable measures of coal. We know that in the almost untrodden wilderness where the Moose and Abittibi rivers flow northward into James' bay there are deposits of lignite, but their extent and value are yet undetermined, and it would be rash to say that we may expect the Hudson bay slope to supply us with lignite of good enough quality and in sufficient quantity to take the place of the anthracite and bituminous coals from the mines an equal or less distance to the south of us.

THE SUPPLY OF PEAT.

There remains another source of heat which though hitherto but little availed of among us holds great possibilities of usefulness for Ontario. Peat exists in very large quantity in the province, but for various reasons has as yet met with little acceptance as fuel. People dislike to change their ways unless they are obliged to do so, and hitherto both wood and coal have been sufficiently abundant and cheap to give them no reason to look to other substances for fuel. The chief hindrance to the use of peat has lain in the difficulties which are met with in the effort to reduce the raw material to a serviceable article at a cost which will allow of competition with wood or coal. Many ingenious attempts have been made both here and in other countries to overcome these difficulties, and much time and money have been spent upon processes of greater or smaller promise, but up to the present time the results have not been wholly satisfactory. The wit and skill of inventors continue however to be addressed to the task, and there is reason to hope that ere long the ingenuity of man will have triumphed, and another victory will have been scored of mind over matter. Some of the most promising of the attempts to surmount the obstacles which present themselves in the economic preparation of peat fuel have been made in Canada, and at least two processes have recently been brought to the notice of the Bureau by which it is hoped that Canadian inventors have solved the problem.

ORIGIN AND NATURE OF PEAT.

Before entering into an account of the difficulties which lie in the way of the utilization of peat, or of the various methods which have been adopted in the hope of overcoming them, it is necessary to devote a few words to the origin and nature of peat itself. In low and moist situations, particularly in the more northerly and colder regions of the globe, where water collects and cannot readily flow off, a growth of a low order of vegetation is induced, consisting of mosses and marsh-plants of various kinds. The plant which is the principal source of peat is a moss of the genus *sphagnum*, of which there are many species, all having the peculiarity of dying at the extremity of the roots below while continuing to grow and increase above the surface. The botanical characteristics of this moss are given by Braithwaite in his work on Peat Mosses as follows :

Plants densely aggregated, without roots except in the young state. Stem with the axile cells soft, becoming indurated at the surface, clothed with a cuticle of one or several layers of large lax cells. Leaves nerveless, of a single stratum of dimorphous cells, the small utricular ones conveying sap and chlorophyl, enclosing the large, empty hyaline ones, which generally contain spiral fibres and have their walls perforated by large or small foramina. Inflorescence axillar, the male amentiform, antheridia globose, with very fine, branched paraphyses. Capsule globose, sessile on the apex of an elongated vaginula; calyptra saccate. Branches in lateral fascicles, aggregated at summit into a dense coma.*

The same author says further :

Between fifty and sixty species of *sphagnum* are known, of which about one-third are tropical; but they are most abundant in the north and south temperate zones, in the higher latitudes of which they cover a great expanse of surface. . . . As to the economic uses of the sphagnaceæ, they are but small, except as a source of easily procured fuel; and in this respect indeed they are of immense importance, for no substitute could be found in the thinly populated and barren districts of the north, where trees become an insignificant object in the scenery, or cease to grow at all; yet nature, by the very means which produce these widely extended solitudes, supplies one of the first requirements of those who occupy them, and everywhere is peat annually cut, dried and stored. With regard to the function of these plants in the formation of peat, I cannot do better than quote Professor Schimper's words. He says: 'Unless there were peat-mosses, many a bare mountain ridge, many a high valley of the temperate zone, and large tracts of the northern plains

*Braithwaite: The Sphagnaceæ or Peat-Mosses of Europe and North America, (1880) p. 10.

would present a uniform watery flat. instead of a covering of flowering plants or shady woods. For just as the *sphagna* suck up the atmospheric moisture and convey it to the earth, do they also contribute to it by pumping up to the surface of the tufts formed by them, the standing water which was their cradle, diminish it by promoting evaporation, and finally also by their own detritus, and by that of the numerous other bog-plants to which they serve as a support, remove it entirely, and thus bring about their own destruction. Then, as soon as the plant-detritus formed in this manner has elevated itself above the surface water, it is familiar to us by the name of peat, becomes material for fuel, and all *sphagnum* vegetation ceases.'*

Where the conditions are favorable peat-beds of considerable thickness are often accumulated in the course of time. The growth of these beds is occasionally quite rapid. Geikie says for instance, that in the valley of the Somme three feet of peat will grow in from thirty to forty years; on a moor in Hanover a layer of peat from four to six feet thick is formed in about thirty years, while near the lake of Constance a layer of three to four feet grew in twenty-four years. When a considerable growth has been attained decomposition sets in, gases are evolved, and the mass assumes a considerable density and becomes of a dark earthy color. The layers nearest the surface are for the most part less compact and of a lighter color than those below, and are less valuable for fuel.

Peat bogs often occupy the site of shallow lakes which have been overrun by vegetation, and in such cases the peat is frequently found resting upon a layer of marl made up of the shells of countless myriads of shell-fish which formerly inhabited the waters. Such marl, consisting principally of carbonate of lime, is valuable as a fertilizer on certain soils and is also used in the manufacture of Portland cement.

CONSTITUENTS OF PEAT.

Peat generally contains a proportion of incombustible matter such as sand, lime or other inorganic substances washed into it by the drainage of the surrounding country or blown into it by winds. These constituents vary in proportion from 1 to 33 per cent. and largely determine the quantity of ash produced by the combustion of any sample of peat. The better qualities of peat seem to yield from 3 to 8 per cent. of ash, and those which contain a much higher percentage are less valuable or altogether worthless for fuel. Deducting the incombustible matter and water, the average composition of air-dried peat may be said to be as follows: Carbon, 52 to 66; hydrogen, 4.7 to 7.4; oxygen, 28 to 39 and nitrogen 1.5 to 3 per cent. The following table from Percy's Metallurgy shows the position which peat occupies as a fuel as compared with wood and coal, carbon in each case being taken at 100:

Substance.	Carbon.	Hydrogen.	Oxygen.	Disposable hydrogen.
1. Wood (mean of several analyses)	100	12.18	83.07	1.80
2. Peat " " "	100	9.85	55.67	2.89
3. Lignite (mean of 15 varieties)	100	8.37	42.42	3.07
4. Ten-yard coal of S. Staffordshire basin	100	6.12	21.23	3.47
5. Steam coal from the Tyne	100	5.91	18.32	3.62
6. Pentrefelin coal of S. Wales	100	4.75	5.28	4.09
7. Anthracite from Pennsylvania, U.S.	100	2.84	1.74	2.63

"Disposable hydrogen" in the above table refers to the proportion of that gas over and above what is required in combination with the oxygen to form water. It will be observed that while the proportion of hydrogen decreases in descending order in the above table, the proportion of oxygen decreases in greater ratio, the consequence being of course that less of the hydrogen is taken up by the oxygen in the formation of water and more is available for purposes of combustion. The percentage of "disposable hydrogen" is therefore a partial index of the value of a fuel.

* The Sphagnaceæ or Peat-Mosses of Europe and North America, pp. 8, 10, 11.

COMPOSITION OF FOSSIL FUELS.

The following figures are extracted from tables given in Percy's Metallurgy, and will suffice to show the chemical composition of peat, lignite and some of the principal varieties of coal.

—	Peat.	Lignite.	Caking coal.	Non-caking coal.	Cannel coal.	Anthracite.
Carbon	54.02	66.31	78.69	78.57	80.07	90.39
Hydrogen	5.21	5.63	6 00	5.29	5.53	3.28
Oxygen	28.18	22.86	10.07	12.88	8.08	2 98
Nitrogen	2.30	0.57	2.37	1.84	2.12	0.83
Sulphur	.56	2.36	1.51	0 39	1.50	0.91
Ash	9.73	2.27	1.36	1.03	2.70	1.61
Specific Gravity	0.850	1.129	1.259	1.278	1.276	1.392

These analyses are exclusive of water, which in the peat amounted to 25.56 and in the lignite to 34.66 per cent.

The following table by Dr. Wagner, quoted by Thurston, gives a somewhat different analysis of fuels, and also represents approximately the gradual change of composition as fossilization affects the alteration of the woody fibre* :

—	Carbon.	Hydrogen	Oxygen.
Cellulose	52.65	5 25	42.10
Peat	60.44	5.96	33.60
Lignite	66.96	5.27	27.76
Lignite (earthy brown coal)	74.20	5.89	19.90
Coal (secondary)	76.18	5.64	18.07
" "	90.50	5.05	4.40
Anthracite	92.85	3.96	3.19

In the above analyses earthy matter is excluded.

Peat is simply one of a group of fuels of vegetable origin which, beginning with the most recent of wood or other plant growth, extends downward to the oldest anthracite. We can readily detect the difference between the various members of the group, but are often at a loss to know where one ends and another begins. For example, wood is quite distinct in physical properties and chemical composition from lignite, and yet specimens of lignite, such as those brought by Mr. Borron from the Moose river, are found showing the scarcely altered wood passing into true lignite, and when the latter is met with approaching the bituminous coals in age it also approximates them in structure and other characteristics. Bituminous coals again probably differ from anthracites only because of their later origin. Similarly, peat taken from the bottom of a bog where it has lain for a long time and has been subjected to heavy pressure is dark brown or black in color, possesses comparatively little external appearance of vegetable origin and is scarcely distinguishable from some forms of lignite. Peat in short may be regarded as incipient coal.

*The Materials of Engineering, by Robert H. Thurston, A.M., C.E. (1884) Part I p. 173.

THE NATURE OF FUEL.

Fire was one of the "elements" of the ancients, but modern science has long since removed it from that category, along with its companions, earth, air and water. Fire indeed though called "the destroyer" is but the energetic indication of a change taking place in the chemical composition of the substance upon which it appears to feed. It annihilates nothing; it only destroys the form in which matter has previously existed, and re-arranges its constituents into some other combinations. The combustion or burning of a fuel is simply the process by which the elements it contains are oxidized or combined with oxygen—usually with the oxygen of the atmosphere. The principal heat-producing elements of ordinary fuels are carbon and hydrogen, and the heat given out by the fuel while burning is evolved by their oxidation. The carbon unites with oxygen to form carbonic oxide (CO) or carbonic acid (CO_2) while hydrogen unites with oxygen to form water (H_2O). A fuel may be judged by the *total amount* of heat, or by the *intensity* of heat, which its combustion is capable of producing. The following extract from the Encyclopædia Britannica states succinctly the difference between these two things:

In the determination of the value of fuel two principal factors are involved, viz., the calorific power, or the total amount of heat obtainable from the perfect combustion of its constituents, and the calorific intensity or pyrometric effect, which is the temperature attained by the gaseous products of the combustion. The first of these is constant for any particular composition and does not vary with the method of combustion, the quantity of heat developed by the combustion of a unit of carbon or hydrogen being the same whether it be burnt with oxygen, air, or a metallic oxide. The calorific intensity, on the other hand, being inversely proportional to the volume of gases produced, it is obvious that if the combustion is effected with pure oxygen the resulting carbonic acid (in the case of carbon) may be very much hotter than when air is used, as the duty of heating up an additional quantity of nitrogen rather more than three times the weight of the oxygen is in the latter case imposed upon a similar weight of carbon.*

In his Elements of Metallurgy Phillips states that "From the mean results of a considerable number of experiments 8,080 (metric heat units) has been decided on as the calorific power of carbon existing in the form of purified wood charcoal, while from the mean of six determinations Favre and Silbermann deduced 34,462 as the calorific power of hydrogen, the weight of hydrogen consumed being calculated from that of the water collected."† The calorific intensity of a fuel cannot be so easily ascertained, being dependent not only on the composition of the fuel itself but also upon various circumstances connected with the mode of combustion. "All calculations," says Phillips, however, "made on this subject so far agree with the result of experience as to show that, practically, the temperature which a fuel is capable of producing is directly proportionate to the amount of carbon it contains."‡ This author defines a fuel in the following terms:

DEFINITION OF A FUEL.

Any substance which admits of being rapidly oxidised or burned by atmospheric air, and evolves during that operation an amount of heat capable of being applied to economic purposes, is called a fuel. Two elements only, namely, carbon and hydrogen, are thus applied. All fuels are of vegetable origin and chiefly consist either of woody tissue or of various products of its natural or artificial decomposition. Although vegetable matter is never free from traces of nitrogen it may be regarded practically as being essentially composed of carbon, hydrogen and oxygen, together with small amounts of earthy or inorganic substances. In all fuels containing carbon, hydrogen and oxygen the proportion of hydrogen may be equal to or greater than that required to form water with the oxygen, but is never less. In such combinations only the hydrogen in excess is considered available as a source of heat, so that in the combustion of a substance of which the composition may be regarded as carbon and water the carbon alone is the source of heat. Indeed in such cases the hydrogen is the cause of the loss of a considerable amount of otherwise available heat, since it may be viewed as existing in combination with oxygen in the state of water, which must be evaporated at the expense of a portion of the heat developed by the combustion of carbon.§

* Encyclopædia Brittannica, article Fuel, vol. IX. p. 807.
† A metric heat unit is the amount of heat required to raise one gramme of water from 0° to 1° C.
‡ Elements of Metallurgy by J. Arthur Phillips, M. Inst. C. E., etc. (1874), p. 23.
§ *Ib.*, p. 15.

Thurston in speaking of fuels says :

The fuels used in metallurgy and engineering are anthracite and bituminous coals, coke, wood, charcoal, peat and combustible gases obtained by the distillation of the solid kinds of fuel. . . The heating power of any fuel is determined by calculating its total heat of combustion. This quantity is the sum of the amounts of heat generated by the combustion of the unoxidised carbon and hydrogen contained in the fuel, less the heat required in the evaporation and volatilization of constituents which become gaseous at the temperature resulting from the combustion of the first named elements.*

FUEL VALUE OF PEAT.

Dealing with peat the same author says :

Dried in the air it, like the lignites, retains moisture persistently, and is usually found to contain 30 per cent. after drying. After completely removing all water, an average specimen would contain about 60 per cent. of carbon, 5 to 10 per cent. hydrogen, and 30 or 40 per cent. of oxygen. The ash varies very greatly, sometimes being as little as 5, and in other cases as high as 25 per cent. A pound of wood charcoal has nearly the same value as a fuel as 1.66 pounds of peat of average quality. Peat is frequently used in large quantities for heating purposes, and attempts have been made, with encouraging results, to use it in metallurgical operations. When to be thus used it is cut from the bog with sharp spades, ground up in a machine specially designed for the purpose, and dried by spreading it where it can have full exposure to the sun and air. It is frequently compressed by machinery until its density approaches that of the lighter coals, and it is used in blocks of such size as are found best suited to the particular purpose for which it is prepared. Its charcoal makes excellent fuel for use in working steel and welding iron. It is frequently found to be a very excellent fuel for other purposes, and is extensively used in some localities. Its specific gravity is usually about 0.5.†

Thurston also gives a table showing the heating effects or calorific power of various fuels, from which the following is extracted, showing the value of peat in this regard as compared with other well-known fuels ‡ The calorific power is expressed in British thermal units, one such unit being the quantity of heat required to raise a pound of water from the temperature 39.1° to 40.1° Fahr.

Fuel.	Calorific power.		Water vaporized at boiling point parts by one part.	Cubic feet required to stow one ton of furnace coal.	Weight pounds per cubic foot as stowed.
	Relative.	Absolute.			
Coal, anthracite	1.020	14,833	14.98	40 to 45	49 to 56
Coal, bituminous	1.017	14,796	14.95	42 to 48	47 to 53
Coal, lignite, dry	0.7	10,150	10 35	42	53
Peat, kiln dried	0.7	10,150	10.25	81	25
Peat, air dried	0.526	7,650	7.73	75	30
Wood, kiln dried	0.551	8,029	8.10	....	....
Wood, air dried	0.439	6,385	6.45	56 to 100	22 to 40

The foregoing statements are sufficient to demonstrate the place of peat in the category of fuels. They show that it occupies a position both in composition and value intermediate between wood and coal. Leaving the proportion of water out of consideration, it contains a higher percentage both of carbon and available hydrogen than wood, but less than any form of coal, while in heating power, as measured by its capacity of evaporating water, it ranks in like order. In its ordinary forms it is also slightly less bulky than wood, but much more so than coal.

PEAT IN EUROPE AND AMERICA.

In the British isles and on the continent of Europe peat has been long in use as a source of heat, particularly among the poorer classes, to whom it possesses the recommendation of being generally obtainable at an outlay of little more than their own

* The Materials of Engineering, part I. p. 154. † *Ibid*, pp. 177-8. ‡ *Ibid*, p. 207.

labor. Since railways and steamships have cheapened the transportation of coal, the use of peat has become less general, but at one time in Scotland and Ireland it was the fuel most largely made use of by the laboring classes, and indeed by the great bulk of the population. The right to take peat from a neighboring bog was one highly prized by the peasantry of those countries, and neither wood nor coal being available, it is difficult to see how life would have been sustained had it not been for the stores of fuel laid up in these bogs by the generous hand of nature. Generation after generation employed in the preparation of peat have given it its rules of manufacture, its appropriate tools of peculiar design, its vocabulary of technical terms and its place in song and story; and many inhabitants of this province, immigrants from the old lands, can speak feelingly of the days spent in "cutting turf" or "casting peats," and the comforts of a seat by the fire-place in winter when a mass of glowing peat sent out its mellow warmth, and spread abroad its pungent odor on the frosty air. Many such immigrants, now old or middle-aged, can well recall the days when, in cold weather, they trudged to school, each with a peat under his arm, as their contribution to the heating of the parish school-house.

Its Preparation in Scotland.

The methods of preparing common air-dried peat fuel are practically the same in all countries, differing only with the nature and particularly with the consistency of the material. In bogs of the usual character the surface is first removed, that portion being of little value for fuel, and the denser part is then cut into brick-shaped blocks which are placed in convenient position for drying. When the latter process is sufficiently advanced the product is ready for use, or to be stored away for consumption in cold weather. A minute description of the process of peat cutting and winning as practised in a lowland parish in Scotland is given by Mr. Alexander L. Gibson, of Wroxeter, Ontario, in a letter to the Bureau, and may be taken as typical of the methods employed elsewhere. It may be worth while to place on record an account of the methods employed in the preparation of the fuel which for centuries was almost the sole fuel of the people of Scotland, and Mr. Gibson's letter is therefore quoted in full. He says:

The peat-moss that we dug our peats in, the Dogden moss, was situated in Greenlaw parish, Berwickshire. It was of very large extent, about 700 acres, and up to my early years had been very extensively worked for fuel. Peat was, even in my father's boyhood, an article of commerce, being carried to such places as Dunbar and Berwick-on-Tweed. The moss was quite contiguous to a hamlet called Bedshiel, where there were twelve families who each had a small moorland holding and kept a few sheep and some "eild" (in modern phrase, young) cattle. Along with their little farming operations they made a business of digging peats and carrying them to the places mentioned, which in the then condition of the roads was no small job. These men were called "peat lords," but that condition of things was done away with before my time. The Dogden moss lay a little distance south from the southern foot of the Twinlaw Cairns, say a couple of miles, and to the north of a gentle elevation of moorland, so that it is likely that at some time in the distant past it was an open lake, with an opening to the east draining into the Faungrass water. On the west were some sandy knolls, famous for rabbits; at this end the moss was partially drained by two routes into the Blackadder, through Halyburton farm. On the northeast were the kames, a high ridge of gravel, rather rough, covered with broom, whins and a wiry sort of grass. The direction of the kames was generally from northwest to southeast, with frequent bends and crooks from the general direction, and they terminated at the southeast end in a round conical hill of much higher elevation. The east end of the lake had evidently been dammed up during the glacial era, and vegetable matter springing up gradually raised the level of the lake until at last the water worked through to the west as above stated. It is to be noted that when in digging the peats we had the good luck to reach the bottom, we invariably found a layer of brushwood, which as invariably seemed to be hazel.

In digging the peats the first operators ages ago commenced at the dry land, that is, where the moss and hard moorland meet, and kept cutting away, year after year, finding the moss gradually growing deeper and deeper until the moss-hag was about eleven feet deep and fully a quarter of a mile from the dry land. The peats, when dry, had to be carried this quarter of a mile, either on hand or wheel-barrows, as no horse or cart could reach the peats where they were made. The moss for about three feet deep consisted of "foggy" growth, and was comparatively worthless for fuel. The hag was a face about five or six feet high, and at the foot of this hag was the "hole" from which a portion of last year's peats had been taken; it was generally eight or nine feet wide, five feet deep, and full of water when we came in the month of April or May to dig the peats for the season. The portion of the hag my father had was about fifty feet long of a face, and according to the quantity intended to be taken out it might be that we cut eight or ten feet in the hag. and dug out that block down to the bottom, when the water did not chase us out. The first process was to "turr" the top of the hag. This was done by cutting off with the spade the foggy top formerly mentioned, and throwing it into the last year's hole, thus forcing the water to find its way in any direction from the "lay ground." Each year's hole was filled up and levelled so as to form a ground on which to lay the newly cut peats till they partly dried. This part soon assumed the appearance of the original moss, and would no doubt after a time (how long I cannot say) again become fit to make peats.

We will now suppose that the block fifty feet by nine or ten is "turred" to the depth of about two feet or perhaps more, and we are ready to "cast" the peats. We take a sharp spade and make a cut about a foot and a half deep and about one foot or fourteen inches from the front of the hag, and six feet or so long. This is called a "bink," and we take the peat spade and cut out block after block about five inches square and a foot or fourteen inches long. Three peats deep will generally take off all that was "ritted," and we have to ritt again. We go on in this manner until the bink is out, that is, taken out down to the level of last year's hole. Bink after bink is excavated until the whole block that was turred is removed, and now as the most valuable part is under our feet we have to commence to "sink." In doing this we cut the peats sometimes not very shapely at first, and gradually working backwards we can cut them nearly straight down, giving them no more slant than will keep them from slipping off the spade. Having gone across the block we turn face and work in a similar manner back to where we began to sink. By this time we are about two feet or more below the level of the lower lay ground. We go on in this way until we reach bottom, which is invariably a fine white sand, and having got our hole sunk we now again turn face to the right or left as required and go on bink after bink until all is out. I am proceeding on the assumption that we have had good luck, which simply means that we have not come across a "gaw," or fissure in the moss, full of water. If we do we must abandon the hole, for it soon fills up, and sink again, leaving a "scarcement" or wall between the new hole and the abandoned one. Now that we have the peats cut we have to carry them away back and lay them out to dry. The first row is laid flat down, and the next with one end of the peats resting on those first laid down and the other end on the ground, so that a current of air circulates below and around them. They lie in this way for about two weeks, if the weather is favorable, and the next process is to "foot" them, *i.e.*, placing four or five together on end leaning to a common centre in such a way that they will stand, and then laying one, two or three on top as may suit. After they have reached this stage they are comparatively safe and are getting quite hard. A week or two weeks more makes them ready for stacking, when they are considered almost secure. When first cut the peat is of a brown color but on a few minutes exposure to the air turns as black as coal. In drying it decreases about fifty per cent. in bulk, and is lighter than coal when dry. I cannot say anything as to its value compared with coal or wood; very little of the latter is used by common people in Scotland.

In some parts of this large moss there are occasionally met what are termed "wigs." These are the roots of some sort of grass that have never rotted, and it is almost impossible to cut them, as they just push before the spade into the soft moss and cause great trouble and hindrance in the work. In some mosses in the neighboring parish of Gordon they do not need to ritt the bink, as they use a "lippy" spade, one push of which forms a peat. In our moss we could scarcely use a lippy for fear of coming across a wig.

This peat is a very valuable article of fuel. It is much cleaner in every way than coal: it gives very much less smoke, almost no soot, and is easily kindled. The peats from the lower part of the moss become quite hard and black when fairly dry. The smell of the smoke is very strong and is perceptible three or four miles away, but is not disagreeable to the natives, though people from districts where coal is used do not like it. When burning the peat does not burn with a flame, but gets into a fine red glow until it is consumed to ashes, of which it does not leave much.

Price of Peat Fuel in Scotland.

Peat is now but little used in Scotland; indeed except in the more outlying places which are far from coal and in the Highlands, whence coal is brought from England, peat is largely a thing of the past. In former days the cost of the labor required to cut and save peat was less than the price of coal, but with the rise in the wages of labor and the extension of transport facilities peat has been very largely supplanted by its heavier and more compact rival. At the present time peat fuel prepared in the ordinary way sells in Scotland for about 13 shillings per ton (2,240 lb.), of which 8 shillings 6 pence covers the cost of labor, the price of coal in the same market being from 13 to 18 shillings 6 pence per ton. It is used for domestic purposes only, and 1 ton 18 cwt. is considered equal in heating value to one ton of coal.

THE PEAT INDUSTRY IN IRELAND.

In Ireland, on the other hand, at any rate in the south of Ireland, the use of peat or "turf," as it is there called, where available, is said not to be on the decline. A recent letter from Mr. J. O'Keeffe, a hardware merchant in Tralee, county Kerry, Ireland, says that "peat is used by the great majority of the rural population in Ireland wherever such can be obtained, but like the great forests of Canada, vast tracts of the bogs of Ireland are already used up, and in some counties the railways have facilitated the mode and cost of transit." Mr. O'Keeffe states that peat is not only used for domestic purposes, but that in dairy and baking operations it is invaluable, and that the dairy-maid and butter-maker in Ireland attribute the excellent quality of their butter to the use of peat fuel. It is also employed under steam boilers in small mills in the country districts where water power is not available, and for the driving of engines attached to threshing machines. The average cost for labor per ton is three shillings for peat saved on the sward. In Tralee market the present (July, 1892) price of peat is about 5 shillings per ton as compared with 23 shillings per ton for Welsh and 18 shillings per ton for Scotch coal, delivered. Two tons of "first cutting" peat are considered to be equal to one ton of Scotch coal and two and a half tons to one ton of Welsh coal.

The method of cutting and preparing the peat is described by Mr. O'Keeffe as follows: Cutting usually commences about 1st May, a short spade about six inches wide at the mouth with a wing at the left side being used, which cuts and squares the sods at one operation. Attending each digger is a man with a two-pronged fork having a handle 5 to 7 feet long, who throws the sod to another, who in turn throws it to another, and so on until the limit of his "sward" or drying-ground is reached. The last person who receives the sod generally spreads for drying, leaving the sods almost horizontal, for if placed perpendicular, or nearly so, and the summer should become rainy or wet the process of drying is slow as well as expensive. Placed in the position first described the "turf" comes in earlier. The process of drying usually takes about two months, but in a season like the present, which has been exceptionally favorable, it has been dried and saved within five weeks.

Mr. O'Keeffe concludes: When peat is plentiful and cheap large fires are kept continually burning, over which generally hangs a large three-legged or sometimes a flat-bottomed pot, and in another part of the premises is a portable boiler for the heating of which peat answers admirably. In the winter-time the housewife feels proud of "the blazing fire high-piled upon the hearth" beside which the stories of a thousand years are told. In many Irish towns where people use ranges very little peat is burned, except for baking purposes, but in the poorer quarters where the open hearth is still in vogue and where the luxury of a range is unknown, it is the fuel used for all domestic purposes. In rural Ireland coal is very seldom used, and will not be for many a year to come.

EXTENT OF EUROPEAN DEPOSITS.

There are very large deposits of peat in England, Scotland, Ireland, France, Holland, Germany, Austria and elsewhere in Europe. It has been estimated that the amount of peat fuel in Ireland, taking the value of crude peat compared with that of coal as 1 to 6, is equivalent to four hundred and seventy million tons of coal, while in France there is said to exist the enormous quantity of six thousand million tons of peat purified and dried in the crude state, or reduced to charcoal two thousand six hundred and ten millions of tons. Mr. O'Hara, in the Dublin Quarterly Journal of Science, estimates the peat-bogs of Ireland at 1,576,000 acres occupying the limestone plains, and 1,255,000 acres on the hills and mountains, making a total of 2,831,000 acres. Mr. Plant estimates the extent of peat in Great Britain at 3,500,000 acres, therefore the total in the British isles will be about 6,000,000 acres; consequently if 12 feet is assumed as the average thickness, each acre will yield 12,000 tons of peat, on the whole at least 72,000,000,000 tons of valuable fuel.* The peat bogs of other European countries are on a similarly large scale.

*Ure's Dictionary of Arts, Manufactures and Mines (1875) vol. III. p. 527.

PEAT DEPOSITS IN AMERICA.

Nor is there any scarcity of this article in North America. The New England and Atlantic states comprise within their borders large peat areas, the great stretch of the Dismal Swamp apparently forming its southern limit in the United States. Peat is found in all the provinces of Canada, the bogs of New Brunswick and Quebec being very extensive. In Ontario, Logan in The Geology of Canada (1863) says:

VARIOUS OCCURRENCES IN ONTARIO.

It occurs in the township of Caledonia, where its thickness does not appear to exceed three or four feet, also at the sources of the Pain river in Roxburgh, Osnabruck and Finch, and in Clarence, Cumberland and Gloucester. In the third, fourth and fifth ranges of the latter township is a tract known as the Mer Bleue, which consists of two long peat bogs separated by a narrow ridge of higher land and occupying each about 2,500 acres. These deposits were sounded in many places with a rod to a depth of twenty-one feet, without finding bottom; in other parts the peat was from eight to fifteen feet in thickness. This tract is situated only three miles from the Ottawa, and is about 280 feet above the level of the sea. Three large areas of peat of from 1,000 to 3,000 acres each occur in Nepean and Goulbourn, one of them to the east and two to the west of the village of Richmond. It is also found on the third and eighth ranges of Beckwith to the east of Mississippi lake; and an area of about 3,000 acres of peat occurs in Westmeath in the rear of front A, and from the first to the fifth range behind it. In the ninth and tenth ranges of Huntley there are about 2,500 acres of peat; which in some parts has a thickness of eight or ten feet, while in other parts no bottom was found at a depth of fifteen feet. It is probable that peat may be met with in many other localities throughout this region.*

THE HOLLAND RIVER BOG.

Along the Holland river in the counties of Simcoe and York, extending for about eighteen miles upwards from where it empties into lake Simcoe, lies the well-known Holland marsh, containing on a rough estimate about 20,000 acres. It lies on both sides of the river and is of varying width, averaging perhaps one and a half miles. This large tract of country is almost wholly waste land, its only products being bull-frogs and a coarse wiry grass, known as "sea-grass," which is cut in July and August and sold in considerable quantities in Toronto and Hamilton for upholstering purposes. A company was formed in Toronto about twenty-five years ago to acquire the upper portion of the marsh, or that part lying south of the Northern Railway bridge at the town of Bradford, with the object of draining the land and reclaiming it for purposes of cultivation. The scheme was favorably considered by the government of the day, which offered to sell the company the land at the rate of fifty cents an acre; but nothing came of the project, and it is doubtful whether it was a practicable one and whether even if the marshy land were drained it would be suitable for agriculture. A recent visit showed the greater part of the marsh to be a quaking peat bog, in places upwards of nine feet deep, and samples taken from six inches to three feet below the surface proved the peat to be of excellent quality, and to improve with the depth. If any of the processes hereinafter set forth for the manufacture of peat on a commercial scale prove successful, this bog offers notable advantages, being easy of access by way of the Holland river, which is deep enough to float vessels of considerable draft (as it used to do many years ago when it formed part of the highway from Toronto to the northern waters), and also conveniently situated for the transport of the manufactured product to the centres of population, either by rail or boat. Such a process would however require to be one which could dispense with drainage, the marsh being practically on a level with the sluggish Holland, and consequently kept constantly full of water. So long as lake Simcoe maintains its present level, so long is it likely that the Holland peat-bog will remain a "wet" one.

THE BERLIN BOG.

A small peat-bog of about twenty-five acres in extent lies immediately south of the town of Berlin, Waterloo county, from which a quantity of peat has this summer been cut by Mr. Allen Huber, who has been experimenting with it as a fuel for use under steam boilers

* Geology of Canada, 1863, pp. 780-1.

and for domestic purposes. A trial was recently made of the fuel in the Dominion Button factory of Messrs. J. Y. Shantz & Son, but owing to the peat not having been thoroughly dried the results were not wholly satisfactory, though quite sufficient to warrant the belief that a properly dried article would answer admirably as a source of heat for steam generating purposes. The peat after exposure to the wind and sun for three weeks was found to retain as much as 53 per cent. of moisture. Further tests are to be made by Messrs. Huber and Shantz, whose experiments will be watched with interest. Similar small bogs are said to be common in Waterloo, and doubtless exist in other districts as well. The Berlin bog is underlaid by a thick deposit of shell marl.

OTHER AREAS IN SOUTHERN ONTARIO.

Peat is also found in considerable areas in the townships of Humberstone and Wainfleet on the Welland canal, in which locality it is understood that an attempt is about to be made to utilize the crude material in the manufacture of compressed fuel by the Dickson process, hereinafter described. There are peat-bogs in the vicinity of Stratford in the county of Perth, in Elgin (near Dutton), around lake St. Clair, in parts of Parry Sound district, and large stretches of peat in the muskegs which line the Canadian Pacific Railway west of lake Nipissing and between Port Arthur and Rat Portage. Though the search for peat-bogs has not yet been quickened by a rise in their value as sources of fuel, it is probable that there are few counties in the province where, in larger or smaller extent, they cannot be found.

THE MOOSE RIVER BOGS.

It was long considered that the most extensive peat-bogs in Canada were situated in the island of Anticosti, where a continuous plain covered with peat extends for upwards of eighty miles with an average breadth of two miles, thus giving a superficies of one hundred and sixty square miles. But the explorations of Mr. E. B. Borron in that part of Ontario lying on the Hudson bay slope have led him to the conclusion that in the unexplored wilderness which occupies the basin of the Moose river and its tributaries there are in the territory belonging to Ontario not less than ten thousand square miles overlaid with beds of peat, the depth of which often exceeds six feet, and is probably twenty feet or more in many places.* In this region the conditions for the growth of the *sphagnum* moss are eminently favorable, the flatness of the plains retarding the drainage and the northern climate affording it the necessary lowness of temperature. Accordingly the *sphagnum* flourishes, to the detriment of most other forms of vegetation, and in many parts the surface of the country appears to be wholly covered by beds of peat which are gradually increasing in depth. Here, it may be, are being provided the stores of fuel which shall serve for future generations, if not for our own, when the wood of the older parts of Ontario shall have gone the way of wood in all other countries, or when the coal deposits in the republic to the south shall have begun to fail under the yearly increasing demands upon them. The Nipissing and James Bay railway has been projected into that now inaccessible region, and it is not impossible that part of its southward freight may some day consist of manufactured peat intended for consumption in the furnaces of the manufacturing establishments and in the cooking ranges of our towns and cities. Not until a railway has penetrated to the other side of the height of land will these immense fields of peat be available, but although their value is prospective rather than present it can scarcely be doubted that a time will come when the vast supplies of carbon they contain will be required and made use of.

METHODS OF PREPARING PEAT FOR FUEL.

The question naturally arises why it is that with these abundant stores of raw material and the large demand which would greet a first-class article furnished at a cost less than that of coal, no one has yet succeeded in placing such an article upon the market. Many attempts have been made to do so, for the successful inventor's reward in a coalless

*See report of E. B. Borron, Stipendiary Magistrate, Ont. Sess. Papers, 1881, vol. XIII., part IV.

country like Ontario would certainly be a golden one, but up to the present the desired end has not been attained. Indeed so formidable have the difficulties proved themselves that the belief is sometimes expressed that the problem is nearly an insoluble one. The history of the numerous attempts which have been made to produce a first class article from the raw material by an economical process, though by no means upholding this view, is a record of partial successes only. Probably Prof. N. S. Shaler of the United States Geological Survey takes the gloomiest view of the case of which the circumstances admit when he sums it up as follows :

In New England and Canada repeated efforts have been made to convert peat into a more compact and serviceable source of heat by various modes of mechanical treatment. None of the methods adopted have proved commercially successful ; though the amount of money and mechanical skill devoted to the end has been great, the failure in all cases has been complete. A similar failure has attended all European efforts having for their objects the improvement of peat for fuel. From some studies of the project which I made about twenty years ago, I came to the conclusion that with ordinary labor at $1.50 per diem it would be possible to make serviceable fuel at the cost of about $5 per ton. The difficulty however is not altogether found in the cost of the treatment of the peat or in the nature of the product, at least as far as the production of heat is concerned, but in the popular prejudice against some of the qualities of the fuel. Peat is generally very ashy, it has a peculiar odor, and the fire made from it is not lasting. It is impossible in this report to give a review concerning the history of peat fuel: such a review would however show that the prospect for utilizing this material in the United States is very small.*

It is doubtless true that in the United States where coal is plentiful and cheap the introduction of a new article of fuel does not possess the same degree of importance as in Ontario where coal does not exist and where it is of necessity dear ; and it may be safely asserted that the amount of "popular prejudice" which a really good peat fuel would have to overcome in Ontario would be very small indeed. Such an article would be received on its merits, and if it successfully stood the test of every-day use would rapidly come into general employment. The fact that some of the largest consumers of coal in Canada, notably the Grand Trunk and Canadian Pacific Railway companies, details of whose tests are given below, have experimented with peat in the hope of finding an efficient and economical fuel which they would be warranted in adopting shows that a hearty recognition awaits the inventive skill of the man who shall place such a fuel at the service of the public.

It may be conceded that if we could hope to have no better fuel than air-dried peat produced from the raw material in the ordinary way, valuable as this is, the likelihood of its ever taking the place of coal to any appreciable degree would be remote, but experience has shown that it is quite practicable to obtain a first-class fuel by means of a number of known processes more or less differing from one another. The difficulty with them all has been very largely one of cost. It has not hitherto seemed practicable to expel the water from the raw peat and reduce it to a sufficient degree of density without incurring an expense which precluded the possibility of its competing with coal. The fault, as Prof. Shaler himself admits, has not been so much with the quality of the fuel, and indeed much evidence can be adduced testifying to the good properties and high calorific value of the manufactured article.

Essential Operations in Manufacture.

Sir Robért Kane, who in his "Industrial Resources of Ireland" and elsewhere has given much information on the subject of peat in that country, states that the average result of a great number of experiments made in Irish bogs show that the general mass of the undrained peat, including both the lighter and the denser varieties, contains from 92 to 95 per cent. of water, while the edges of the bog and parts more or less drained, in the state in which peat is usually cut, contain from 88 to 91 per cent. The turf, as used in that country often holds from 20 to 35 per cent. of water, while that which has been stacked from six to twelve months still retains from 18 to 20 per cent., and that which has been kept in a dry house for two years, from 10 to 15 per cent. of water. Air-dried,

* Fresh-Water Morasses of the United States, by Nathaniel Southgate Shaler, Tenth Annual Report U. S. Geological Survey, pp. 303-4.

uncompressed peat is a very bulky fuel, its specific gravity being about .85 while that of coal is from 1.25 to 1.39. The essential operations, then, in the manufacture of condensed peat are, first, to get rid of the water and, second, to reduce the material to a density more nearly resembling that of coal.

Details of processes by which these ends have been sought to be accomplished, are given by Logan in the Geology of Canada (1863), and by many other writers on the subject.

VARIOUS PROCESSES REVIEWED.

The process patented by Linning in 1837, and used at Ekman's iron works in Sweden has been followed substantially by many other experimenters. The peat is first ground to a homogeneous mass in a pug-mill, similar to that used by brick-makers, afterwards moulded into convenient shapes and consolidated by a hydraulic or other press, after which the blocks are dried by artificial heat. An excellent fuel is the result. This is substantially the method adopted by Weber, of Staltach, in Southern Bavaria, by Gysser, of Freiburg, who invented a portable hand-machine to bring the operation within the reach of persons of limited means and dried his blocks in the air only, by Schlickeysen, who also dispensed with artificial heat for drying, and by numerous other inventors on the continent of Europe. The common feature of these processes is the grinding or triturating of the peat into a pasty mass, the end being to reduce it in bulk. Charcoal prepared from peat manufactured in this way is said to be much firmer, more compact and better suited for heating purposes than that made from either air-dried peat, or peat which has been subjected to compression only.

Williams' plan at Cappogue, Ireland, was to place the ground peat between cloths and subject it to a powerful hydraulic press. By this means he succeeded in reducing it to one-half its original weight, and one-third its volume. The remaining water was, however, difficult to be expelled from the consolidated peat, and the more fibrous varieties expanded a good deal in drying.

This experiment was afterwards repeated on a considerable scale by the Irish Peat Company, and with similar results. They also built large drying-houses in which attempts were made to dry ordinary peat by artificial heat, but the quantity of fuel required to expel the great amount of water from the peat was found to be so considerable that the process was not economical.

A plan followed at Rosenheim, in southern Bavaria, is, after drying the peat in the ordinary manner, to pulverize it by passing it through rollers, then to drive off the remaining water by heat and consolidate the dry powder by powerful pressure. The peat is made into small blocks of eight to ten ounces, weighing from 70 to 80 pounds per cubic foot, which corresponds to a specific gravity of 1.25, or nearly that of bituminous coal.

Hodgson of Ireland adopted a plan for securing a cheap and abundant supply of dried and powdered peat by passing a very light harrow over the surface of the bog and thus breaking up a thin layer. After a few hours exposure to the air, for draining and partial drying, this is removed by scraping, and a supply of powdered peat much drier than the general mass may thus be obtained. It is then heaped in embankments and dried by being spread on iron plates warmed by the waste steam from the compressing engine. The pressing machine consists of "a horizontal reciprocating ram," said to be capable of turning out 1,500 lb. of compressed peat per hour equal in density to coal.

The process patented by Gwynne & Co., differs from Hodgson's in depriving the raw peat of a large part of its moisture by subjecting it to the action of a centrifugal machine, after which it is ground to powder and passed through a series of cylinders revolving in a heated chamber, where the remaining moisture is got rid of. It is then compressed at a temperature of 180°, at which temperature the tarry properties of the turf are just sufficiently developed to form a good cementing compound, and the result is a dense and very pure fuel.

In 1856, Exter, of Bavaria, carried into operation on an extensive scale under the Bavarian government a method of preparing peat fuel which in its initial stages is practically identical with Hodgson's, described above. After scraping together the broken and partially dry peat it is, if necessary, further pulverized by passing it through toothed rollers. It is then introduced into a complicated drying oven, along the various floors or chambers of which it is moved by spiral conveyors exposed to a temperature of from 120° to 140° Fahr. The peat is then subjected to the action of a powerful eccentric press and formed into blocks which occupy about one-fourth the space of the same weight before pressing, the cubic foot weighing about 72 lb. In 1857 the cost of peat produced in this way was estimated at about 6 cents per 100 lbs., and was of excellent quality, being used exclusively for firing locomotives. Exter's process was adopted with some modifications in Hungary and Hanover, in the latter country unsuccessfully, owing to the fact that it is suited only to the better kinds of peat.

Elsberg, of New York, invented a modification of Exter's method by which the peat, air-dried as in Exter's process, is further broken in a cylindrical pug-mill and at the same time subjected to a current of steam admitted through a pipe and jacket surrounding the cylinder. The steamed peat is then condensed by a pair of presses fed directly from the mill. In this way the complicated drying oven of Exter is dispensed with.*

THE DE BRUGHAT METHOD.

The Dublin University Magazine for October, 1873, states that during the previous year (1872)—

A commission was organized under the auspices of Alderman Purdon, of Dublin, for the purpose 'of investigating in the public interest by personal examination, such of the best modern systems of preparing improved fuel from peat as are now to be found elsewhere.' With this view the commission visited several of the chief localities on the continent where the manufacture of peat fuel is carried on, and found various methods of manufacture at work, but they say that 'the principle in all is the same; the raw peat is subjected to a pulping process indispensable for the production of density, without the aid of any mechanical compression.' . . . . . In reporting the result of their investigation however they declare that 'in the application of the principle of macerating raw peat and in the air drying process will be found the only reasonable system of producing dense turf upon a commercial basis, and then they go on to recommend that owing to our variable and humid climate the manufacture would be greatly facilitated by the erection of drying sheds.†

The University Magazine claims for M. Challeton de Brughat, a French gentleman, the honor of having invented this process, which it describes as one in which thoroughly decomposed peat is well puddled together with a due admixture of water and then passed through a very fine sieve, which separates the minute carbonaceous particles; these when submitted to a process of drying are found to possess an adhesive affinity the effect of which is to combine them together in one solid mass analagous in density and hardness to ordinary coal.

De Brughat first brought his invention under public notice at the Paris Exhibition of 1855, and again in 1867, on both occasions receiving prize medals. A modification of his method was adopted by the Irish Peat Fuel Company as follows: The raw peat after having been properly macerated in a powerful disintegrating mill, cleansed from impurities and reduced to pulp, is conducted into reservoirs 160 feet long by 42 feet wide and 18 inches high. The sides of these reservoirs are made of a kind of basket work, and the water in which the peat particles are held in suspension flows rapidly away on all sides, acted on by the force of subsidence. When the pulp has acquired sufficient consistency its surface is marked out by a cutter into regular brick-like shapes, which facilitates the process of drying so much that in twenty-four hours afterwards they are generally dry and firm enough to bear handling. They are then removed and placed on light frames where they remain for a month, when they are completely dry and ready for delivery.

In May, 1873, a quantity of de Brughat's peat-coal was tested on the North London Railway, England, a trial run being made from Broad-street station to Kew, a distance of 29 train miles, with a train consisting of an engine and nine carriages. The results gave

*See Peat and its Uses, by Samuel W. Johnson, A.M., Professor of Analytical and Agricultural Chemistry, Yale College, p. 121 *et seq.*

†Dublin University Magazine, vol. LXXXII. p. 388.

the highest satisfaction. The steam was abundant and the engine worked up to 165 lb. pressure. The consumption of fuel for the total run was 48.3 lb. per mile, leaving off with a large, clear fire; there was no clinker in the bars and but a small amount of debris in the smoke box. The average consumption of the best coal by the Kew and Richmond passenger train for the same number of carriages is 32 lb. per mile.

One and a quarter tons of de Brughat's peat-coal are said to be equal to one ton of the best English coal for ordinary steam purposes, while for household use and for furnaces having little draft and with the fire bars close together one ton of peat coal is equal to the same quantity of pit coal.

As to the commercial aspect, it is stated that de Brughat's own manufacturing experience, extending over many years, proved beyond a doubt the remunerative character of manufacturing peat-coal. The total cost of producing this article on a large scale at de Brughat's works is 6 shillings per ton, while he gets for it on the spot 28 shillings per ton and from 33 shillings 6 pence to 36 shillings per ton at Paris, at which price the demand is active for all he can supply. The same gentleman also manufactures peat charcoal at a profit of 300 per cent. in actual operations. The charcoal is stated to cost practically nothing to manufacture, owing to the value of the other products evolved in the process; and it sells at £6 to £6 8s. per ton in Paris, wood charcoal bringing between £5 and £6 per ton.

The foregoing statements are all taken from the article in the Dublin University Magazine above mentioned, and if they even approach the truth they establish beyond a doubt that the manufacture of peat fuel can be conducted on a commercial basis.

THE CLAYTON METHOD.

In Ure's Dictionary of Arts, Manufactures and Mines (1875) it is alleged that for practical purposes peat as prepared in Ireland in the ordinary way is absolutely spoiled. One pound of pure dry turf will evaporate six pounds of water; now, in one pound of turf as usually found there are three-quarters of a pound of dry turf and one-quarter of a pound of water. The three quarters of a pound can only evaporate 4½ pounds of water, but out of this it must first evaporate the quarter pound contained in its mass, and hence the water boiled away by such turf is reduced to 4¼ pounds. The loss is here 30 per cent., a proportion which makes all the difference between a good fuel and one almost unfit for use. When turf is dried under cover it still retains one-tenth of its weight of water, which reduces its calorific power 12 per cent., one pound of such turf evaporating 5⅓ pounds of water. This effect is sufficient however for the great majority of objects; the further desiccation is too expensive and too troublesome to be used except in special cases. The same authority gives the following account of the Clayton system of preparing peat, which it will be seen is similar in some respects to the de Brughat plan already described.

The Clayton method is simply to cut the peat into fragments in its raw, moist state, drain off as much of the water as will freely run away; then masticate the fibres and whole mass of peat together in a machine until it becomes difficult to distinguish any ligneous fibre distinct from the humus in which it is so entirely mixed. The pulped peat is forced out through orifices in the end of a cylinder on to rollers which carry it to trays where it is cut into lengths and then taken to the drying-sheds, where it remains about three days; it is then dry enough to be stacked in open racks where the final drying is completed. The most important feature in this system is the breaking up of the cellular tissues of the peat and thus getting rid of the fixed moisture: and the remarkable reduction in the size of the blocks of peat during the process of drying shows that this is done in the most complete manner. The condensed peat becomes very firm and solid, and the whole process does not take more than seven or eight days. Messrs. Clayton, Son and Howlett assert that this fuel can be produced at a cost of from five to six shillings per ton.

A EUROPEAN METHOD.

The article further states that an idea of what is being done on the continent of Europe may be obtained from the following account of a method of condensing peat:

The peat press consists of a wooden tub about six feet high and two feet wide, chained upon a kind of sledge. The wooden vessel contains an upright shaft which may be set in motion by means of a horse-gear. This shaft carries on the bottom an iron disk, above it two revolutions or turns of screw blades and above these four similar blades, each forming a quadrant and so arranged that they form a complete revolution. Knife-like projections in the wooden vessel prevent the peat revolving with the blades and shaft. The opening for the introduction of the peat is at the back on top; in front is the iron delivery which may be opened by means of a lever, and contains a wooden conical mould through which the peat issues in four endless strings or streams on an inclined table, on which it is cut in pieces or blocks of convenient length. These are then dried in the open air. The peat having gone through this machine dries much more quickly and burns with greater intensity of heat, and the lightest and poorest stuff so worked is fitted for consumption under steam boilers. One volume of this pressed peat is equal to two of Hanover peat, or to three of ordinary cut peat, and the intensity of heat developed stands in the same proportion.*

OTHER METHODS OF TREATMENT.

The same authority describes other methods of treatment as follows:

Danchelle's peat-fuel and peat-filters for sewage were exhibited at Manchester in 1874. The samples of manufactured peat-fuel made from the light brown moss of Red Moss, Horwich, Lancashire, differed from other specimens of peat-fuel in that the humus and ligneous fibre of the peat were macerated and reduced to a state of a fine chocolate-paste. The machine used to effect this consists of a long cylinder, in which works a shaft armed with proper cutters and disks, by which the crude peat is soon reduced to the consistency of pasty pulp, and issues in a long roll of any shape or diameter; this is cut into briquettes by a wired frame, and the briquettes are dried in the usual way, under a covered shed; in drying they lose in their bulk, but they are in a fortnight converted into a good hard fine-grained fuel, and when roasted with charcoal are about one-third their original size. The producers of the Danchelle peat-fuel also convert the peat into sewage-filters by incorporating the peat with a mixture of clay and charring them. Experiments have been made and are continued with these filters in Bradford, Yorkshire, and in Paris, and the results are stated to be very satisfactory. Peat-fuels are prepared in Sutherland by charring the peat, which has been broken up by a machine, so as to leave it in a rough granular state, and afterwards worked up with crude shale-tar, and pressed into bricks by a moulding machine. The quantity of shale-tar taken up by the vegetable peat is very considerable, and gives it a thoroughly carbonized appearance.

Mr. Robert Kerretichison breaks up his peat with a machine, by means of which it parts with a great deal of its water. It is then manufactured in a masticator, and finely-broken asphalt is mixed with the mass. It is then shaped into briquettes and dried under sheds. Its specific weight is less than most other peats, and the addition of asphalt adds to its cost, but gives it greater value for furnaces and for raising steam.†

In Austria and some parts of Germany, a process obtains of grinding the peat as rags are ground in a paper mill, by the addition of water, to a very fine pulp, which is placed in suitable receptacles, and by filtration and evaporation relieved of most of the water. It is then cut into blocks and stacked away for use at a later day. The product is said to be excellent, but the process is slow and expensive.

The treatment adopted at Horwich, Lancashire, England, presents some points of difference from any of the foregoing. The peat is pulped in a mill arranged for the purpose, and conveyed by means of an endless band to a moulding machine, which cuts it into blocks of any required size. The blocks then travel backwards and forwards in a drying chamber on moving bands exposed all the time to a current of heated air. The product is said to be hard, dense and of excellent quality.

The apparatus invented by Mr. Buckland of South Wales consists of a solid, obtuse iron cone, having a spiral groove on its exterior, and revolving vertically within a hollow cone of iron plate, perforated everywhere with small round holes like a colender. The peat is put into the space between the solid and hollow cones and by the revolution of the former is forced in worm-like form through the holes in the latter. It is then fashioned into bricks by any convenient machine, and artificially dried. This process is said to produce a good quality of fuel, but to be of small capacity and expensive to work.

Other methods of treatment on the continent of Europe consist in passing the crude peat in its moist state through rollers which reduce it in bulk, and deliver it in soft blocks or sheets, which are afterwards removed to spreading-grounds or sheds to be dried;

* Ure's Dictionary of Arts, Manufactures and Mines (1875), Vol. III. p. 526.
† *Ibid.*, p. 527.

or in pulping the raw peat with the addition of considerable water, and dividing it in this state into moist blocks which are dried in kilns or the open air.

PROCESSES TRIED IN THE UNITED STATES.

The attempts to convert raw peat into a serviceable fuel have been fewer in the United States of America than in Europe, largely, no doubt, because of the comparative cheapness and abundance of wood and coal in the former country. Nevertheless, the problem has been attacked by a number of experimenters, some of whom have been content to follow European processes, while others have invented plans of their own. It was thought by some of them that the peat as it was taken from the bog could be wholly freed from water by compression, and presses of great power were brought to bear upon it with this belief. Experience showed however that a considerable percentage of the moisture is retained by the peat with such tenacity as not to be amenable to pressure only.

Under the patents of Ashcroft and Betteley operations were carried on at Lexington, Mass., for several years subsequently to 1864. Their process consisted in reducing the raw peat to a pulp, which was then conveyed into high tanks where it was allowed to remain until of its own weight and pressure it became sufficiently dense to be formed into blocks, when small gates were opened at the bottom of the tanks, and the superincumbent mass forced the peat out in a continuous sheet of uniform size. This was cut into blocks which were laid away to dry. Experiments were also made with the view of drying peat by absorption, the plan being to cover the spreading-ground with a layer or pavement of porous brick, on which the soft pulp was laid as it came from the machine. No great measure of success seems to have been achieved by either of these methods.

By a machine set up at Pekin, N.Y., in 1865, the invention of M. S. Roberts, the peat was ground to a pulp with water to the consistency of mortar, and then, by means of a long conveyer attached to the machine, spread on the ground and cut into blocks, which were left to solidify and dry in the open air.

THE LEAVITT PROCESS.

In the process patented by T. H. Leavitt of Boston, Mass., the apparatus consists principally of a strong box 3 feet square and 6 feet high, supported upon a stout framework about 4 feet above the floor of a suitable building, which should be near the bog, and is best constructed on a side hill, so that easy access can be had to the lower story on one side from the foot of the hill and to the second story on the other side. The top of the tank should be open, and even with the floor of the second story, so that the raw peat can be dumped directly into it. Within the tank, and firmly fixed to its sides, are numerous projections of a variety of forms, adapted to the treatment of the material in its several stages as it passes through the mill, which is divided into three apartments. Through the centre of the tank revolves an upright, to which are affixed knives and arms varying in form and structure to correspond to the stationary projections in each apartment; below the tank is a receiver or hopper, and under this is a moulding or forming machine, 2 feet wide and 12 feet long, of simple construction, which receives the condensed material from the hopper and delivers it in blocks of any desired form and size, to be afterwards laid out upon the ground or on frames to dry. The whole is adapted to be driven by a small steam engine, and requires about six and ten horse power respectively for the two sizes of machines constructed, of the capacity of 50 and 100 tons each of crude peat per day of ten hours. It is claimed for this treatment that it entirely destroys the original organization of the peat and expels the air from its cells, thus allowing the water to evaporate so freely that at the end of eight or ten days the peat is in a condition to be housed or transported to market. Figures are given by the inventor to show that in 1867, with ordinary labor at $1.75 per day, twenty-five tons of merchantable fuel could be prepared per day at an outlay for wages of $37.75, the cost of the apparatus itself being $4,500. The product was said to weigh from 65 to 80 pounds per cubic foot, which is equal to a specific gravity of from 1.04 to 1.28.

THE WALKER MACHINE.

Another machine is that of Thomas George Walker, which both grinds and artificially dries the material. The wet peat, after being puddled in a pug-mill vat and heated by waste steam, is forced through the bottom into a box, whence it is blown by a steam jet through 400 feet of 6-inch cast iron pipe, coiled up in the furnace under the boiler, by which means it is thoroughly dried. It then passes through a larger pipe into a receiver, at the bottom of which it falls into a mould, where it is pressed into form by a plunger. The residual steam and gases pass from the top of this receiver in a tank through another pipe whose end is under water, in which any dust carried off by the steam is deposited; and the waste steam and gases thus purified pass thence back to the pug-mill jacket, where they are used to heat the new material. A second tank, under the pug mill, receives the water from the waste steam condensed in the jacket, and all combustible gases rising to the top are conveyed through a pipe to the furnace and utilized as fuel. The successive heating of the peat in the pug-mill vat and in the long passage through the 6-inch pipe so prepares it that it is easily moulded into a compact form as it leaves the receiver.

Canadian Methods of Treatment.

The utilization of the great peat deposits of Canada is no new project, and at various times during the last thirty years there have been brought to public notice processes which were claimed to have brought the production of a first-class peat fuel at a sufficiently low cost well within the domain of fact.

THE HODGES SYSTEM.

The Hodges system of peat manufacture, described by Sterry Hunt in the report of the Geological Survey of Canada for 1866, was deemed by that eminent scientist to be a very promising one and likely to lead to the development and utilization of the supply of peat in Canada. It consisted in a manufactory which should float about in the bog, cutting its own channel, excavating and pulping the peat and finally spreading it out to dry; the whole without manual labor. The peat after all sticks and roots were removed was passed through machinery which destroyed its fibre and reduced it to a homogeneous mass of soft pulp like well-tempered mortar. This was then spouted out to the surface of the bog, previously levelled and prepared for its reception, and spread in the form of a thin sheet nine inches in thickness and ninety feet in width. After lying a couple of days it began to consolidate and was then divided by transverse cuts at intervals of six inches. In a few days more it was divided longitudinally, and in about a fortnight the shrinking of the peat caused the cuts to open, and gave the whole bed the appearance of an immense floor covered with bricks eighteen inches long by six inches wide. As soon as these were sufficiently hard for handling they were taken up and stacked for drying.

The manufacture of peat after this process was carried on by Mr. Hodges at Bulstrode on the Three Rivers and Arthabaska railway. Fifty tons of the air-dried peat fuel could be produced in a day of ten hours, costing, when dried and put into barges on the canal, according to Dr. Hunt, ninety-two cents per ton. As thus prepared it contained about twenty-five per cent. of water, the greater part of which was lost by further drying. Numerous experiments were made with peat prepared after the Hodges plan as a fuel for locomotives on the Grand Trunk railway with "signal success." To quote from the report:

A subsequent trial with an express train from Montreal to Kingston, 177 miles, showed that one ton of 2,240 pounds of peat holding 20 per cent. of water was consumed in running 50½ miles, being equal to 44.5 pounds of peat to the mile. With Pictou coal on the Boston and Worcester Railway, for the month of August 1866, the average distance run was 59.9 miles per ton of coal, being equal to 37.3 pounds of bituminious coal to the mile. Peat is found to require for its combustion in the fire-box of a locomotive little or no blast, the production of which, for wood or coke, involves a great expenditure of steam power; and it is supposed that by altering the blast to suit the requirements of peat a great economy in the use of this fuel may be attained. It is also found that in burning it even with the present great blast, no sparks are produced, so that the use of peat affords a guarantee against the frequent fires arising from the sparks of engines burning wood. . . In one experiment, the minutes of which are before me, an engine with a train of twelve loaded cars on the Grand Trunk Railway consumed in running 44 miles, 2,440 pounds of peat, equal to about 40.3 miles to the ton or 55.5 pounds of peat to the mile. In doing this 1,900 gallons of water are said to have been evaporated. If we take these to be American standard gallons this gives 6.48 pounds, and if imperial gallons not less than 7.78 pounds of water evaporated for each pound of fuel consumed.*

It seems probable that Dr. Hunt underestimated the cost of producing this peat fuel, or that further trial did not confirm his account of its heat-producing qualities, as in the quarter of a century which has elapsed since he made his report the Hodges system has not come into vogue, and the problem of producing a cheap and efficient peat fuel has yet to be solved.

THE AIKMAN PLAN.

The process invented and patented by Mr. David Aikman of Montreal, is thus described by Mr. Aikman himself, in the specification forming part of letters patent granted him by the United States patent office on 2nd October, 1888 :

In manufacturing my improved fuel I prefer to take the peat in a semi-liquid or pulpy state and after removing the sticks by any of the well-known devices, evaporate and remove the surplus water by stirring the pulp in a steam-heated vessel or chamber, and then complete the drying process by passing the peat through heated rollers or between rollers and heated plates. This liberates the lighter volatile vapors and leaves the peat in small flakes or particles ; but while undergoing the above operation the carbon-cells are only partly broken, and in order to finish what may be called the "fracture" of the cells and saturate the free carbon again with the highly inflammable tarry and resinous substances, and bind the same permanently together in a solid compact mass having the qualities above specified, I direct the peat thus dried and prepared into moulds kept at a high temperature by the direct application of fire, or by using superheated steam, and there reduce the same to a charred or carbonized condition. While this carbonizing is going on the peat is kept under heavy pressure in the moulds by plungers or like devices (also brought to a highly-heated condition) until the fibrous or vegetable matter and the volatile elments are thoroughly incorporated together, and the exterior of the block is coated with the resinious matter and glazed by the friction and heat and thus rendered water and air proof.

Practical difficulties in the way of constructing suitable compressing apparatus have it is said retarded the manufacture of peat by the Aikman process on a commercial scale, but sufficient quantities have been produced to prove that a satisfactory fuel can be made in this way. A test of Aikman's peat fuel as compared with Sydney soft coal was made under a stationary boiler in the locomotive shops of the Canadian Pacific Railway Company, Montreal, in 1887, under the direction of Mr. Francis R. F. Brown, mechanical superintendent. In his report to the company Mr. Brown says :

As we did not go to any expense in getting up a special grate of a wood-burning class for testing the peat and as the test was made on a coal-burning grate, we may consider the results obtained from the peat as satisfactory. The temperature and state of the atmosphere were also in favor of the coal. I am satisfied that with a suitably arranged grate a much better result would have been obtained, but even leaving the grate as used for coal burning providing we could obtain the peat at $2.25 per ton it would still be a saving over coal. This peat fuel has proved itself superior to the best wood, and the difference in wear and tear on a locomotive fire-box between wood and coal is too well-known for me to dilate on. . . . . . The test was conducted in one of the Lancashire boilers, and commenced each day about 8 a.m., and a little irregularity occurred in consequence of the coal test extending over the dinner hour from 12 noon to 1 p.m. . . . . . The coal-grate was shortened about one-third to prevent any loss of steam by blowing off, due to the great amount of flame produced by the peat. Some peat also fell through the bars partly consumed, and though no opportunity offers to ascertain still it is probable that some was carried into the flues by the draught. The firing was light and the damper well down when the peat was tested, which explains the difference of water evaporated per hour, that being in no way to be attributed to the kind of fuel. I have no doubt that if tested under more favorable conditions, and when better acquainted with the class of fuel, the peat would give a relative efficiency of 75 per cent. as compared with the same class of coal as used, which was of good quality, being Sydney. Taking the coal as costing $3.50 per ton in the works, the peat (at 68 per cent.) would be worth $2.38 per ton delivered here.

* Geological Survey of Canada, 1866, pp. 289-90.

Following is the result of the test:

Description.	Coal. Sydney, soft.	Peat. West Farnham compressed; brown, soft.
Date of test	September 5th, 1887	October 13th, 1887.
Weather	Warm; fine	Wet; dull.
Duration of test	5 hours, 45 minutes	3 hours, 20 minutes.
Total fuel burned	3,360 pounds	2,625 pounds.
" water evaporated	25,900 pounds	12,610 pounds.
Average steam pressure	66.3 pounds	64.6 pounds.
Temperature of feed water	66° Fahrenheit	55° Fahrenheit.
Water evaporated per pound	7.07 pounds	4.8 pounds.
do comparative from and at 212°	8.35 pounds	5.7 pounds.
Relative efficiency	100	68.

An objection to the use of this fuel for locomotives is its tendency to disintegrate on being exposed to the weather. For domestic purposes however this objection did not apply, and Mr. Brown, who used it in his own house for some weeks continously, speaks very highly of its qualities as a domestic fuel, being easy to kindle, lasting a long time, giving out a great heat, cleanly to handle and leaving very little ash. A chemical analysis gave the following as the composition of a sample of the fuel:

Moisture	3.84
Volatile combustibles	41.22
Fixed carbon	48.04
Ash	6.90
Total	100.00

In view of the excellent character given the Aikman fuel it is to be hoped that the attempts now being made to overcome the mechanical difficulties in its manufacture may be successful.

FEATURES OF THE DICKSON PROCESS.

A method of preparing condensed peat fuel which has recently been invented by Mr. A. A. Dickson of Montreal contains some new features, and seems likely to lead to important results.

In Mr. Dickson's process the peat is cut direct from the bog or bed and elevated by carriers consisting of buckets attached to an endless chain, and discharged into a hopper from which it is fed automatically through a novel three-roller pressing mill having hollow cylinders of perforated metal or wooden slats covered with felt cloth about 1½ inches in thickness, which extracts the greater proportion of the moisture and delivers the peat in a semi-dry and spongy state, its fibrous nature not being destroyed or the component parts ground or pulverised as is the case under most other processes. The peat is then lifted into a revolving cylinder constructed of boiler plate, having upon its inside longitudinal shelves of plate and hung with the axle of the intake end about six inches higher than the axle of the outlet end. This cylinder is kept at a temperature of about 420° to 450°F. by exhaust heat of the boiler furnace delivered through a pipe, and with each revolution the peat is tossed and carried forward through the hot chamber to the outlet. Thence it is taken by carriers and delivered to another revolving drier which consists of a series of cylinders one arranged within the other, each being the frustrum of a cone connected by openings at the ends, and as the larger diameter is at the farther end the peat is carried forward from one cylinder to another by a steady progressive movement towards the outlet with every revolution. Hot air is supplied in the same way as to the first cylinder, and when the now practically dry peat is finally discharged through a shoot it is taken up by an endless chain carrier and conveyed to a compressing machine where it is subjected to a pressure of about ten thousand pounds to the square inch, formed into the shape desired, and is then ready for market.

The felt rollers expel about 60 per cent. of the water contained in the peat as it comes from the bog; of the remaining 40 per cent., 30 is driven off by the heated cylinders, and 10 per cent. is retained in the finished article, Mr. Dickson stating that he finds it preferable to allow the fuel to contain this proportion of moisture.

The effect of the pressure is said to be to bring the oily and tarry constituents of the peat to the surface of the block, thus giving it a coat of inflammable material which makes the fuel readily ignitible and at the same time renders it impermeable to moisture. The size of the blocks is preferably about three inches long and three inches in diameter, each block weighing about a pound.

The process is automatic throughout, the material being taken from the bog and carried through each successive operation without handling or interruption. As a consequence the manufacture proceeds very rapidly, and the raw peat is converted into dry, condensed fuel in twenty minutes from the time it is lifted from the bog. This, at any rate, is what the inventor hopes to achieve by his apparatus, which has not yet been constructed upon a commercial scale. A working model has been erected at Montreal capable of turning out 400 or 500 lb. per day, which the inventor states works most satisfactorily and has met his expectations in every way.

A full set of machinery, exclusive of motor power, will cost about $6,000, which would be capable of producing 50 tons of manufactured fuel per day of twenty-four hours at a total cost of $75, or $1.50 per ton, the labor of eight men being required. An engine of 40 horse power keeps the machinery in motion, and with boiler to correspond brings the whole cost of the plant up to about $10,000.

The machinery is placed on board a scow which floats on the bog, and being wholly under cover can be worked in winter as well as in summer.

The fuel made by the Dickson process has been tested with good results. In April of the present year a quantity was tried at the works of the Toronto Street Railway Company by Mr. Jackson Pollock, who gives the following account of the experiment:

The fire was raked out clean off the grate bars, and a new fire started with shavings, the steam standing at 60 lb. The first of the peat was thrown on at 3.05 p.m., 487 lb. in all being used for the test. The pressure rose to 80 lb. and remained stationary at 80 lb. until 4.50 p.m., one hour and three quarters, when it fell away to 60 lb. I then threw in coal upon the balance of the peat remaining on the grate. The steam was very steady and we were using all our power. No smoke was to be seen from the chimney, and there were no clinkers or cinders to clean out of the fire. The boiler tubes were dirty; I left them so purposely to give the fuel as hard a test as possible. The peat was not as solidly compressed as sample, and as you describe it it should show still better results. The average daily consumption of coal for six months ending January 31st was 2,074 lb.

An analysis of a sample of Dickson peat showed it to be composed as follows:

Moisture	8.55
Volatile combustible matter	56.34
Fixed carbon	31.04
Ash	4.07
Total	100.00

A small quantity of this peat was submitted by the Bureau to Prof. W. H. Ellis, of the School of Practical Science, Toronto, for the purpose of having a test made of its calorific value as compared with that of coal. Following is Prof. Ellis' report, dated 16th June, 1892:

I send herewith the results of my examination of the compressed peat you sent me. The sample contains 10.2 per cent. moisture and 2.9 per cent. ash. It gives in Thompson's calorimeter a heating power of 5,280 metric heat units; that is, one gramme of it will raise 5,280 grammes of water one degree centigrade.

The samples of coal you sent me gave when tested in the same instrument: No. 1, 7,425; No. 2, 6,820; No. 3, 7,480; mean of the three, 7,241.

Coal sample No. 1 was Massillon coal from Ohio; No. 2, Hocking coal from Ohio, and No. 3, Reynoldsville coal, from Jefferson county, Pennsylvania. They are all bituminous varieties. Mr. Elias Rogers, Toronto, from whom the samples were obtained, says as regards their qualities: "The Massillon coal is a superior coal for grate purposes; the Hocking coal is fair coal for grate purposes and fair coal for steam; the Reynoldsville coal has the control of this market for steam purposes. The average price of Reynoldsville delivered would be about $4.25 per ton, although for large factories where it is a convenient delivery less prices are made."

It will be seen that the heating power of the sample of Dickson peat was very nearly three-fourths of the average of these well-known brands of coal.

The superiority of the fuel manufactured by this process over that produced by nearly all others lies, according to the inventor, in the fact that the original fibre of the peat is retained intact, and with it the whole of the tarry and oily constituents as well as the gases contained in the peat, all of which are valuable factors in the calorific power of the fuel. The retention of the fibrous condition is also an aid in the rapid drying of the peat. The trituration and grinding of the raw material characteristic of most of the older processes has the effect, it is alleged, of liberating a large proportion of the gases, which are thus wholly lost. In addition to this the finely divided pasty condition to which the peat is reduced in these processes renders it so tenacious of moisture that it can only be dried by applying sufficient heat to cause partial carbonisation, during which process a further loss of the tarry and volatile combustible constituents occurs.

Mr. Dickson has patented his invention in Canada, the United States, Great Britain and France, and is at present engaged in forming a company for the manufacture of his fuel in this province.

TESTS OF PEAT FOR FUEL.

Many experiments have been made in various parts of the world with peat, both in an air-dried and a compressed condition, as a fuel under the boilers of railway locomotives and steamship engines. It is in regular use on the railways of some of the continental countries of Europe, for example, Bavaria, Oldenburg and Russia.

It does not appear however to be coming rapidly into favor for this purpose, one serious defect being that except in the best samples of condensed peat much more space is required for stowing it than for an equivalent quantity of coal. For the same reason the cost of handling is greater and more time is needed for renewing stocks of fuel.

Time and space are everything on board railway trains and steamboats, and so long as coal does not rise materially in price above its present figure it is unlikely that peat will usurp its place in the bunkers of the steamboat or the tender of the locomotive.

Another objection to its use on railways is the fact that most of the varieties of peat hitherto manufactured crumble more or less upon exposure to the weather.

On the other hand, the use of peat is much less detrimental to grate bars and furnaces than that of coal, and there is an absence of cinders, clinkers, and to a great degree of smoke.

In 1881, 60,885 tons of peat turf were used on railways in Russia; in 1891 the quantity had fallen to 51,678 tons.

RECORDS OF VARIOUS TRIALS.

There is not space here to quote the details of the numerous trials made with peat as a railway and steamship fuel; some of them have not been satisfactory, but many go to show that even for this use, for which it is perhaps not so well suited as for domestic purposes and generating steam in stationary boilers, while not so valuable as coal it nevertheless constitutes an important resource which some day is likely to be taken advantage of. A few examples of the use of peat in this way may be given, and the records of some tests made in Canada may be of interest and value.

As early as 1844, Sir Robert Kane informs us, steamers plying between Limerick, Clare and Kilrush in Ireland were using peat for fuel. The "Garry Owen" steamer made the passage between Clare and Limerick (distance about 45 miles) fired with turf in 3 hours 20 minutes.

Still earlier Professor Emmons in a report to W. H. Seward, Governor of New York, in 1839, speaks of some experiments with peat as a fuel for steam engines in which a small quantity of tar was mixed for the purpose of creating a larger volume of flame, and says: "The experiments referred to were made on board the 'Great Western' during her last passage, and such was the result that a large amount of peat was taken on board for her homeward passage."

The locomotive engineer of the Belfast and Northern Counties Railway had tried the condensed peat on that line. In a trip of 74 miles the total quantity of fuel burned was 14 cwt., 1 quarter, 14 lb.—the train, including engine and tender weighing 70 tons. The time occupied was three hours, nine minutes. The trial proved satisfactory. . . . . . The locomotive superintendents of three railways in Ireland made a trial of condensed peat on the same railway to test its fitness for locomotives. During a trip of 27 miles there was an excess of steam though the fire door was continually open and the damper down for the greater part of the distance. The pressure at starting was 100 lb. The commencement of the trip was up an incline of 1 in 80, four miles long, with double curves. While ascending this incline the pressure rose to 110 lb. and afterwards to 120 lb. with the fire-door open. The speed was 40 miles per hour. While running there was no smoke, and little at the stations. The fire-box was examined at the end of the trip and very little clinker was found, and the smoke-box was free from cinders and dust—a proof that the fuel had stood the blast well; and it is the recorded opinion of the experimenters that the peat was in every respect well suited for locomotives.*

A trial on the Paris and Lyons (France) Railroad is thus reported by the engineer: We got up steam with peat in thirty minutes, coal requiring two hours. We ran 16 miles to a gravel pit, up a steep grade, and from there took a load of 136 tons 80 miles further, when the blaze escaped a considerable distance above the chimney which became red hot, and the boiler covering taking fire we had to stop and extinguish it. After repairs we returned to Paris at a speed of 38 miles per hour, the heat again increasing as we advanced. The fuel having no smoke and much gas keeps up a constant hot flame. The pressed peat gives far better results than that which is not pressed. In fact while using it the generation of steam was so rapid that I stood with my hand on the valve lever all the time fearing an explosion.†

A trial was made on the New York Central Railroad January 3, 1866, of which the following account is furnished us by the master machinist: Left Syracuse at 8 o'clock and 40 minutes (40 minutes behind time) with 25 empty 8-wheel box freight cars. Started with 120 lb. of steam. The engine worked well and took us along pretty sharp, as we made up the 40 minutes in going 25 miles and arrived at Port Byron on time. The steam did not run below 120 lb. any of the time and was often from 125 lb. to 130 lb. When the engine was working the strongest she would steam the best. We made time all the way very easy although we had a strong head wind all the way, and snowing at times quite fast, and very cold. We took on a trifle over four tons of peat at Syracuse which was all we had. . . Five tons of peat would have taken us to Rochester with the train we had although it was a very bad day. The same engine would have used about 3½ cords of wood running to Palmyra, while we used not quite 4 tons of peat for the same distance. It gave us as much steam as wood and burned a beautiful fire. Our trip was a perfect success, and I am sorry there were not not more present to witness it. We used a coal-burning grate.‡

Accounts of similar experiments on the Hartford and Springfield Railroad, the Hudson River Railroad and the Eastern and the Vermont Central Railroads are given in the same volume from which the foregoing extracts have been made, and in every case successful results are said to have been obtained.

GRAND TRUNK EXPERIMENTS.

In 1866 the authorities of the Grand Trunk Railway experimented pretty freely with peat, using the condensed article made by the Hodges process at Bulstrode, Que. The effect of the trials was apparently to show that peat could be used with advantage as a locomotive fuel. So satisfactory indeed did the company consider the result that a contract is stated to have been entered into extending over five years or seasons, during the first of which it was to take 100 tons per day, and during the four succeeding seasons 300 tons per day.§

Following are the particulars of some of these experiments: Well dried peat fuel was used with engine No. 158, 5-feet driving wheels, 16-inch cylinders, and 26-inch stroke, drawing twelve loaded cars.

Distance run per ton of 2,240 lb. of fuel	40.33 miles.
Fuel used per mile	55.54 lb.
Greatest pressure of steam	140 lb.
Least pressure of steam	100 lb.

* Facts about Peat, by T. H. Leavitt (1867), pp. 201, 203, 204. †*Ibid*, p. 206. ‡*Ibid*, pp. 208-9. §*Ibid*, p. 98.

During the experiment fuel was put on in small quantities. No smoke issued from the stack, a steady, brilliant, white fire was kept up, and steam generated with great rapidity. The damper was kept closed and air admitted through a slot in the furnace door. Not an atom of ash or cinder was left in the smoke-box, ash-pan, or upon the wire gauze of spark-catcher. The grate inside was one of Lester's patent, having a well in centre with horizontal openings to admit draft. The bottom of fire-box was scarcely ever entirely covered with the fuel, the steam being generated too rapidly to allow of a large quantity of fuel being put into the furnace.

Experiment with green peat fuel containing 25 per cent. of water, upon engine No. 65, 6-feet driving wheels, 15-inch cylinders, 21-inch stroke, drawing an express train of 9 passenger cars all heavily laden, from Montreal, going west, October 3, 1866:

Distance run	101 miles.
Fuel used	8,000 lb.
Fuel used per mile	79 lb.
Average speed, including stoppages, per hour	23 miles.
Greatest pressure of steam	123 lb.
Least pressure of steam	90 lb.

This experiment was one to show whether with an engine out of order and very much overburdened, steam could be made with green peat in sufficient quantities to meet an unceasing demand during the whole time of running. . . Abundance of steam was raised, and for a distance of many miles the pressure of steam did not vary. On the return trip next day, with a similar weight of fuel and train of six passenger cars, like results were obtained, but the quantity of fuel used per mile was reduced to 71 lb.

Experiment with engine No. 65, in good working order, and with peat fuel containing about 20 per cent. of water (express train consisting of six passenger cars):

Total distance run	177 miles.
Total consumption of fuel	7,936 lb.
Consumption per mile	45 lb.
Maximum consumption between stations	60 lb.
Minimum consumption between stations	30 lb.
Average speed including stoppages	25½ miles.
Greatest pressure of steam	125 lb.
Least pressure of steam	86 lb.
Distance run per ton of fuel	50½ miles.
Cost of fuel for the trip at $3.50 per ton	$12.25
Cost per mile run for fuel	7 cents.

On the return trip the consumption of fuel was less, the train being lighter.

Another experiment was made on the same road with the view of determining whether with a diminution of the blast the same quantity of steam could be generated as obtained on former occasions with the blast usually employed for wood. By this diminution of the blast additional power was gained and the consumption of fuel smaller than on any previous occasion.*

Notwithstanding the seemingly favorable results of these and other trials, peat has not been adopted by the Grand Trunk railway as a fuel for use in its locomotives; perhaps some experiments made at a later date, and with compressed peat of different manufacture may have led that company to the conclusion that as coal has answered its purpose in the past it may be trusted to do so in the future.

As it is not the purpose in this paper to overrate the qualities and advantages of peat, but to state as fairly as possible the conclusions which experience and careful experiment have reached, whether such conclusions be favorable or adverse, the following particulars are appended of comparative trials of peat, wood and coal, made by the Grand Trunk railway company in 1876, such particulars having been furnished the Bureau by Mr. E. Wragge, local manager Grand Trunk railway company, Toronto.

Experiments on the comparative values as fuel of coal, peat and wood in locomotive engine No. 303, built by the Rhode Island Locomotive Works, and running between Mont-

*Facts about Peat, p. 212 *et seq.*

real and Richmond on Nos 9 and 10 freight trains; cylinder 17 in. x 24 in., drivers 5½ feet diameter. James Millar, engineman; Wm. Walklate, inspector.

	Peat.	Wood.	Coal.
Date of experiment	Sept. 23.	Oct. 3.	Oct. 5.
Description of fuel	Compressed.	Hard maple.	Russell new black vein S. Wales.
Train miles	145	145	145
Car "	3,134	3,279	3524
Ton "	49,407	48,433	50,337
Average train tonnage	340	334	347
Average car "	15.76	14.77	14.29
Average cars per train	21.58	22.61	24.30
Fuel consumed, in lb	17,925	12,780	5,330
Fuel consumed, in lb, per train mile	123.62	88.13	36.75
" " " " car mile	5.71	3.89	1.51
" " " " ton mile	.362	.263	.105
Water evaporated in lb per lb of fuel	2.33	3.09	7.94
" " total lb	41,820	39,520	42,330
Time occupied in experiment, hours	13½	14¼	15
Speed in miles per hour, deducting stops	17¼	16	14¼
Hours engine was under steam	17	17	17
No. of stoppages on trip	140	168	156
Average boiler pressure in lb per square inch	120	130	135
Weather	Fair & warm.	Fair & mild.	Rain & cool.
Wind	Slight.	Strong side.	Strong side
Rails, condition of	Good.	Good.	Moderate.
Price of fuel	$2.53 per 2240 lb	$2.88 per 4031 lb	$4.77 per 2240 lb
Cost in cents of hauling 100 tons one mile	4.09	1.87	2.24

N.B. Peat delivered at St. Lambert's; wood sawn and delivered on G. T. R. track; coal in pile at Point St. Charles.

G. T. Ry. Mechanical Supt's Office,
October, 1876.

(Sgd) HERBT. WALLIS,
Mechanical Supt.

Similar experiments were also made under the direction of Mr. Wallis at the same time with the view of ascertaining the value of peat for use under stationary boilers, as compared with wood and coal, which, though more favorable in their results to peat than the experiments detailed above, nevertheless failed to show its superiority over its rival fuels.

Experiments on the comparative value of fuel of coal, peat and wood in No. 1 stationary engine:

Diameter of cylinder	22 inches.
Length of stroke	42 "
Engine	Horizontal class.
Outside lap	$1\frac{5}{16}$ inches.
Inside lap	$\frac{5}{16}$ "
Lead, front	$\frac{3}{16}$ "
Lead, back	$\frac{1}{8}$ "
Heating surface of box	150 89 feet.
" " tubes	1,094 "
Boiler area of fire grate (locomotive class)	1,868 "

	Peat.	Wood.	Coal.
Date of experiment	Oct. 12-13	Oct. 17-18	Oct. 19-20
Description of fuel	Compressed.	Hard maple.	Russel new black vein, Wales.
Price	$2.53 per 2240 lb	$2.88 per 4031 lb	$4.77 per 2240 lb
Average temperature of atmosphere	48.83°	41.02°	48.19°
Fuel consumed, in lb	18,157	17,065	6,615
" " per h.p. per hour	18.96	18.31	7.30
" " per hour	955.63	898.15	348.15
Total ashes, lb	532	265	649
" per 100 lb. fuel	2.92	1.49	9.81
Average boiler steam pressure per square inch	81.54	80.88	76.07
" cylinder " " "	13.97	13.88	13.33
Greatest initial pressure in cylinder	39	35	35
Average indicated horse power	50.40	48.95	47.63
" number of revolutions per minute	44.76	43.76	44.33
" piston speed in feet per minute	313.32	306.72	310.31
Total hours under steam	19	19	19
Cost in cents per h.p. per hour	2.14	1.30	1.55

N.B. Peat is delivered on G.T.R. cars at St. Lambert's; wood on track and sawn at various parts of the line; coal in coal pile at Point St. Charles.

G. T. R. Mechanical Supt's Office,
Montreal, Oct. 31st, 1876.

(Sgd) HERBT. WALLIS,
Mechanical Supt.

Mr. Wallis, in his report to the Grand Trunk Company upon these experiments, remarks that they show the peat to be better adapted for stationary boilers than for locomotives on account of the heavy work performed by the latter, but that it cannot commence to compare economically with coal or wood in either stationary or locomotive boilers. He enumerates the defects of the peat as a locomotive fuel thus:

It loses materially in weight, it is very objectionable to fire on account of the pain it inflicts upon the eyes, it is very liable to be set on fire, it requires a different kind of grate to burn it, it is not impervious to the weather, and it causes very considerable delay upon the road in wet weather.

It is evident from the results of these experiments that the peat which Mr. Wallis had under trial was of inferior quality, and although it is stated to have been "compressed," the fact that he objects to it on the score of its losing materially in weight shows that it cannot have been properly dried. No one could pit green or air-dried peat against dry hard maple or Welsh coal with the expectation that it would compare favorably with either. The tests appear to have been fairly and carefully made, but if the peat was not a representative article in point of quality, as is probable was the case, they ought not to be considered as conclusive evidence of its inferiority to the other fuels with which comparison was made.

The later trials made by Mr. Brown for the Canadian Pacific railway company, as well as the previous tests on the Grand Trunk railway, afford sufficient ground for believing that, while not equal to coal, peat when properly prepared has some not inconsiderable advantages in its favor, and can under certain circumstances be used as an efficient substitute.

Mode of Burning Peat.

With respect to the way in which peat may be burned, Prof. Johnson says:

In the employment of peat fuel regard must be had to its shape and bulk. Flat blocks are apt to lie closely together in the fire and obstruct the draft. A fireplace constructed properly for burning them should be shallow, not admitting of more than two or three layers being superposed. According to the bulkiness of the peat, the fire-place should be roomy as regards length and breadth. Fibrous and easily crumbling peat is usually burned upon a hearth, *i.e.*, without a grate, either in stoves or open fire-places. Dense peat burns best upon a grate, the bars of which should be thin and near together, so that the air may have access to every part of the fuel. The denser and tougher the peat, and the more its shape corresponds with that usual to coal, the better is it adapted for use in our ordinary coal stoves and furnaces.*

Peat Charcoal.

Peat can be reduced to charcoal in a manner very similar to that employed in the case of wood, and the proportion of carbon contained by peat being greater than that of wood, the percentage of charcoal yielded is correspondingly greater.

The average quantity of charcoal produced by the common stack or meiler process from ordinary wood is about 22 per cent. When the distillation is carried on in close ovens this quantity is frequently increased to 27 per cent.; but as about five per cent. is required for heating the oven this method in reality affords results very little superior to those obtained from the common charcoal-mound. Peat, on the other hand, yields from 23 to 35½ per cent. of its weight in charcoal on being charred in the ordinary way; the product of carbonization in ovens is not greater than that obtained by the ordinary process, yet the supply of air and the rapidity of charring being more easily regulated, the operation is more cheaply executed when ovens are employed.

Lignite yields from 29 to 62 per cent. of charcoal or coke, while from the most suitable sorts of bituminous coal as much as 90 per cent. of their weight is yielded in coke; ordinary yields are from 65 to 75 per cent.

The charcoal of peat is largely used on the continent of Europe for domestic purposes, its price being about the same as that of wood charcoal, and nearly twice that of mineral coal.

* Peat and its Uses, pp. 102-3.

It would seem that peat charcoal might be introduced as a fuel for household use here provided always it could be produced and sold at a price not greater than its equivalent in wood or coal. As to this it is stated that peat charcoal has been manufactured in Ireland at a cost of not more than 8*s.* 4*d.* ($2) per ton, but as applied to its cost here this is undoubtedly too low an estimate.

Mr. E. B. Borron gives it as his opinion that with the aid of recent discoveries peat charcoal may be manufactured in Ontario for $4 per ton on the spot where the peat mosses are situated.*

The selling price of this article in Paris, which appears to be not less than $25 per ton, would seem to preclude the possibility of producing it at so low a cost as that named by Mr. Borron, otherwise it might be expected that competition among manufacturers would have the effect of lowering its price. The high esteem in which it is held is shown by the fact that the people of Paris are willing to pay twice as much for peat charcoal as for an equal weight of coal, or even more, and thousands of tons are annually consumed in that city.

Its Value for Iron Furnaces.

The principal purpose for which coke is used is the smelting and manufacture of iron, the large proportion of carbon which it contains rendering it capable of producing the high temperature requisite for the successful carrying on of the processes.

Peat and coal have been employed in their uncarbonized condition for the smelting of iron ore, peat generally in conjunction with coal, while the latter is sometimes employed alone. Better results are obtained when the fuel is used in the carbonized form, as coal usually contains a considerable percentage of sulphur which is very deleterious to the product of iron, and which is wholly or partially got rid of by carbonization, and the charcoal and coke yield a greater intensity of heat in combustion than the raw fuels. Sir Lowthian Bell, one of the greatest living authorities on the manufacture of iron, places a low estimate upon the value of peat as a fuel for the smelting of iron. He says:

In 1876 a trial was made with compressed peat at one of the Vordenberg furnaces. Particulars of the experiment are given by Anton Einigl. When about 29 per cent. of the total weight of fuel was peat, the remainder being charcoal, the actual work done was such that one ton of the charcoal was worth nearly three tons of the peat. The low value of peat as a blast furnace fuel is due to the large quantity of water and volatile gases it contains. Of the really useful constituent, viz., fixed carbon, it gave only in this case 32 per cent. The statements just made in reference to lignite and peat may be accepted as an indication of the great inferiority of these varieties of fuel as compared with charcoal or ordinary coke, for the purpose of smelting iron.†

At Konigsbronn in Wurtemburg, at Ransko in Bohemia and elsewhere on the continent of Europe, on the other hand, satisfactory results are said to have been obtained in the smelting of iron by the use of air dried peat alone or mixed with a nearly equal weight of wood charcoal. Peat has even been used in Canada in the manufacture of iron, and to good effect, as will be seen by the following statements:

Mr. McDougall, of the Caledonia Iron Works, Montreal, who supplies the Grand Trunk railway with car wheels, states that for giving toughness to the metal and uniformity of chill, qualities so essential to car wheels, peat fuel is unsurpassed. We have the following brief report of an experiment in smelting iron with peat at these works made in October last (1866). The cupola was charged with two layers of iron and anthracite coal. The third and topmost layer was iron and peat. The time was forty minutes less than with coals alone. The iron smelted by the peat was hotter when drawn off from the coals and was said to be more compact and more like wrought iron than the other. The test was a severe one, the proportion being twelve of iron to one of peat; the proportion for coals being seven to one.

The Montreal Gazette of December 1, 1866, says: We were shown yesterday a small piece of bar iron from the puddling and rolling mills of Messrs. Morland, Watson & Co., from the first blooms ever made in this country with peat fuel alone, and we believe the first on this continent. The specimen shown to us was of the very highest quality and equal to the very best Swedish iron. It was bent when cold by a vice, and doubled close up at right angles with an edge, without a crack or flaw appearing, the outer edge remain-

* Ontario Sessional Papers, 1881, No. 44, p. xix.

† Principles of the Manufacture of Iron and Steel by Sir I. Lowthian Bell, pp. 136-7.

ing smooth and sharp. A severer test of the tenacity of the iron could not have been applied. . . We may add that the time taken in the manufacture was not greater than that usually taken when coal is used. There was no special adaptation of appliances. The furnace was an ordinary coal one, and the men were accustomed to the use of coal.

Mr. Campbell, manager of the mills above referred to, states that the peat fuel was tested in an ordinary puddling coal furnace, and no alteration or adaptation was made, although this might have been done and a large saving of fuel effected. The pig iron used was Dalmellington brand A, a strong iron, soft and very tough. The quantity of peat fuel consumed was nearly double the weight of coal used on ordinary occasions. In my opinion, and with the present furnaces, by mixing peat with Pictou coal we could produce iron equal to the best charcoal iron, and at no more expense than the present cost of our iron, the quality of which is equal to the best refined English iron.*

Peat charcoal, especially that made from compressed peat, appears to be much preferable to the uncarbonized article in the smelting or refining of iron. Charcoal prepared from common air-dried peat is subject to disadvantages which prevent its general application to ordinary metallurgical purposes. Being light and friable it soon falls to pieces, and is thereby rendered worthless as a fuel. In smelting furnaces where it has to sustain the weight of the charges above it, this charcoal is found to crumble and choke the blast, and it can therefore be employed only under steam boilers, in forge fires, or in reverberatory furnaces.† By coking compressed peat however the resulting charcoal may attain a density of 1.040, which is far superior to that of wood charcoal and even equal to that of the best coke made from coal. In its calorific effects this charcoal is about the same as coal coke, and little inferior to wood charcoal.‡ One advantage over coke which peat charcoal possesses in common with wood charcoal is its freedom from sulphur,§ which is frequently present in the former in proportions as high as one or even two per cent., to the great detriment of the iron produced.** Tests made in England as well as elsewhere, show that peat charcoal may be made to serve a very important use in the puddling and refining of iron, and in southeast Germany and Russia it is extensively used in metallurgical operations.

The charcoal made from peat at Horwich, England, is extremely dense and pure. Its heating and resisting powers have been amply and severely tested, and with the most satisfactory results. At the Horwich works pig-iron has been readily melted in a cupola. About 80 tons of superior iron have been made with it in a small blast furnace, measuring only six feet in the boshes, and about 26 feet high. The ore smelted was partly red hematite and partly Staffordshire; and the quantity of charcoal consumed was 1 ton 11 cwt. to the ton of iron made; but in a larger and better constructed furnace considerably less charcoal will be required. It has also been tried in puddling and air furnaces, with equally good results, considerably improving the quality of the iron melted. For this purpose the fuel was only partially charred, in order not to deprive it of its flame, which is considerably longer than that from coal. Some of the pig-iron made at Horwich was then converted into bars, which were afterwards bent completely double when cold, without exhibiting a single flaw. . . .

Mr. Fothergill, when reporting on experiments with peat-charcoal iron conducted under his supervision at Messrs. Platt's iron works at Oldham, says: "I have no hesitation in stating that the experiments were a great success. The directors can judge of the tenacity and quality of the iron from the severe character of the test to which it has been submitted, namely, having been completely doubled over when cold without exhibiting a single crack." . . .

Professor Emmons, geologist to the State of New York, concludes some remarks on the subject of peat as follows: "I shall state only one more application of this material, viz., as a substitute for charcoal in the reduction of iron. The coal which is formed from it is equal to any coal, hence it may become of great importance in those sections of country where fuel is scarce, or as it furnishes a resource in this important business when the ordinary means are expended.††

Sterry Hunt, in the report of the Geological Survey of Canada, 1866, refers to the trials made a short time before with peat for puddling iron in Montreal, which he states gave satisfactory results, "as might have been expected from the success which has so long attended its use for such purposes in Europe." Dr. Hunt further makes mention

* Facts about Peat, pp. 194-5.
† Elements of Metallurgy, p. 612.
‡ Ure's Dictionary of Arts, Manufactures and Mines, vol. III. p. 522.
§ Facts about Peat, p. 190, etc.
** Materials of Engineering, Part I. p. 180.
†† Facts about Peat, pp. 191-3.

of an ingenious application of peat to the smelting of iron by Mr. Hodges, whose method of preparing peat fuel has already been described. This application, as stated by Dr. Hunt, consists in moulding a mixture of magnetic iron-sand with pulped peat into bricks, which when dried and treated in a proper furnace, readily yield malleable iron by a single operation, the particles of ore being enveloped in a reducing matrix. This sand is found in considerable quantity on the shores of the lower St. Lawrence, and wherever it can be cheaply obtained may probably be wrought with advantage by this method.

Dr. Hunt goes on to say: "Mr. Hodges has further suggested the application of this process to the treatment of artificially pulverized magnetic and specular iron ores, which in the vicinity of the great beds of these ores, so abundant in this country, can probably be obtained at a much less cost than iron-sand, so that this process, if we may judge from the results of the first experiments, is destined to render our peat deposits very serviceable for the manufacture of iron."*

FUEL FOR REGENERATIVE GAS FURNACES.

The Siemens' regenerative gas furnace, the great invention of the brothers Siemens, which has been so extensively used in the manufacture of iron and steel, appears to have opened up a wide field for the employment of peat which it is somewhat surprising has not been more extensively availed of. The fuel employed for the production of gas for use in this furnace is usually bituminous coal, but coke, lignite, peat and even sawdust may be used for the same purpose, as whatever the fuel may be, it is not burned with the view of applying its heat directly to the contents of the furnace, but rather subjected to a process of distillation or imperfect combustion with the object of producing gases, mostly carbonic oxide (CO) and hydrogen (H). These gases are conducted to the regenerators where, streaming through a mass of loosely piled fire-bricks previously heated by the waste gases escaping from the furnace, they are raised to so high a temperature that on entering the furnace proper they immediately enter into combination with the atmospheric air which has passed through a similar regenerating chamber, and so produce an exceedingly intense heat with a great economy of fuel.

Dr. Reynolds, as the chairman of the committee of the Royal Dublin Society on the use of peat by Siemens' regenerative furnace reports very favorably of its use in manufactures requiring intense heats. Ordinary air-dried peat containing on an average 25 per cent. of water when used in this furnace compares more favorably with coal than in any other way. The general heating power of 2¼ tons of peat is equivalent in practice to that of 1 ton of average coal, but in the Siemens furnace its value appears equivalent to not less than 65 per cent. of that of Staffordshire coal.† When fuel containing water is used for the production of gas in this furnace, the resulting moisture must be got rid of, as its presence is very objectionable. To accomplish this the gas as it comes from the producers is passed through cooling tubes which condense all the moisture present. This provision enables fuels containing very large proportions of water to be utilized; indeed Dr. Hunt informs us that by the aid of the Lundin furnace, combined with the regenerators of Siemens, steel has been produced using only pine sawdust as fuel. He adds: "When such results can be obtained with sawdust or ordinary peat, the want of mineral coal need no longer be an obstacle to the development of the metallurgical industry of this country."‡

In the natural gas fields of the United States that fuel has proven itself exceedingly economical and valuable when applied to a great variety of industrial uses, such as the manufactures of steel, glass, etc., while for domestic purposes, both of heating and lighting, it is highly prized by the inhabitants of those districts.

The use of gaseous fuels presents many advantages, which are summarized by Thurston as follows: (1) Convenience of management of temperature, (2) freedom from liability to injure material with which the products of combustion may come in contact,

* Geological Survey of Canada, 1866, p. 291.

† Ure's Dictionary of Arts, Manufactures and Mines, vol. III p 526.

‡ Geological Survey of Canada, 1868, p. 298.

and consequently also allowing the use of fuel of inferior quality as a source of the gas, (3) the facility with which thorough combustion may be secured, (4) the readiness with which the flame may be given either an oxidizing or a deoxidizing character, and (5) in many cases economy in expense of operation. The disadvantages are, (1) danger of explosions when carelessly or unskilfully handled, and (2) expense of plant.*

The advantages of natural gas, which include all those given above, so far outweigh its disadvantages, as to cause those who have once used it to be very unwilling to give it up. This course however appears likely to be forced upon a great many consumers in the gas fields of the United States, where the flow of that useful mineral is steadily decreasing and threatens in time to cease entirely.

Under these circumstances it is probable that other sources of a gas which may take the place of the natural article will be sought for. As has been shown above, gas answering admirably for use in the Siemens' regenerative furnace can be obtained from peat, while it is also well known that gas of high illuminating power can be distilled from the same article in a well-dried state.

On Dartmoor, England, the peat is cut by convicts working in gangs, and being dried it is carefully stored away in one of the old prisons. From this peat by a most simple process gas is made with which the prisons at Princetown are lighted. The illuminating power of this gas is very high. The charcoal left after the separation of the gas is used in the same establishment for fuel and for sanitary purposes, and the ashes eventually go to improve the cultivated land in that bleak region.†

Professor Emmons in his report on the Geology of New York, says: Peat furnishes an abundance of carburetted hydrogen, and hence may be employed for producing gas-light. Dr. Lewis Feuchtwanger, of New York, has made known to the American public the experiments of Merle, a director of a gas-light company in France. The advantages of peat for the production of gas are as follows: (1) It is less expensive than gas from coal, oil or resin, (2) the product is nearly as much as from those substances, (3) the gas is quite harmless and inoffensive, and has in respect to healthfulness great advantages over some of the other kinds of gas. After it has been used for gas the coke may be employed as fuel, and is equal to any charcoal.

Other experimenters return its yield of gas as considerably in excess of that of bituminous coal, and equal to that of the best cannel coals. The chief impurity in peat gas is carbonic acid, which is present in considerable quantity, especially if the peat from which it is manufactured is insufficiently dried.

It is possible that the electric light will in time supersede gas altogether for lighting purposes, and so render the use of peat for the production of illuminating gas unnecessary, but should the threatened failure of natural gas in Ohio, Pennsylvania and elsewhere actually take place the users of that article for heating and industrial purposes may with advantage to themselves investigate the possibility of utilizing peat as the source of an efficient substitute.

A beginning has been made in the use of natural gas in our own province, and when we have consumed or wasted the store which provident nature has laid up for our benefit, or exported it to another country, we shall be in a position to benefit by the researches and experience of the people of the gas-producing states to the south of us.

OTHER USES OF PEAT.

There may be procured from the destructive distillation of peat a variety of chemical products, of greater or less value. These include sulphate of ammonia, acetate of lime, pyroxylic spirit (wood alcohol), naphtha, heavy and fixed oils, and paraffine. Various attempts, notably in Ireland and on Dartmoor, England, have been made to obtain these substances on a commercial scale, but such operations appear to have usually resulted in loss.

Peat charcoal is highly esteemed as a disinfectant and deodorizer, and it is also used as a filtering medium for foul water and sewage. The raw peat itself is applied to cer-

* The Materials of Engineering, Part I., p. 190.
† Ure's Dictionary of Arts, Manufactures and Mines, vol. III. p. 523.

tain soils as a fertilizer with good effect, supplying a considerable proportion of nitrogen and vegetable humus. The ashes of peat and peat charcoal are also valuable manures.

The upper portions of peat bogs consisting of growing and undecayed mosses are utilized in Germany in the production of "moss litter," which is simply such mosses teased and opened out and freed from dust and other impurities It is baled like hay and shipped in quantities to London, England, and other large cities where it is used as bedding for horses. It has the property of absorbing as much as twenty-five times its own weight of moisture, and when it has fully served its purpose in the stable is in a condition to be used as a very valuable fertilizer.

GENERAL CONCLUSIONS.

The fuel question is one of such importance, and touches the general welfare so closely, that no apology will be required from the Bureau should it recur to the subject on a future occasion. It would be desirable to submit further information as to the extent to which the use of peat obtains in other countries at the present time, the forms in which and purposes for which it is employed, and the modes of its manufacture which have stood the test of time and experience. Here in Ontario the whole question is in its infancy; peat fuel is as yet a thing practically unknown, and it is the part of wisdom to avail ourselves of the experience of other nations in order that we may be warned by their failures and may profit by their successes.

Meantime, the facts which have been presented in the foregoing pages may warrant the following conclusions:

1. The peat-bogs of older, and more especially of newer Ontario, are of great extent in the aggregate, and should an economical process be devised for the manufacture of a good fuel therefrom their future importance can hardly be over-estimated.

2. Air-dried peat, from its bulkiness and the considerable percentage of water it usually retains, is not likely to come into general use in Ontario so long as wood and coal do not rise materially above their present price.

3. The tendency of both wood and coal to rise in price will undoubtedly have the effect of turning attention to other kinds of fuel, of which peat is one of the most available.

4. A first-class article may be produced from the crude material by various methods of compression or condensation, particularly when coupled with the application of artificial heat, but it has hitherto been at too great a cost; and as a source of gaseous fuel for use in manufacturing centres peat offers considerable advantages.

5. For domestic use, for generating steam under stationary boilers and for heating purposes generally, there is every reason for believing that a good peat fuel would answer admirably; while for railway or steamboat use, or wherever space is a prime consideration, it would seem that peat must take second rank to coal.

6. It is an object of national importance to obtain, if possible, a home fuel which will render us independent of a foreign country for one of the necessaries of life; and this aspect of the question becomes greatly intensified in view of the oppressive combination now formed in the United States to control the output and price of coal.

7. The progress which has been made, and is now being made, in the effort to manufacture a first-class fuel from peat which shall combine efficiency with economy affords good grounds for hoping that the day is not far distant when such a fuel will be presented to the people of Ontario. But the history of industrial development shows that the perfecting of processes is often slow and attended with many disappointments; and before the problem of peat fuel has been satisfactorily solved many improvements in methods may yet be found necessary.

T. W. G.

TECHNICAL INSTRUCTION.

The value of technical education in all departments of manufacturing or productive industry has long been recognized, and in the keen competition engendered by the conditions of modern life he who is best equipped with a knowledge of the principles and details of his business will, other things being equal, bear the palm.

It was once the prevailing idea that actual every-day work was the only kind of education worth anything in the way of imparting a genuine knowledge of any business. It is doubtless true that experience gained in this way is the best education, but there are many callings in which it is in the highest degree advantageous to the student to begin his career by laying down a foundation of technical instruction, leaving the practical work of his business to follow in its proper order.

Particularly is this the case with the man who intends to follow mining. In most countries where that industry has got beyond the experimental stage, the demand for skilled and educated labor to conduct and superintend the winning and refining of ores has led to the establishment of schools of one kind or other where instruction in the various branches of mining and metallurgy may be obtained.

MINING SCHOOLS IN FOREIGN COUNTRIES.

In Germany, France, England and the United States many institutions have been founded for the purpose of training miners and mining engineers, and of teaching the most approved and scientific methods of treating ores and minerals.

THE FREIBERG SCHOOL.

Perhaps the most famous school of mines in the world is the Bergakademie of Freiberg, Saxony, which celebrated its 125th anniversary last summer. It has the advantage of being situated in the heart of an important mining district where lead and silver ores are raised and treated in large quantities, and where the students are permitted to witness in the large smelting works adjoining the town the actual processes used in refining the ore. The staff consists of twelve professors with five assistant professors and docents, and instruction is given in mineralogy, geology, metallurgy, mining engineering, and the whole range of subjects bearing directly and indirectly upon mining. The laboratories are well equipped and the mineralogical collections complete. Liberal terms of admission are accorded to foreign students, and of an average attendance of 149 since 1878 there were 58 from foreign countries. A few of these were from Canada, and many from the United States, in which country a number of the most successful mining superintendents and engineers are graduates of the Freiberg school.

SCHOOLS IN THE UNITED STATES.

In the United States the Columbia School of Mines, the Massachusetts Institute of Technology, the Houghton School of Mines, together with the mining and metallurgical departments of a number of Universities and other institutions supply the demand existing there for skilled and educated labor.

The Columbia School of Mines is one of the best known institutions of its class in the United States, its main object being to train students to become professors in colleges as well as consulting, mining and civil engineers. A complete course extends over four years, and about 300 students attend annually.

The Michigan Mining School at Houghton, in the northern peninsula of Michigan, established in 1886, is modelled on a somewhat different type, the end at which its efforts are aimed being to turn out practical assayers, surveyors and draughtsmen, and to give instruction to the sons of miners and miners themselves which may fit them, with the experience gained in actual work, to take the position of mining superintendents. Being situated in a mining district every opportunity, as at Freiberg, is afforded the students to familiarise themselves with mining processes as actually carried on.

PRACTICAL METHODS IN NEW ZEALAND.

One of the most practical methods of education in connection with mining is that which has been adopted by the colony of New Zealand. Schools of mines are formed on the various gold and coal fields in which miners and others may receive instruction regarding the minerals in which they are interested. For the convenience of those engaged in carrying on their ordinary work during the day night classes are formed, and these constitute indeed an essential element in the scheme.

The course of study does not aim at being exhaustive, but rather at giving the miners an elementary but practical acquaintance with those branches of science most intimately related to minerals and mining matters, and at teaching them methods of determining minerals, how to ascertain the percentage of metals contained in ores, the best way of treating refractory ores, etc.

The system was begun in 1884, and in his report for the year 1891 the Minister of Mines thus speaks of the results obtained:

Since the establishment of schools of mines throughout the colony the miners have far more knowledge about the mineral ores that are met with and the percentage of metals they contain. This will tend to cause mining to be conducted on a more intelligent basis, and cannot fail to produce a beneficial effect on the industry. The inauguration of this system of technical education is due to Professor Black, wh o by his energy and perseverance caused the miners in every district to take an interest in the subject, and by practical demonstration showed them that in order to follow their avocation with success it was necessary to be able to distinguish the mineral ores met with, and also their value. It must however be admitted that any system of peripatetic teaching can only have the effect of temporarily arresting the attention of those wishing to acquire knowledge on this subject, but it cannot be denied that it has a great impetus in inducing men to attend these schools for a considerable time in order to get a sound practical training. The greatest success attending this system of technical education has been at the Thames, where the teaching is carried on continuously by holding day classes for those who can attend, and night classes which the workmen from the mines and others avail themselves of. The result of teaching at this school last year has been very encouraging, the average attendance being forty-five regular students and fifty-one pupils from the public schools attending Saturday lectures. It is gratifying to find that many of the miners attending the night classes are taught drawing, mathematics, surveying, mining, geology, chemistry and assaying. The large attendance at this school and the great interest taken in the work may be partly attributed to the mines at the Thames being concentrated within a small radius, which admits of the workmen attending at night, and also to the large number of mineral lodes in this part of the colony containing complex and refractory ores requiring different methods of treatment from those formerly adopted to make them pay for working. . . . The expenditure on the schools last year amounted to £1,392, and the total expenditure since their inauguration six years ago has been £12,986, of which amount £3,000 was given towards the School of Mines in connection with the University of Otago.*

TECHNICAL SCHOOLS IN CANADA.

The comparatively backward state of the mining industry of Ontario must be attributed largely to other causes than the lack of skilled superintendence of mining operations, yet it is a fact that many ventures have come to failure through want of prudent and intelligent management. The geological formations of our province are so peculiar, and the modes in which minerals occur so different from those of other countries, that even experienced miners when first set down among our Huronian rocks find the knowledge gained in other lands of little avail and have often to confess themselves at a loss. And even when the search for ore in paying quantities has been rewarded with success, the refiner is sometimes confronted with pecularities in the nature of the ore which call for all available skill and intelligence. The sulphurous magnetic iron ore of some parts of

*Report of the Minister of Mines on the Mining Industry of New Zealand, 1891, pp. 13-14.

eastern Ontario, the unique pyritous copper-nickel ores of the Sudbury region, the auriferous mispickel of the Marmora district and other ores present problems of treatment which may well engage the attention both of students and professors at any school of mines, and whose complete and economical solution would confer important benefits on the mining industries of Ontario.

As yet technical instruction in mining and kindred subjects has not had much more than a beginning in Ontario. Most of the actual mining hitherto done in this province has been carried on under the direction of American or English superintendents, but it is gratifying to know that existing institutions of learning are recognising the importance of providing the youth of our province interested in mining with an opportunity of receiving such instruction as will fit them to take an intelligent part in the development of the mineral resources of their native province. The following information respecting the facilities afforded at the School of Practical Science, Toronto, Queen's University, Kingston, and McGill University, Montreal (which though in a sister province is conveniently situated for students from eastern Ontario) is furnished by the authorities of those institutions.

School of Practical Science, Toronto.

The Mining Engineering department of the School of Practical Science has been included up to the present in the department of Civil Engineering, an option of suitable subjects being allowed in the third year.

This department is intended to afford the necessary preliminary preparation to students intending to become civil engineers (including under this term mining engineers).

Students who wish to devote themselves to the practice of mining engineering are allowed to take the work specially mentioned under this head in the third year, and to omit the work in experimental physics.

They are advised however to take, if possible, the regular course in civil engineering and the special work subsequently as special students.

The subjects for the first year are as follows: Mathematics, mechanics, drawing, surveying, chemistry; for the second year, mathematics, physics, experimental physics, drawing, engineering and surveying, chemistry, mineralogy and geology; and for the third year, experimental physics, drawing, engineering and surveying, applied chemistry, mineralogy and geology.

The appliances for the equipment of the department consist at present of (1) collections of minerals and models of crystals, of ores, of rocks, and of specimens to illustrate structural geology; (2) of blowpipe tables with the necessary tools; (3) of gas and charcoal furnaces, balances and other requirements for assaying. It is intended during the present year to add largely to the outfit above mentioned, and to provide collections, models and apparatus to illustrate the subjects of ore dressing and metallurgy.

The staff consists of a professor of Metallurgy and Assaying in addition to the Civil Engineering staff. There are now 67 graduates and 74 students in the combined departments of civil and mining engineering, the statistics of the two not having been kept separate.

Diplomas are given on completion of the three years' course, and provision is made for a fourth year's post graduate work.

Students of the Mining department of the School of Practical Science have access to all the courses of lectures and laboratory work in the University of Toronto in addition to the work of the school itself.

The fees for instruction in any of the departments are for the first year, $34; the second year, $44, and the third year, $54.

Diplomas are granted in civil engineering (including mining engineering), and the degree of Civil Engineer of the University of Toronto is open to candidates holding the diploma in civil engineering of the School of Practical Science who have spent three years in the actual practice of the profession of civil engineer. Candidates for this degree are required to prepare for the approval of the senate of the University an original essay on some engineering subject, accompanied with detailed explanations, drawings, specifications and estimates, and may also be examined on the subject of the essay as well as on the work or works on which they have been engaged.

The staff of the school is as follows :

J. Galbraith, M.A., M. Inst. C. E., Principal and Professor of Engineering.
A. P. Coleman, M.A., Ph.D., Professor of Metallurgy and Assaying.
W. H. Ellis, M.A., M.B., Professor of Applied Chemistry.
L. B. Stewart, P.L.S., D.T.S., Lecturer in Surveying (Secretary).
C. H. C. Wright, Grad. S.P.S., Lecturer in Architecture.
T. R. Rosebrugh, B.A., Grad. S.P.S., Lecturer in Sanitary Engineering.

QUEEN'S UNIVERSITY, KINGSTON.

Mineralogy, geology and chemistry, the subjects most nearly related to mining and metallurgy, have for many years received a good deal of attention at Queen's University.

When the present University building was erected in 1877-78 good laboratory, museum and lecture room accommodations were provided for these subjects. Since 1883 the development in the direction of sound practical work in chemistry, mineralogy and geology has been steady. Special attention has been given to assaying methods, to identification of minerals at sight and by simple tests, and to the study of mineral deposits in relation to geological formations.

The geology and mineralogy of Ontario have occupied a prominent place in the curriculum. The excellence of the work done in these directions is attested by the success of the science masters who have taken these courses at Queen's University, and by the fact that several of the graduates in chemistry, mineralogy and geology have, without any further special training been appointed to responsible positions as assayers and analysts. In estimating this fact it is to be remembered that the scientific work was done as part of a broad honor course in arts.

So far no special course has been marked out for those wishing to pursue merely technical studies.

This year (1891) the advance in the direction of mining and metallurgy has been rapid. The John Carruthers science hall has been completed and furnished, and now affords facilities rarely found even in more pretentious Universities than Queen's. There has been added to the staff, in the person of Mr. William Nicol, M.A., a man trained at Freiberg Academy, the best school of mines in the world; and the imperative demand for special courses for prospectors and others can now be more easily met.

The course of study comprises Latin, Moderns (or Greek), English, philosophy, mathematics, physics, chemistry, mineralogy, botany, zoology and geology. These are the subjects of course 12 for the degree of Master of Arts. Chemistry, mineralogy and geology are carried through the four (or five) years necessary to complete this course.

Chemistry of the first year embraces elementary chemistry and laboratory practice; for the second year advanced chemistry, simple qualitative analysis, blowpiping and organic chemistry; for the third year general chemistry, history of chemistry, organic chemistry, metallurgy, complex qualitative analysis, quantitative analysis and metallurgy; and for the fourth year general chemistry, history of chemistry, chemical technology, quantitative analysis, furnace and blowpipe assaying and metallurgy. Graduates frequently spend a fifth year in special work.

Mineralogy in the second year takes in elements of mineralogy, including general study of the properties of minerals, and the elements of crystallography; third year, systematic mineralogy, including crystallography, the classification of minerals, and the use of the blowpipe and other means of identifying minerals; fourth year, descriptive and and determinative mineralogy, including detailed study of the principal mineral species, and systematic testing to determine species, analysis of minerals and economic minerals of Ontario.

Geology covers in the second year lithological and dynamical geology, geological history of the globe, with special reference to the formations found in Canada; third year, physical geography, geology and palæontology, and examination and determination of minerals, rocks and fossils; fourth year, a special study of Canadian geology, examination of rocks, fossils, etc.

The building devoted to chemistry and mineralogy has a large lecture room, three class rooms, four laboratories, two balance rooms, a furnace assay room, a blowpiping room, a machinery room, and store rooms for the lecture room and for each of the laboratories. There are also the usual rooms for the professors, and a comfortable library and reading room.

The lecture room and laboratories are particularly well suited for their purposes. The building is not yet completely furnished, but the lecture room and two of the laboratories offer every facility for good work. The apparatus for lecture, class and laboratory work has been carefully selected, with a view to its being immediately useful. A large quantity of good material was brought from Freiberg by Mr. Nicol. This has been added to by subsequent orders. The collection of minerals is good, and is being constantly added to by graduates and other friends. Prospectors are availing themselves of the facilities here afforded, and are adding to the mineral collection.

Geology is taught in the main University building, where there is a lecture room and an excellent working museum for that purpose.

The staff for physics, chemistry, mineralogy, geology and mathematics consists of four professors, one lecturer, one assistant, and a lecture and laboratory assistant.

About twenty students annually complete the first two years. Of these about five finish the course.

The complete course in chemistry and mineralogy costs $24 for class fees and $40 for laboratory fees. Each year a deposit of $5 is made by each student at the beginning of the session. After breakages and fines are deducted, the balance of this is returned at the close of the session. The course in geology costs $12 for class fees.

At the close of the session in April, practical examinations are held in each subject.

The course outlined is for the degree of Master of Arts. For the Bachelor of Arts the subjects are not usually carried farther than the second year. No special degree in science has so far been instituted, but the necessity for special courses and degrees has become so pressing that steps are being taken towards establishing them.

The wants of prospectors are being met in a way which is so far satisfactory. Free access is given to the standard specimens of minerals for purposes of comparison, etc. The members of the staff always spare enough of their well occupied time to examine specimens, and to give information and direction. They also, so far as occasion permits, show simple ways of identifying minerals. Hardly a day passes but advantage is taken of these opportunities. In this part of Canada the interest in mines and minerals is becoming very lively.

The following gentlemen compose the staff referred to in the above memorandum:

Nathan F. Dupuis, M.A., F.B.S., Edin., Professor of Mathematics; N. R. Carmichael, M.A., Assistant.
D. H. Marshall, M.A., F.R.S.E., Professor of Physics.
James Fowler, M.A., Professor of Geology.
W. L. Goodwin, D.Sc., Professor of Chemistry.
William Nicol, M.A., Lecturer in Mineralogy and Metallurgy.
Alfred Deane, Laboratory Assistant.

McGill University, Montreal.

The instruction in the faculty of applied science in McGill University is designed to afford a complete preliminary training of a practical as well as theoretical nature to such students as are preparing to enter any of the various branches of the professions of engineering and surveying, or are destined to be engaged in assaying, practical chemistry, and the higher forms of manufacturing art. Five distinct departments of study are established, viz.: (1) Civil engineering and surveying; (2) Electrical engineering; (3) Mechanical engineering; (4) Mining engineering; and (5) Practical chemistry. The course in each of these extends over four years, and is specially adapted to the prospective pursuits of the student.

In the department of mining engineering the work includes such portions of the civil and mechanical engineering course as are essential to the education of a mining engineer. A thorough training is provided for in geology and mineralogy, and in order to give a practical character to the work frequent geological excursions are made and numerous minerals and rocks are determined and analyzed in the laboratory. In the lectures special attention is devoted to the economic aspects of geology.

Work in the chemical laboratory is begun in the first year and continued throughout the course, mainly consisting in the fourth year of assaying by the dry, wet and electrolytic methods.

In the third year a special course of lectures on mining is given. It is illustrated by diagrams and models, and includes the discussion of blasting, quarrying, hydraulic mining, boring; special methods of exploitation employed in the working of metalliferous deposits and coal seams; ventilation of mines, pumping, etc.

In the fourth year the lectures on metallurgy are illustrated by diagrams, models and collections of ores and metallurgical products.

The subjects of instruction in the mining engineering course are as follows:

In the first year, chemistry, English, French or German, mathematics, freehand drawing, geometrical drawing, shopwork.

In the second year, chemistry, English, French or German, mathematics, physics, surveying, zoology, drawing, physical laboratory and shopwork.

In the third year, chemistry, determinative mineralogy, geology and mineralogy, mathematics, mechanism, mining, physics, theory of structures, drawing, physical laboratory.

In the fourth year, assaying, geology and mineralogy, hydraulics, mathematics, metallurgy, applied mechanics, laboratory and museum work.

As yet there is no special mining laboratory in which practical operations in ore-dressing, etc., can be carried on, but it is hoped that this deficiency will be supplied in the near future.

The chemical laboratories are three in number, one for students of the first, one for the second and third years, in which it has been found necessary to carry on both qualitative and quantitative work, and one which is reserved for students of the fourth year and for special students who may wish to carry on original investigations. There is besides a special room in the basement which is fitted up for fire assaying.

An examination for the degree of Bachelor of Applied Science is held at the end of the fourth year, in all the subjects of that year.

The degree of Master of Engineering is conferred upon candidates who pass the required examinations. They must be Bachelors of Applied Science of at least three years' standing, and must produce satisfactory certificates of having been engaged during that time upon *bona fide* work in either the civil, electrical, mechanical or mining branch of engineering. They must pass with credit an examination extending over the general theory and practice of engineering, in which papers will be set having special reference to that particular branch upon which they have been engaged during the three preceding years.

The fees for all students, excepting such as entered previous to September, 1890, are $100 per annum, this amount including matriculation, tuition, gymnasium, library and graduation fees, and also the use of the machinery and other apparatus, as well as the cost of material in the workshops and engineering laboratories.

Of 126 students at present in the Faculty of Applied Science about 20 are taking the mining course or preparing for it.

The following gentlemen compose the staff of the School of Applied Science:

Sir William Dawson, C.M.G,, LL.D., F.R.S., Principal.

Henry T. Bovoy, M.A., M. Inst. C.E., F.R.S.C., Dean of the Faculty. and Professor of Civil Engineering and Applied Mechanics.

B. J. Harrington. B.A. Ph.D., F.R.S.C., Greenshields-Professor of Chemistry and Mineralogy.

C. H. McLeod, Ma.E. Professor of Surveying and Geodesy, and Superintendent of the Observatory.

G. H. Chandler, M.A., Professor of Practical Mathematics.

Charles A. Carus-Wilson, M.A., A.M. Inst. C.E., A. Inst. E.E., W. C. McDonald-Professor of Electrical Engineering..

John T. Nicholson, B. Sc., Thomas Workman-Professor of Mechanical Engineering.

W. A Carlyle, B.A.Sc., Lecturer in Mining and Metallurgy.

There are besides five Associate Professors and six Associate Lecturers.

T.W.G.

ALEXANDER MURRAY, F.G.S., F.R.S.C., C.M.G.

By Robert Bell, B.A.Sc., M.D., LL.D.

The subject of this biographical sketch was assistant provincial geologist of Canada (as it was before Confederation) from the commencement of the Geological Survey of the united provinces in 1843 till 1864, and afterwards director of the corresponding Survey of the island of Newfoundland from 1864 to 1883.

It was my good fortune to be tolerably well acquainted with Mr. Murray's history both in Canada and Newfoundland—otherwise I would not have attempted the present task. Not only was I associated with him for seven years at the headquarters of the Geological Survey in Montreal, but I accompanied him one year, as assistant, to his favorite haunts among the Huronian rocks of lake Superior and Huron, which, it is well known, he was the first to investigate; and, as regards Newfoundland, I have had opportunities of going over his work in different parts of the island and afterwards of discussing its geology with him during several weeks' residence at St. John's in the winter of 1868-69.

Mr. Murray was a friend of my late father, the Rev. Andrew Bell, who had given much attention to the geology of Upper Canada and had mapped the distribution of the rocks in the lake peninsula, according to the divisions which had been made by the geologists of the state of New York, before the commencement of the government Geological Survey of Canada. It was when on a visit to my father, in 1850, who was then living in Dundas, that I first saw Mr. Murray. Although only a boy at that time, I have a distinct recollection of him as a bright, genial and pleasant looking man. On this occasion my older brothers assisted him to measure the strata in the cliffs around the head of lake Ontario, among which was the "Sydenham Road Section," published in his report for that year, and which has been so often used for reference in regard to the rocks of the surrounding country. During this visit my father, who was familar with the country northward to Georgian bay, furnished Mr. Murray with information which enabled him to lay out his time in examining it to the best advantage—all of which he acknowledged in his report to the government. I renewed Mr. Murray's acquaintance in 1857, when I joined the staff of the Geological Survey, and have followed his labors to the close of his life.

Murray was born at Dollerie House, Crieff, in Perthshire, Scotland, on the 2nd of June, 1810, and died in the same town on the 16th of December, 1884, in his 75th year. He was the second son of Anthony Murray, Esq., of Dollerie House, Anthony being the eldest, and William, who was killed in the Indian mutiny in 1857, being the third son. They belonged to the family of the Murrays of Ochtertyre, referred to by the poet Burns in his song "Blithe was She," and were cousins of Sir Patrick Murray, the present proprietor of the estate of his forefathers.

Murray was educated at the Royal Naval College, Portsmouth, entered the navy in 1824 as midshipman, passed for lieutenant in 1833, and retired in 1834. Although he did not remain long in the service, the atmosphere of a man-of-war of those days clung to him throughout life. He was fond of nautical terms and illustrations and the strong language of naval officers of the olden time. On account of these peculiarities, when he removed to the seafaring colony of Newfoundland he was christened Captain Murray by the people, and among them was always known by this honorary title.

During his career as a naval officer he had an opportunity of seeing some active service, and was present in the "Philomel" at Navarino on the 20th of October, 1827, where he was wounded, and received a medal for the part he took in that engagement. At the time of the rebellion of 1837-38 in Upper Canada he volunteered his services to the government and was on duty for a short period.

The salary attached to the position of assistant provincial geologist does not appear to have been sufficient to secure his services for the entire year, and Murray was allowed to devote part of his time to agriculture. He purchased land in the township of Blandford, not far from Woodstock, one of the best districts in the upper province, and continued to hold his farm all the time he was connected with the Geological Survey of Canada. For the first few years he kept the management of it in his own hands, his wife looking after matters while he was absent on geological field work a part of each summer, or at the office of the Survey in Montreal a portion of each winter. He found however that in his case "gentleman farming" would not pay, and so he rented this property and took a house in Woodstock. Here his wife died in the winter of 1862-3 while her husband was temporarily residing at the headquarters of the Survey in Montreal.

Murray was a man of medium height, rather fair complexioned, with blue eyes and flaxen beard. He was well built and had powerful muscles until he was overtaken by a paralytic stroke previous to 1856, after which he refrained from performing the feats of strength in which he had formerly delighted.

He was noted as an ardent sportsman and lover of dogs, guns and fishing rods. But he confined himself to the lines he could follow in a wild country, and neglected most of the sports of civilized regions, such as horseracing, cricket, etc. But when Murray was a young man, before public sentiment became so refined as it is at the present day, he did not deny having a weakness for the "manly art" and some other sports which are now tabooed in "society."

The animals he killed during his surveys and explorations in the backwoods always formed a welcome addition to the diet of salt pork, and often it constituted the only food in camp. He was an excellent shot with both rifle and gun, and many a bear and deer fell under his aim, to say nothing of the multitudes of ducks, grouse, snipe, woodcock and other wild fowl. He had a great fondness for fly fishing, which he considered "the grandest sport in the world," and he would go into raptures over the capture of an extra big trout.

A cold bath every morning was regarded by Murray as more essential than his prayers, and no matter how inclement the weather might be, or how inconveniently his tent might happen to be pitched for getting at the water, he would never allow the cold, rain or wind, or such obstacles as a marsh, a jam of driftwood or the tangled brush, to prevent him reaching deep water and enjoying his "dip." Late in the autumn, after the snow had whitened the ground and the ice was forming around the shores, he still continued the practice with unabated rigor. Cleanliness was a sort of hobby with him, and he had a very poor opinion of anyone who did not "tub" with reasonable regularity. When on an exploratory "traverse" in the woods, if a river or a narrow lake lay across his course, he would not hesitate to plunge in and swim to the other side rather than lose time in making a raft, as most explorers do under such circumstances.

Socially, Mr. Murray was always in great demand during his sojourn both in Canada and Newfoundland, although he was not very fond of "going out" in society. When he and Sir William Logan were present in any social assembly they always formed the centre of attraction and charmed the company with their entertaining stories, jokes, or general conversation, and occasionally by a song. These were cheerful days in the Survey offices in Montreal. Every now and then the pleasant voice of Logan or Murray might be heard echoing through the rooms, and the dull quiet work over maps, rocks and fossils, was relieved by many a hearty laugh. A visit to the museum was a treat to strangers if they should be fortunate enough to be escorted through it by either of these men.

Murray's voice was seldom heard in public, yet he was a good speaker when occasion required. His speech at the Toronto banquet to Logan after his return, newly knighted, from the Paris Exhibition of 1855, was the best of the evening, and was regarded as a very fine effort. On 15th February, 1869, I had the pleasure of listening to his popular lecture on "The Economic Value of a Geological Survey," delivered in the Athenæum Hall in St. John's before a large and intelligent audience, which included the governor of the colony and most of the members of both branches of the legislature. The subject matter of itself, his method of treating it and the delivery, were all excellent and called forth a very hearty vote of thanks.

Mr. Murray having been the first to survey and map the river now known as the Petewawe, gave it this name after an old Indian friend of his whose principal camping place was at the mouth of the river, and who was well known to all frequenters of old Fort William, which stood on the opposite side of the Ottawa.

Mount Logan, in the Shick Shock range in Gaspé, was so called at the suggestion of Mr. Murray, and he also gave the names they now bear to many of the geographical features in the country north of lake Huron, which he was the first to lay down correctly on the map He was an excellent surveyor and astronomical observer, as well as a neat and skilful draughtsman, as witnessed by the numerous large and well executed maps of his in the office of the Survey. Most of his surveys were plotted with his own hands, in the field. The numerous latitudes which he took have been found of great service in fixing positions in many parts of old Canada and Newfoundland. His surveys of lake Nipissing and the various channels of French river, made in several different years, were found sufficiently accurate for the purposes of the Ottawa Ship Canal survey, and were adopted by the engineers of that project—Shanly, Clark, Perry, Norman and Galway—who gave him credit for the use they had made of them.

In 1842 the Geological Survey of Canada was instituted by the government, on a petition of the Natural History Society of Montreal, made at the suggestion of the late Rev. Dr. Mathieson. Mr. (afterwards) Sir W. E. Logan was apppointed provincial geologist, but owing to unfulfilled business engagements in England he asked for leave of absence and spent the winter of 1842-43 in the old country. Here he appears to have first met with the subject of our sketch in the beginning of 1843, and to have engaged him as his assistant. Little is known of Murray's early studies as a geologist, but even when a midshipman he appears to have had a taste for the science, and had some practical training under Sir Henry T. De la Beche, with whom he served on the Geological Survey of Great Britain during 1841; while his nautical education had already fitted him to undertake topographical surveying. He arrived in Canada in May, 1843, and immediately commenced operations in the western province, while Logan returned from England by Halifax the same spring. On his arrival the latter proceeded to the northwestern part of Nova Scotia and measured the celebrated section of the Carboniferous rocks at the Joggins, near the head of the Bay of Fundy, which is published in detail in the Report of Progress for 1843. He then went to the eastern part of Gaspé and examined the coast in detail from Cape Rosier to Paspebiac. This was the commencement of the Geological Survey, which has since been extended to nearly all parts of the northern half of the continent.

Murray wrote little for publication besides his official reports to the governments of Canada and Newfoundland. When the Royal Society of Canada was founded by the Marquis of Lorne it was made to include Newfoundland, and Murray was appointed one of the original Fellows. In 1882 he contributed to its Transactions an interesting paper on "The Glaciation of Newfoundland." He was elected a Fellow of the Geological Society of London in 1870, and in 1878 was created a C.M.G. through the recommendation of Sir John Glover, then Governor of Newfoundland.

When Logan and Murray commenced the Geological Survey of old Canada the greater part of the areas of both provinces were uninhabited, unsurveyed and unknown. The problem before them was to ascertain the general geological structure and the geographical distribution of the rock formations, in spite of these difficulties. The region was so vast that it required some courage for two men to undertake this task. It was impossible for them to map out the rocks without making their own topographical surveys simultaneously with the geological ones. They could only do this by following the rivers and lakes through the forests and mapping them out as they went along. These surveys have subsequently proved to be wonderfully accurate, considering the difficulties under which our pioneers had to labor, and ever since they were made they have been found to be of the greatest service, even up to the present time; and, as topographical surveys alone, they have repaid many times over their small original cost.

But in addition to much of this kind of work Murray made regional geological surveys of a considerable area on the north side of the north channel of lake Huron, of the area south and west of a line from Kingston to Penetanguishene, including the lake peninsula of Upper Canada, and of the country between the St. Lawrence and Ottawa rivers as far west as a line from Kingston to Bytown. Besides assisting Logan in exploring parts of the north shore of lake Superior, Murray's own work on that lake consisted of surveys of the Kaministiquia river, Dog lake and river, Michipicoten river and Batchawana bay, and also an examination of the south shore as far west as L'Anse and Limestone mountain, with a view to correlate the rocks of the two sides.

His topographical and geological surveys in the country directly north of lake Huron embraced a greater or less portion of the course of each of the following rivers: Echo, Garden, Thessalon, Mississaga, Serpent, Blind, Spanish, Whitefish, Wahnapitae, Sturgeon and Maskinongé; also lake Wahnapitae and numerous lakes connected with the Thessalon, Mississaga, Blind and Maskinongé rivers. Between Georgian bay and the Ottawa he surveyed most of the numerous channels of the French river, the Sturgeon, Maganetawan, Muskoka, Petewawé, Bonnechere, southwest branch of the Madawaska, and the head waters of the Otonabee river and many lakes connected with them, including lake Nipissing and Muskoka lake. In Lower Canada he surveyed the Bonaventure, St. John or Douglas-town, Matane and Ste. Anne des Monts, and assisted Logan (in 1844) to measure a traverse from the St. Lawrence to Baie de Chaleur by way of the Chatte and Cascapedia rivers. During the season of 1849 he was again with Logan in making a geological survey of the region between the Chaudière river and the Temiscouta road.

The early finding of nickel ore on the north shore of lake Huron is worth referring to in connection with Mr. Murray's work and the subsequent discoveries of this metal in such abundance in the Sudbury district. In 1848 Murray examined the Wallace mine, near the mouth of Whitefish river, where the initial discovery was made and which had been opened the previous year. The ore which he brought to the laboratory of the Survey at that time was found to contain 8.26 per cent. of nickel, "but as two-fifths of the specimen consisted of earthy materials which might readily be separated by dressing, the quantity of nickel in the pure ore which this would represent would equal nearly 14 per cent." The country rocks of the Wallace mine belong to the same part of the Huronian system as those in the vicinity of Sudbury Junction, which lies on their general strike to the northeastward.

The original work that Mr. Murray performed in Newfoundland during the twenty years which he devoted to it were of more service in making the island favorably known to the outside world than anything which had previously occurred. The economic results of the Geological Survey have been very important. Before it was commenced the interior of the island was unknown, even geographically, and the great value of its mineral, timber and agricultural resources was unsuspected. The fisheries were supposed to be the only source of wealth and the interests of the mercantile class were opposed to the development of any others. At first Mr. Murray's reports, pointing out the other riches of the island, were received with incredulity, but after a time there was a reaction in the opposite direction and a mania for mining and prospecting set in. Copper was successfully mined in large quantities in several places, but many speculative enterprises failed, and blame was unreasonably cast upon the Survey. The information contained in Mr. Murray's reports in regard to the timber led to the carrying on of lumbering operations in several quarters. These reports also showed the existence of considerable areas of cultivable land around bay St. George, and in the valleys of the Humber, Exploits and Gander rivers, and more serious atttention has since been paid to the agricultural capabilities of the colony. All this has given the people new ideas and has led to great changes in the positions of classes. The affairs of the colony are no longer controlled entirely by the merchants, nor do the working men depend so exclusively as formerly upon the fisheries. Other industries are springing up and a railway is being built across the island.

As before remarked, he was created a C.M.G. in 1878. He acted as aide-de-camp to Sir John Glover, Sir Henry Maxse and Sir Frederick Carter, respectively, while these gentlemen were Governors of Newfoundland. He was highly respected by all members of the different governments under which he served, and was most kindly supported by his brother officials who reciprocated his obliging disposition and good-will.

Having while in Canada been thrown so much into contact with the aborigines, and knowing their character, he became the great friend of the Indians of Newfoundland, some of whom served him for as long as fourteen years. They are said to speak of him yet as the best hearted man that ever lived. His house was their home in St. John's, and the photographs of Murray and his family are to be seen in all their wigwams, where they are highly prized.

While living in St. John's his manner was very unobtrusive and he appeared to care little for any society but that of his wife and family. Latterly he became a member of the Church of England and appears to have manifested a simple Christain piety. He enjoyed his full pay from the Newfoundland government to the close of his life, but no pension was granted to his family, who were left ill-provided for, and would have fared badly but for the great and continued generosity of Sir Patrick Keith Murray and the present laird of Dollerie, Mr. Anthony Murray, mentioned in a previous part of this article.

REPORT OF THE INSPECTOR OF MINES.

I have the honor to submit herewith my Report on the Inspection of Mines for the year 1891.

The mining industry for the year has not made as rapid progress as may have been anticipated by many. A limited population, with a limited capital, want of enlarged experience in mining, and in some instances want of training in management of work, as well as the serious difficulty of obtaining at reasonable cost suitable and necessary appliances for carrying on the work successfully, are among the causes which have retarded its development. But the chief obstacle which the operator has met is the high tariff wall reared at our boundary line, barring him from free access to the large market which otherwise would be open for the products of the mine.

As to many of the properties and mines referred to herein, full descriptions have already been given and will be found in my Report for 1890, and in the Report of the Royal Commission on the Mineral Resources of Ontario, to which reference may be made.

GOLD.

The gold locations in the vicinity of Rat Portage have been worked to a limited extent only during the year; most of them are lying idle. But the completion of the reduction works is likely to give a new impetus to operations, and considerable quantities of ore have been taken out on two or three properties since the works were started.

The Sultana Mine.

During the latter part of the season work was actively carried on at the Sultana mine and suitable machinery introduced, the use of which has greatly aided in the rapid development of the property. A considerable quantity of free milling ore has been taken to the reduction works at Rat Portage, and so the outlook at present is encouraging.

The Crescent Mine.

The Crescent property is situated on lots 16 and 17 in the eleventh concession of Marmora. It was purchased by the Crescent Gold Mining Co. in July, 1890. The capital stock is $100,000, and the offices of the company are located at the mine and in Montreal. This mine had been extensively worked by the former owners, and from their 10-stamp mill several valuable shipments of concentrates were made. Work has been actively carried on by the present owners since November, 1890, and a considerable staff of laborers employed both in the mine and mill. Twenty-one men were at work late in December under the control of Captain John McFee of Belleville, who had charge of the work for the former owners. An incline shaft following vein matter from the surface has been sunk to the depth of 70 feet. The hanging wall is diorite and the foot wall is still covered with mineral, the vein being 50 to 60 feet in width. Several other openings have been made by drifts and stopings. The daily output is about 16 tons of ore, which is raised with a steam winch, dumped into a car and carried over the tramway a distance of 500 feet to the mill.

Three other separate veins of ore have been opened on this property on which considerable surface work has been done, and on one a shaft has been sunk to a depth of 60 feet, following the mineral nearly the entire depth.

A new mill has been built and operated since the 1st of August last, capable of treating 14 tons of ore per day of 24 hours, requiring five men to work it, three on the day and two on the night shift. Four cords of wood are consumed daily. The ore from the Blake crusher passes into self-feeding hoppers which supply the 10 stamps of Fraser and Chalmers make. The first amalgamation takes place in the battery boxes, passing through a 40-mesh screen; it then passes over two electroplated copper plates, 4 by 8 feet, and from them to the improved Frue vanners which separate most of the gangue matter from the mineral. The concentrates give an average of 80 per cent. The mill is three-quarters of a mile from Malone station on the Central Ontario Railway, and on the banks of the Moira river.

I had occasion to call the attention of the manager to an exposed abandoned pit and also to some parts of the machinery, which required fencing. The main works of the mine were in a satisfactory condition.

The Belmont Mine.

This new mine was visited in December. It is situated on lot 20 in the first concession of Belmont. It was purchased recently on option by the South African General Exploring and Mining Co. of London, England. Mr. F. R. Lingham of Belleville is the Canadian agent of the company.

The work was begun on this property by the present owners in September last with a force of 25 men, under the directions of Captain John O'Neal, who remained in charge until November. Since November Captain George Davidson has had charge of the mine. A. W. Carscallen of Marmora has the general management.

The Carscallen shaft, which is nearly vertical, has been sunk to the depth of 75 feet, following the ore from the surface to the bottom. This shaft is 10 by 10 feet, and follows a well-defined hanging wall of talcose slate, and is cribbed from the surface to the solid formation.

A second shaft, distant 600 feet from the former, known as the O'Neal, has been sunk to the depth of 24 feet through a similar class of rock and ore. The vein matter at the surface of this opening measures 52 feet in width. A third shaft, distant 500 feet east from the Carscallen, and called the Strickland, has been sunk to a depth of 32 feet.

In these shafts the vein matter contains a small percentage of sulphurets of iron and carries gold varying from $6 to $600 per ton as shown by numerous assays. The mill tests of the surface ore have determined its value to be $12 per ton. About 1,000 tons of ore have been taken out, and two car loads of the ore have been shipped to London, England, for treatment as a test. A gin is used for hoisting ore and the water which accumulates in the sump, but it is to be displaced by a steam hoist and pump for that purpose at the beginning of the new year.

This mine is located eight miles in a northerly direction from the village of Marmora, upon a public road and within half a mile of the terminus of the new railway now being constructed by the Belmont Bessemer Ore Co., which owns the iron mine situated on the adjoining lot.

The company has nearly completed a mill plant in the village of Marmora of 12 tons capacity (or four mills of three tons each) in 24 hours to be run by water power, known as the Crawford process, to test the ore. The Crawford process has been on trial for several months past and these mills have proven to be eminently successful in the treatment of low grade gold ores. The company purchased the patents for this process at a cost of $500,000, and is now manufacturing the mills in London, England; several are in use in California, and a large number have been sent to South Africa for use in the company's mines and by others operating the gold mines of that country.

The introduction of this new mill for the treatment of low grade gold ores and the opening of this extensive gold mine may impart new life to the entire gold bearing regions of Marmora and Madoc.

Locations in Fairbank and Creighton.

The Canadian correspondent of the Financial and Mining Record, published in New York, referring to gold properties in Ontario writes as follows in the October number:

The syndicate represented by Mr. J. M. Clark are sinking a 100-foot shaft with two drifts on their gold location in Fairbank. They have traced and stripped a vein along the top of a bluff for nearly 600 feet, then down the face of the bluff nearly 100 feet. Near the base of this bluff a quantity of gold ore was blasted and crushed, the result averaging $15 to the ton. The vein is between four and five feet wide. According to the opinion of a Chicago expert ore of the character here found can be reduced for $3 per ton. Gold has thus far been traced across part of Creighton, all of Fairbank and into Trill township, a length of about twelve miles.

The Fairbank Consolidated Mining Company with a capital stock of $500,000 owns 1,150 acres in the townships of Fairbank, Creighton and Trill in the Sudbury district. Toronto gentlemen are the officers of the company, including Messrs. Henry Lowndes, O. A. Howland, J. L. Nichols and others. The company have opened up three different veins and are awaiting the result of the milling test. One assay of a piece of surface ore showed $22 of gold to the ton. The veins are very promising on or near the surface. I am informed that the company is about to dispose of a section of its property to an American syndicate.

A correspondent of the Toronto Globe writes from the Sudbury district as follows:

A number of men have been engaged cutting roads for taking provisions, lumber, etc., from the railway to the mineral properties in Trill, Fairbank and Creighton. A mining expert who has been investigating the districts in the vicinity of Vermilion and Gordon lakes, and who has had extensive experience in the mines of the United States and Mexico, states that several of the quartz veins in the township of Fairbank very strongly resemble the Homestake mines of the famous Black Hills country.

SILVER.

The silver mines of the lake Superior country have been worked more generally throughout the year than heretofore and some of them on an extensive scale. Towards the end of the year however a report gained currency which for a time seemed likely to seriously depress the value of mining property in that district, viz.: that in the lower beds of the Animikie formation the veins carried so little silver as to hardly pay the cost of working. This report was strengthened by the action of the Beaver Mining Company in closing its works, and although this company published no statement there were many who thought that the shutting down of the mine had no other explanation. On this subject Mr. Walpole Roland, M.E., of Port Arthur, reports that one or two of the new lodes now being operated in the lower beds, including the Empire, are proving to be richer than lodes situated in the upper or true Animikie series. The only difference between the upper and lower beds, Mr. Roland says, is that the latter is more silicious and consequently carries less clay than the former. From personal examination he writes as follows:

Beginning with the Empire lode on the north half of lot 2 in the second concession of O'Connor township, the occurrence of this interesting discovery of black and native silver in view of the conflicting opinions and theories of latter-day scientists is of more than ordinary moment. There at a point 220 feet below the main tunnel of the famous Beaver mine, three-quarters of a mile away, and at a point approximately corresponding with the appearance of the lower series of the Animikie slates or cherts in that mine, we find the Empire's openings producing rich silver with excellently defined true fissure veins that so far as can be determined from the present stage of development (viz.: 21 feet deep) and the general appearance of the gangue of the lodes give great promise of continuity in depth. It is also significant to note that the Beaver Mining Company through its zealous agent and manager, Captain Hooper, has already solved this important problem and proved by actual work and tests that of the two series of beds the lower is the richer, as may be inferred from the large shipments from that mine as well as from the promising characteristics at the Empire and other well known lodes similarly located. . . . There now exists very little difference of opinion among practical mining men as to the lower beds being as rich as if indeed not richer than the upper, as latest shipments of silver ore from this immediate vicinity fully demonstrates. The other notable occurrences of rich silver in this formation include the Gopher and Star mines north of Whitefish lake, and the Silver Centre (R 83 and R 64) near the Crown Point mine on Silver mountain. These two locations, 83 and 64, occupy the same relative geological position to the Crown Point mine that the Empire mine does to the Beaver. They are immediately below the workings of the Crown Point and are traversed by the same strongly defined lode. R 83 wherever tested in the lower beds there prevailing invariably shows silver abundantly.

MURILLO MINE.

The Murillo mine was visited in July. Work on this mine had been suspended for about one month previous to my visit. The property had been worked with a force of 16 men from December 1st, 1890, to about the middle of June in the current year under the management of Mr. John S. Winter. The new boiler and pump referred to in my first report had been placed in position and extensively used. The result of the operations of this mine since my former report was as follows: The shaft was sunk to the depth of 135 feet, an increase in depth of 49 feet, and two levels have been run in. The first, 60 feet from the surface, extends a distance of 75 feet in a southerly direction following the vein, which was well mineralized, carrying an average of 15 ounces of silver. The second level was at a distance of 123 feet from the surface and has been driven in 25 feet in a southeast direction following the vein matter, which was more broken than in the drift above; it also carries a less percentage of silver.

Four test pits have been opened; the first northwest of the shaft 100 feet and sunk to the depth of 12 feet, opening up the vein; the second and third test pits are 100 feet apart in the same direction and have been sunk 8 and 10 feet respectively; the other opening southeast from the shaft has been sunk to the depth of 22 feet in barren rock.

Mr. George Sowman, assayer, had charge of the property. Considerable water was standing in the mine. I have learned since my visit that this property has been put on the market.

The St. Joseph mine on the adjoining lot is still lying idle.

THE BEAVER MINE.

This mine has been constantly worked and the mill running since my previous inspection.

Additional work has extended the upper level a distance of 53 feet. Number 4 level has had additional extension to the north 66½ feet and south 21 feet. Number 3 level has been run in an additional length of 96 feet. New work on the cross-cut vein has reached a distance of 106 feet east and 80 feet west. The winze in the bottom of No. 4 evel has been extended 10 feet.

The output of the mill rock averages 20 tons daily or 520 tons per month, equal to 8,000 cubic feet monthly. In addition there would be removed from the stopes as much more of refuse or barren rock not taken to the mill. This mine is kept in first-class order and is worked with remarkable economy.

In the mill another one of the old Frue vanners has been removed and a Hooper vanner substituted. There are three of the old and four of the new vanners used now. The mill is running to its full capacity and the concentrates sustain the usual high percentage of silver.

A new opening has been made at a distance of one-quarter of a mile east of the Beaver mine on the company's property known as the North Bluff. A drift has been run in from the side of the bluff a distance of 600 feet in an easterly direction, and at the distance of 300 feet from the mouth of the level the drift taps the ore and follows the vein matter. From this working about 50 tons of ore have been sent to the mill and 50 tons are lying on the dump. This new opening indicates that a large body of milling ore is accessible.

THE BADGER MINE.

The Badger mine (comprising the old Badger and Porcupine) has been constantly worked throughout the year. About 80 men are employed. All the works are in good condition, under the management of Mr. Herbert Shear.

But little work has been done on the old Badger vein during this year, most of the work being confined to the Porcupine and the new vein mentioned in my report for 1890.

On the new or No. 2 vein a shaft has been sunk 150 feet deep and about 800 feet of drifting done on the vein. Developments on this vein have been quite satisfactory, the ore all being of a good milling quality, with a considerable quantity of a high shipping grade.

The Porcupine shaft has been sunk to a total depth of 130 feet. Drifting has been done both east and west at 80 feet from the surface and connection made through the hill to the west with No. 1 adit level, the total length being 735 feet from the shaft. This level has been driven east from the shaft 190 feet, making a total length of 925 feet. No. 2 level was started at 130 feet from the surface and has been driven east 130 feet and west 250 feet, making a total of 380 feet. No. 1 winze was sunk 175 feet west of the shaft, connecting the first and second levels.

Regular shipments of ore have been made from this mine during the year.

No. 3 vein on the Porcupine location has been put under development during the year. The vein is well defined and has the same characteristics as the other veins on this property. About 500 feet of drifting and cross-cutting has been done, and quite a quantity of ore of good quality produced.

Considerable prospecting has been done, particularly on No. 5 vein on the Badger location, where about 350 feet of drifting has been done on a vein which has some encouraging features; but so far no regular ore body has been developed.

The stamp mill has been running steadily since April 1st, and about 3,500 tons of ore have been treated.

The Climax Mine.

This mine was discovered in August, 1891, by Peter Young. It is on mining location 145T, and adjoins the Porcupine mine. It was sold December 1st to a syndicate in Minneapolis, and is now being put under development, 12 men being employed under the management of Captain J. M. Sinclair. Two veins have been found on the property, both of which are well defined and well mineralized, the ore being of a high grade.

West Silver Mountain Mine.

This mine was visited in July. The property is now owned by Mr. Elias Drake of St. Paul, having been purchased by him about July, 1890. It has been worked constantly since the purchase. It is under the management of Capt. William Rapsey of Port Arthur, with a force of 25 men. Since my first inspection the water has been pumped out and shaft No. 2 has been sunk to a further depth of 55 feet, reaching a total depth from the surface of 105 feet. The timbering and ladder-way have been repaired in the shaft.

The first drift at a depth of 37 feet from the surface has been run in from the side of the mountain to intersect the shaft and extends west until its total length from the shaft is 80 feet. At the distance of 25 feet below the first a second level has been run in 72 feet west and 30 feet east from the shaft and considerable stoping done; the work has been neatly done and properly timbered. A winze is being opened between the first and second levels. A third level has been run in from the shaft at a distance of 96 feet from the surface, extending 132 feet west and 89 feet east of the shaft. At the time of my inspection most of the work was being done in this level. A large stope had been made in the west end, also cross-cuttings of about 100 feet in extent. It is the intention to continue this shaft, which has an incline of 80° north, to a further depth of 60 feet, and then run in another level. Although varying in width the vein averages 7 feet at the third level.

The ladders in the shaft used for going in and out of the mine are securely placed, but are not walled off from the part used for hoisting the rock the entire distance of the shaft. The ventilation was bad in the lowest level. I gave written instructions to have the remaining part of the ladderway walled off within 30 days, and if this did not secure proper ventilation in the lowest level, that a winze should be opened between the second and third levels. Capt. Rapsey advised me in due time that the necessary work has been done and that perfect safety is assured to the workmen, and free circulation of air obtained in this part of the mine. A new shaft has been sunk to the depth of 80 feet, but was not used and was nearly filled with water. Good steam power is used at the mine.

A shipment of 12 tons of high grade ore to Omaha had been made about the beginning of July ; previous shipments of excellent grade had also been made.

Gopher Mine.

The Gopher mine is situated about 8 miles from the West Silver Mountain mine, two miles from Whitefish lake and about 5 miles from the Port Arthur, Duluth & Western Railway. A force of five or six men has been employed in opening up the property. I have been informed that machinery was procured and placed in the mine.

The Augusta Mine.

This mine is situated on lot 1 in the first concession of the township of Strange, one mile southeast from West Silver Mountain and 1½ miles south of the P. A. D. & W. Ry. There is a good waggon road via West Silver Mountain from the mine to the station, a distance of 2½ miles. At the time of my inspection in July Mr. Wm. H. Brandon, superintendent of the mine, was working with a force of 12 men. The property is owned by Silas Griffin & Co., of Port Arthur, who have been the owners since July, 1880. The principal part of the work on this property had been done within the preceding six or seven months, and consisted of drift No. 1 on the north side of the escarpment run in a distance of 100 feet on the vein matter, which is well mineralized and carries some silver. The vein is between slate and trap formation. The end of the drift is about 100 feet from the surface. Level No. 2 is driven in a distance of 240 feet, starting at a depth of 150 feet from the entrance of the first drift and following the vein matter in the same direction. At a distance of 125 feet from the mouth of this drift a cross-cut has been made in a southeast direction with a view of tapping the main lead, which was expected to be reached at about 30 feet. This drift and the cross-cuttings are in slate and solid formation, and no timbering is required for the safety of the workmen. A good boarding house and seven other buildings have been constructed for the convenience of the workmen.

Silver Bluff Mine.

This property is situated three-quarters of a mile west from the Augusta, on the location known as "Silver Bluff." It is owned by parties residing in Minneapolis, Minnesota, and had been worked for only three weeks with a force of 5 or 6 men under the charge of Mr. Walter Middaugh of Port Arthur, formerly of Grand Rapids. The work so far consisted of clearing the surface and doing test driftings ; from the sample shown it may prove a productive property.

East Silver Mountain.

This mine is known by the name of Shuniah Weachu. Work has been constantly carried on since my last visit of inspection with a varying force of from 20 to 50 men under charge of Capt. Henry James. Mr. Arthur McEwen is the mining engineer.

Additional work has been done on the main shaft in sinking it another 50 feet ; the total depth is now 750 feet. Work has been suspended in the bottom of this shaft, and it was partly filled with water.

A cross-cutting was being made in the first level, 100 feet from the surface and about 150 feet from the shaft, the extent being 25 feet. Two men were engaged at this work.

A new shaft had been sunk at the foot of the mountain to the depth of 54 feet at a distance of 300 feet from the mouth of the old drift. Work was suspended in this shaft on acconnt of water. At the same point a new drift had been run into the mountain a distance of 200 feet west, following a vein of good milling ore for the entire distance in slate formation. Timbering was required for only a short distance in this drift.

A new discovery of ore was made at the distance of 300 feet from the mouth of the second old level and a drift following the lead for 50 feet had been made and a considerable quantity of valuable ore taken out. Four men were employed on this lead.

Another important discovery had been made a few days before my visit, distant 700 feet from the first new find. Work was being vigorously pushed at this point, and the vein showing exceeding richness in native silver had been uncovered 50 feet. The hanging wall is slate and the foot wall quartz.

Assays were made showing from 300 to 5,000 oz. per ton. Several valuable nuggets of silver had been collected from the rock at this time. I have been informed that a large quantity of valuable ore has been obtained from these workings.

Crown Point Mine.

Crown Point mine has been lying idle throughout the year, otherwise than being kept in good condition.

Silver Centre Mine.

Mr. S. J. Dawson has by several cross-cuttings opened some rich ore in the Silver Centre mine, which is in fact an extension of the Crown Point lode.

Palisades Mine.

This property is situated 5 miles east of the Shuniah Weachu, and on the public road leading to Murillo station. It is owned by Mr. Walter Middaugh and was being worked with a force of 4 men under the supervision of Mr. Winchell, an American geologist, who is also interested in several other mining properties.

A drift had been run in from an incline below the high ledge of rock a distance of 150 yards through a clay deposit and was well supported by timber. The perpendicular bold cliff had been penetrated to a few feet when the vein matter well mineralized was tapped.

From recent reports of this mine it appears that a considerable quantity of valuable ore has been taken out.

The Lily of the Valley Mine.

This is a discovery of ore of exceeding richness in native silver, and carrying some copper and galena. It is situated on lot 19 in the second concession of the township of Paipoonge, 11 miles from Fort William and 16 miles west of Port Arthur. It has led to further exploration, and the vein has been traced and uncovered on the two adjoining lots east and west.

The rock formation is quartz and slate, the latter cropping out at the surface. The discovery was made in the fall of 1890, but silver was not found until June, 1891, in an opening made on a small elevation covering an area of two or three acres. Four distinct veins had been uncovered, showing valuable mineral stretching a distance of 200 yards. A keen interest has been awakened throughout the community and a large amount of prospecting done, and this discovery may prove to be a fine mineral field in this old settled part of the township. The property was discovered by Mr. Henry Parsons, who retains a three-eighths interest. One-eighth is owned by Mr. John Woodside and one-half by Mr. W. J. Barry, all of Port Arthur.

NICKEL AND COPPER.

The nickel and copper mines of the Sudbury district were less active during the past year than the former one, but although the quantity of ore raised was less the furnaces were steadily employed and a large amount of matte was disposed of at fair prices. The United States Government having after a series of tests demonstrated the superiority of an alloy of nickel and steel for the armour of battle ships, decided to adopt that armour for all vessels under contract, and under an appropriation of Congress the Secretary of the Navy purchased last year 4,536 tons of nickel matte containing about 900 tons of nickel for this purpose. The whole of this matte was supplied by the Sudbury furnaces, and smelting operations were active throughout the greater part of the year. The results of experiments carried on by officers of the British Admiralty are not as well known as those of the United States, and it was late in the year before any decision was arrived at. The only information respecting it is contained in a memorandum published by Lord George Hamilton for the guidance of the Imperial Parliament in voting this year's supplies for the Admiralty, in which he says:

Nickel steel has been experimented with largely. Four firms have succeeded in producing successful specimens of thin armour of this quality; while two firms have manufactured 10½-inch nickel steel plate, some of which well combined resistance to perforation with freedom from serious cracking and compared favorably with nickel steel armour made abroad. Extensive orders have been placed for nickel steel armour, forming the secondary defence of the battle ships now in progress. Several ships are either fitted with this kind of armour, which has been proved sensibly superior to ordinary steel when used in thicknesses of 3 or 4 inches. For greater thicknesses the experimental results do not at present place nickel-steel in so good a relative position; but the enquiry is still incomplete. So far as it has gone it has proved that British armour plate manufacturers are keeping pace with the manufacturers of other countries, and the information will be of the greatest value when deciding on the armour to be used in future ships.

On the whole there is reason to look with confidence to a growing demand for nickel not only for use in the production of armour plate, but for a great variety of other uses in the industrial arts.

Copper Cliff Mine.

I visited the Copper Cliff mine late in July, and found that work had been suspended since the beginning of the year, with the exception of keeping it in a state of good repair.

One of the smelters was running and the supply of ore on hand I was informed was ample to keep the smelters running to their full capacity for a year; about 125 tons were treated daily. When the ore is required the work in the mine will be resumed on a scale sufficiently large to supply the smelters. Among the material improvements being made at the mine was the enlarging of the rock house to double its former size, but considerable time would still be required to complete this extensive work.

The new building which was in process of erection for the re-treating of the matte when I was last at the mine has been now completed, and the three converters and the new furnace for melting the matte have been placed in position. By this process of re-treating the matte it will be raised to double its former richness before shipment, thereby saving much expense in freight and greatly increasing the value of the product. The final process of refining will also be greatly cheapened.

A notable process has been invented and placed in operation at the smelter by Mr. McArthur, who has charge of the smelting department, for disposing of the slag. It is drawn off from the water-jacketed furnace in a continuous stream into a spout by which it is conveyed a short distance from the smelter and emptied into a large water tank; from this it is lifted by a chain elevator in a granulated state and poured into a lateral worm conveyer, carried a distance of 150 feet and dumped into a pile. This product although counted of no commercial value will probably eventually be used by mixing it with other suitable material for constructing macadam and concrete roadways, pavements, etc.

The large quantity of matte on hand at the time of my previous inspection had been since shipped to a profitable market. The working force had been reduced from 300 to about 100 men.

The Evans Mine.

Work on this mine has been suspended, as in the case of the Copper Cliff, but will be resumed when ore is required for treatment at the smelters. All about the mine is kept in good condition.

The Stobie Mine.

The Stobie was being worked with a force of 18 or 20 men under Capt. William Blewett. The principal additional work done was at the mouth of the adit in opening a pit 60 by 100 feet and 35 feet in depth, from which had been taken nearly 9,000 tons of ore. The ore after being carefully sorted is hauled over the railway track to the ore beds near the Copper Cliff smelters. This road was graded by the company and the rails laid by the C. P. R. company. The repairs are done by the mining company. I noticed 25 or 30 tons of high grade copper ore which had been sorted for separate treatment.

THE MURRAY MINE.

The Vivian Company which owns this property placed the management of the work in the hands of Mr. George N. Hendrickson, formerly of Norway, in March last; the previous year he was the cashier for the company.

The shaft formerly reported as the Vivian is now designated shaft No. 6, and is sunk to the depth of 100 feet.

At the 60-foot level the northeast drift has been extended 94 feet, the whole length now being 184 feet, in which extensive stopes have been made leaving an opening 50 feet long, 40 feet wide and 20 feet high. The southwest drift from this level has been extended a distance of 40 feet, making a total distance of 100 feet; in it a stope of 40 feet in length, 45 feet in width and 20 feet in height has been made. From the north end of this stope a drift has been run in westwardly a distance of 20 feet, and from its extremity it is intended to sink a winze to the level below. At the bottom of the shaft a drift has been run in westwardly 28 feet; about the centre of this drift another drift of 8 feet has been started following the lode in a southerly direction which was to be continued, and at the further distance of 30 feet would intersect the winze above mentioned from the upper drift. The surface workings at this mine have been carried on extensively both northeast and southwest from the shaft, from which upwards of 4,000 tons of ore have been removed and hauled to the ore beds.

The smelter was undergoing important changes and it was expected it would be in full operation again in about a month. This department of the work is under the management of Mr. W. Edwards, formerly of England, who has held this position since the beginning of the year.

Former shipments of matte from this smelter had reached to 8 per cent. of nickel. By the use of the converters it is now raised to the standard of 35 per cent. through the bessemerizing process being applied to the nickel matte. A few thousand tons of roasted ore were on hand ready for the furnace, and a considerable quantity in process of roasting.

The additional buildings consist of a new residence for the manager and a few houses for the workmen. An excellent rock house is being constructed. The working force has now reached about 200 men.

THE BLEZARD MINE.

The present depth of No. 1 shaft is 172 feet below the crown of the hill, and at the bottom a drift has been run in 60 feet to the northeast and from the end of the same stoping has been commenced.

The rock roof over the extensive excavation referred to in my former report has been partially removed, showing a thickness varying from 18 to 27 feet, and a good view of the interior workings can now be had from the surface, which tends to confirm the previous description and proves the safety of the work at the date of my former report.

The pillars of ore which were left to support the rock roof are still in place and will be removed as the ore is required for use.

A new shaft, called No. 4, northeast of the old workings, has been sunk to a depth of 65 feet and is in ore nearly all the way down. Some additional outside improvements have peen made, and a working force of 200 men is employed.

The smelter was in operation, treating about 125 tons daily. The matte as fast as made is sent to market.

THE WORTHINGTON MINE.

Work on the Worthington property has been steadily progressing throughout the year. Shaft No. 1 has reached a depth of 35 feet. Shaft No. 2 has been sunk 95 feet; from this shaft a southwest drift has been run in 60 feet and a northeast drift to the distance of 50 feet. The former drift is intended to intersect shaft No. 1, which will be sunk to a depth to meet it. This work is necessary to secure proper ventilation in the mine, which in this respect I found to be bad. Better facilities were required for getting in and out of the mine. The necessary changes to remedy this were to be completed at an early date.

A shipment of 70 tons of first-class nickel ore was recently made to England, and a shipment of copper ore to the United States.

A roast heap of first-class nickel ore similar to that shipped was being prepared for smelting at the Blezard furnace. Considerable ordinary grade ore is being taken from this mine and regularly roasted and sent to the furnace. The working force at this mine is from 15 to 20 men ; a boarding house and other suitable accommodations are provided for the workmen.

Late in the year work was suspended on the Blezard, and it is reported that a sale of this mine has been made. In a recent issue of the Toronto Daily Globe reference is made to this as follows :

This property has been purchased by an English syndicate at the price of £400,000 sterling. The mine for the coming year will be operated on a much more extensive scale. The plant will be increased and the most modern machinery and appliances introduced. Less than five years ago this property was offered to a Toronto syndicate for $23,000. Machinery was put on the property and enough metal was sold previous to this sale to recoup the owners their entire expenditure for property, machinery and development. This price of $2,000,000 is the largest price ever paid for mining property in Canada.

The report of this sale has been confirmed by other publications, but up to the present time no formal notice of the change of ownership has been received by me under "The Mining Operations Act," section 12 of which provides that this shall be done within two months from the date of the transfer.

The Chicago Nickel Mine.

This property is situated on lot 3 in the fifth concession of Drury, four and a half miles north from Worthington station on the Sault Ste. Marie branch of the C. P. R. It was purchased by the present owners in 1890, and work was begun in February last, a force of 20 men being employed in the construction of roads and buildings and doing development work. I found a force of 12 men at work under the management of Mr. Thomas Travis, one of the owners of the property, with Mr. Alexander Strom as foreman. Work had been constantly carried on since its commencement. An opening has been cut on the surface of the hill for a distance of 200 feet following a vein of nickel ore varying from 8 to 20 feet in width. The depth of the cutting for a considerable distance is 20 feet. At the crown of the hill, about midway on this opening, a cross-cut has been made 15 feet north in ore the entire distance; 200 feet east from the east end of the main opening above described, on the opposite side of a small ravine, a shaft was being sunk with the view of tapping the vein, the depth reached being 15 feet. About 3,000 tons of ore were on the dump, and I was informed that frequent assays had determined its value to be as high as 7 or 8 per cent.

A steam drill has been in use from nearly the commencement of the work, and it is the intention of the company to push the work rapidly and determine by actual development the value of the property. Should bodies of ore in sufficient quantities be opened a smelter will be constructed at the mine for its treatment. The present indications are that this property will prove to be one of great value at no distant date.

A good winter road has been made from the Worthington station to the mine, which is now used for carrying in supplies. An easy grade is available over this road for the construction of a tramway.

One and a half miles north of the mine is situated the beautiful Fairbank lake, three miles in length and three-quarters of a mile in width, to which a good road has been constructed and from which an abundant supply of ice is obtained for summer use at the mine. There is within 100 yards of the mine a living stream of pure water sufficient to supply all the water that may be needful for a smelter and other uses at the mine.

Other Locations.

Several nickel properties have been opened and worked to a limited extent in the Sudbury district, some of which I was unable to visit. I have been informed that in the early part of the year openings were made and development work done to the extent of $500 or $600 on lot 12 in the third concession of Denison, 1½ miles from Worthington station and three-quarters of a mile from the railway track. A vein was opened which showed but two inches of ore at the surface and widened to two feet at a depth of four feet. From it was taken what is said to be a new mineral for Canada (Gersdorffite), assays of which reached 55 per cent. of nickel. Analyses of 20 European samples given by Dana give an average of 29.77 per cent. nickel, ranging from 19.59 to 40.97 per cent. The Sudbury vein has been traced over 100 feet on the hillside.

On lot number 11 in the fifth concession of Lorne township development work has been done in opening shaft No. 1 to a depth of 35 feet; shaft No. 2, 22 feet; shaft No. 3, 15 feet; shaft No. 4, 12 feet, and several smaller openings. About 500 tons of two per cent. ore is now lying upon the dump. This mining location contains 261 acres and is situated one and a half miles east of Nelson station on the Sault Ste. Marie branch C.P.R. and is 31 miles west of Sudbury. The property will be worked later in the season by the Algoma Nickel Company which has made an option purchase of it.

On lot 7 in the second concession of Levack work has been done by sinking several shallow test pits at intervals over a few hundred feet. One surface drift has been extended up the mountain side 125 feet, uncovering ore the entire distance along the contact of diorite and syenite rock. Over 100 tons of low grade nickel ore carrying a small percentage of copper have been taken out of the works. This property was purchased after a careful examination for an English company by Mr. Huntington, who accompanied the members of the Iron and Steel Institute on their visit to the Sudbury district, and embraces 240 acres.

Lot 6 in the second concession of Levack, containing 160 acres, was also purchased by the same company at the same time. Work has been done on this property by stripping the ore and sinking shallow test pits over an area of 120 feet in length by 80 feet in width. A large quantity of ore has been exposed of similar grade to that described on the former property. About 100 tons are lying on the dump. These properties are about 4½ miles from Onaping station, on the main line of the C. P. R., 24 miles west of Sudbury.

Lot 2 in the fourth concession of the same township, 6 miles from Onaping station, contains 160 acres, and is owned by the same company. Test pits have been sunk on the northwest corner of the lot at short distances apart over about 10 acres, showing an abundance of mineral. From these openings a few hundred tons of ore of similar grade to that found on lots 6 and 7 have been raised. On the east side of this lot eight test pits have been sunk, stretching a distance of 150 feet; the result is an excellent showing of mineral. A small dwelling house and a blacksmith shop have been built.

A good winter road has been made to these several properties, and two sample car loads of ore have been sent to England for treatment.

On lots 5 and 6 in the third concession of the same township Mr. Babcock and others of Sudbury have done considerable test work with good results. Openings have been made with excellent showings, the assays reaching 4½ per cent.

On the south half of lot 4 in the fourth concession of the same township similar results have been obtained by test workings. The expenditure on the Babcock properties in th early part of the year was about $800.

Dr. Robert Bell in the recent report of his geological survey of the Sudbury district says:

Other metals, including gold, platinum, tin, lead, silver, zinc and iron, have been found in the Sudbury district, and probably some of them may prove to exist there in paying quantities. The presence of a considerable proportion of nickel in the ore of the Wallace mine, on the shore of lake Huron and in the strike of the Sudbury deposits, was ascertained by Dr. Hunt more than forty years ago; yet the presence of this metal in the latter does not seem to have been suspected for a considerable time after they had been worked for copper alone.

The October number of the Engineering and Mining Journal of New York contains a dispatch from Ottawa which says that nickel-bearing ore has been found on the farm of G. S. McFarlane, 19 miles from Ottawa. "Samples analyzed at the office of the Geological Survey in Ottawa are said to have proved to be as rich as the best ore of the Sudbury district."

Mr. J. Cozens of Sault Ste. Marie writes to me of recent date regarding his Michipicoten copper mine as follows:

I have done a certain amount of surface exploring, finding heavy bodies of native copper, but have done no mining in depth. I have kept everything in first-class order and looked into the question of my water power, which I hope to develop for mining and milling purposes early next season. I have an inexhaustible supply of water and 228 feet head, so I think that I can mill copper now cheaply.

Of copper ore Dr. Robert Bell in his report above referred to states:

The Huronian is notably a copper-bearing system. West of Sudbury, in the great belt we have already traced, this metal occurs around Batchawana bay, north of Sault Ste. Marie, at little lake George and Echo lake, at Huron Copper bay, in Wellington and Bruce Mines, on Thessalon and Mississaga rivers, and elsewhere. To the northeastward it has been found on both sides of lake Wahnapitae, on Temagami and Lady Evelyn lakes, along Montreal and Blanche rivers, on the watershed east of the canoe route between lakes Temiscaming and Abittibi, and finally near the southern extremity of lake Mistassini. The search for this metal along the Huronian belt, which has been described above as running for more than 600 miles, is only in its infancy, and the copper-mining industry may some day be very extensively carried on in various parts of this, as yet, almost unknown section of Canada.

The Smelting of Copper-Nickel Ores.

I herewith subjoin an article of much interest to Canadian investors in copper and nickel properties in Ontario taken from the Canadian Mining Review of Ottawa, December number, page 253, containing excerpts from the second edition of the work of Dr. E. D. Peters, jr., on Modern American Methods of Copper Smelting, in which he also discusses largely the treatment of nickel ore and nickel matte.

Dr. E. D. Peters, jr., well-known to Canadians as the first manager of the copper-nickel mines of the Canadian Copper Co. at Sudbury, where he demonstrated the feasibility of smelting these ores on a large scale in water-jacket furnaces, has issued through the medium of the Scientific Publishing Company, New York, the second edition of his well known and widely read work, "Modern American Methods of Copper Smelting." The book, apart from its great value as a reference to metallurgists generally, is of particular interest to Canadians, inasmuch as it contains the latest addition to the literature of nickel metallurgy. As Dr. Peters assisted in the opening of the mines, and the first smelting works were built under his direction, he speaks authoritatively of such matters as came under his personal observation, and within the sphere of his own practice. A few excerpts from his references to the mining of the nickel in this country will not be out of place:

"On an average the ore treated at the principal mines carries some 4 per cent. of copper, though if selected it could easily be brought up to 8 or 10 per cent. But up to the present time experience has shown that it pays about as well to mix all the ores and smelt them as they are as to try to make two grades of matte, one rich in copper and poor in nickel and the other high in nickel and low in copper. By pursuing the latter course a slightly better price can be obtained from the refiners, but the metallurgical operations are seriously embarrassed, as if the heavy nickel ore is smelted alone it produces far too basic a slag; while if the richer copper ore is fused by itself the slag is too silicious to smelt easily. By mixing the two varieties of ore in their proper proportions a good slag is obtained without the addition of flux, not a pound of the latter being used during the time I was in charge of the work. Besides, the ores roast much better when mixed than if separate."

Dr. Peters then fully describes the methods of roasting the ore, in which he calls attention to the vital importance of having a proper and well-drained roast ground.

"In the severe climate of northern Ontario it was sometimes necessary in inaugurating a new plant to build a heap on frozen ground, or ground that was not thoroughly drained. In both cases the results were miserable, the escaping steam seeming to completely impede the combustion, and the resulting heap when torn down revealing isolated spots, each containing many tons of ore that were not roasted at all, only the surface being slightly scorched, though the greatest pains were taken in building and managing the heap."

He points out that an absolutely dry and unfrozen ground is essential to success, and if snow falls it must be carefully cleared away before laying the wood down, and after the wood is once in place no snow or rain must fall upon either the fuel or ore. Where the ground is frozen the results of the roasting are always unsatisfactory.

"A few hours after lighting the heap, water begins to flow out from under it, and for a day or two a continuous stream will pour out from the lower side of the pile, generating steam in quantities and extinguishing the fire as soon as the lumps of ore are scorched a little on the outside."

Dr. Peters then goes on to discuss the treatment of the nickel-matte, and the subject is so attractive that we cannot refrain from giving his remarks in full:

"In nickel smelting, when the matte is obtained it still remains to be refined, and only those who have been through such an experience realize the difficulties of disposing of it.

"In the first place it becomes a question of calculation whether it will pay better to ship the matte at about a grade of 25 per cent. as it is produced from the furnace, or to concentrate it on the spot by a second series of roasting and smelting operations. Until the local conditions, wages, scale on which operations are conducted, exact character of ore that is treated, etc., are known, this question cannot be answered. The matte is enriched by roasting it and resmelting it in a water-jacket or other furnace, with quartzose flux to take up the iron. It is a question to be determined by circumstances whether the roasting should be executed in heaps, as with the ore, or whether it should be crushed and calcined in a few hours in calcining furnaces. Heap roasting of matte takes about as long as the ore, because it has to be re-roasted two or three times, as it does not roast freely like the ore. But as there is only about one-sixth so much to handle as the raw ore, the expense per ton of ore is not heavy. A matte of about 50 or 60 per cent. of nickel is produced by the so-called concentration smelting.

"This concentrated nickel matte has a high point of fusion, and easily forms crusts and accretions.

"It is impossible to smelt it in a furnace with brick fore-hearth, as may be advantageously done with the ore, for it soon fills up the front crucible, necessitating its substitution and leaving a 'salamander' weighing a ton or two that is difficult to break up.

"After much experimenting I have returned to the old practice of using 'steep,' or a mixture of pulverized coke and clay, for a fore-hearth, cutting in it a small crucible connected with the furnace crucible by a deep groove. Out of this crucible the rich nickel matte can be either tapped or ladled into moulds, and as this method of procedure involves frequent though very slight repairs it will save much delay to make the fore-hearth broad enough to permit of two such crucibles, side by side. Thus one can be repaired and dried while the other is in use.

"The further treatment of the nickel matte, according to the old practice, is well known and its description would be out of place in this connection.

"Being expensive and slow, efforts are being made to improve upon it, and one of the principal nickel-smelting companies at Sudbury is erecting a plant to bessemerize this rich sulphide of copper and nickel.

"According to the laws of chemical affinity, as modified by the high temperature employed, we know that the iron still remaining in the matte ought to oxidize first, forming with silica a slag that may be poured off. Next, the nickel should oxidize and slag away, leaving behind the pure copper. But whether such accurate results will be reached in practice seems to me somewhat doubtful.

"In the bessemerizing process as applied to iron the entire mass of metal remains homogeneous throughout the operation, the impurities being gradually oxidized until it is all converted into steel. And the total amount of these impurities is only four or five per cent., so that the mass of fluid metal operated upon is not perceptibly lessened.

"But in bessemerizing a mixture of the sulphides of iron, copper and nickel the number of different chemical compounds having differing specific gravities and tending each to form its separate stratum in the converter, is too great to even enumerate.

"As soon as sufficient sulphur is removed to correspond to the iron present, we shall have a layer of oxide of iron (combined with silica from the converter lining) on top, while below the sulphides of nickel and copper will remain comparatively unaltered. Then may come a period when we have the same silicate of iron on top, followed by a little silicate or oxide of nickel, whilst some metallic nickel has formed and sunk to the bottom, and the rest of the nickel, in its original condition of sulphide, forms a stratum below the unaltered sulphide of copper.

"These reactions and products increase in number and complexity as the operation advances, and remembering the great difficulties encountered in bessemerizing even so simple a substance as copper matte one cannot help feeling some curiosity as to the practical success of this operation.

"That nickel and copper can be rapidly reduced from the condition of a matte to that of separated metals, the author has convinced himself. But business considerations prevent the further elucidation of this subject.

"The final treatment of the nickel-copper alloy, or of the already separated metals, does not fall within the scope of this work.

"But it must be evident to every one familiar with the facts that the commercial electrolysis of copper on the one hand and the electrolytic deposition of nickel in our nickel-plating establishments on the other hand point out a path to follow that is too plain to be neglected.

"And as our chemists find no difficulty in precipitating with the electric current chemically pure copper from a solution containing both copper and nickel, and then, by slightly altering the conditions, precipitating all the nickel in absolute purity from the same solution and with the same current, it would seem that our refiners might reasonably expect to effect the same results on a commercial scale, especially as there is practically no loss of acid in the operation.

"Nor can I see any reason why nearly all our metallic nickel should be offered to the trade in little cubes less than an inch square. Of course this peculiar form has resulted from the practice of the nickel refiners to reduce the oxide of nickel obtained by the methods now in use to metallic nickel. Being mixed with rye meal as a reducing agent it is formed into these little cubes, and a number of these packed in crucibles are exposed to a sufficient heat to reduce the nickel to a metal without fusing it. This makes a small porous fragment of metal suitable for solution in acids and where nickel is to be used in minute quantities. But it adds materially to the expense of refining, and there is really no more reason why nickel should be so treated than copper or iron.

"Although the fusion point of nickel is rather high, yet a sufficient temperature to make nickel pour as readily as copper is obtained without difficulty in metallurgical practice, and there is little doubt that before long nickel will be refined in bulk and cast into suitable ingots, as is copper or lead.

"Indeed at Vivian & Company's nickel works in England a small reverberatory heated by gas has been in use for several years for refining nickel, some 2,000 pounds being refined at a charge; and the superb display of solid nickel articles and ingots made by Joseph Wharton of Philadelphia shows that he experiences no difficulty in melting and casting nickel like other metals.

Another feature of Dr. Peter's book of interest to Canadians is the detailed plan of the large reverberatories now being constructed by the Eastern Development Company at their mines at Coxheath, C. B. These drawings cover nine full size pages, and probably form the most complete and detailed working drawings of a modern reverbatory furnace that have yet been published. They are accompanied by exact estimates of the cost of every detail of the furnace. The book is nicely gotten up and in every sense merits the careful attention of everyone interested in the metallurgy of copper.

IRON.

The extensive iron belts in western Ontario have not been worked during the year 1891, but the limited prospecting carried on has confirmed the wide area over which the deposits extend and the richness and purity of the ores. The Atik-okan district has attracted the special attention of foreign capitalists, and large investments are reported to have been made. The Weekly Herald of Port Arthur of December 15th reports as follows :

ORE DEPOSITS LEASED BY THE BELGIAN BANK.

Ferdinand Vanbruyssels, Belgian Consul-General for Canada, left for home to-day accompanied by Messrs. Wiley and Russell of Port Arthur. Before leaving he succeeded in closing contracts for the Belgian Bank of all known ore deposits on the Atik-okan iron range, covering an area in length of twenty miles. They propose mining there, building the Atik-okan railway, and erecting blast-furnaces, rolling mills and other iron industries here. The Canadian Pacific will lease and operate the railway, which will be sixty miles in length.

BELMONT IRON MINE.

This property is situated on lot 19 in the first concession of Belmont, county of Peterboro', and comprises 100 acres. The mine is owned by Mr. T. D. Leyard of Toronto and others, and was leased in March last by the Belmont Bessemer Ore Co., composed of American capitalists with capital stock of $600,000. The company has offices at 103 Bay street, Toronto, and 290 Broadway, New York. Work had been done previous to leasing the property in stripping the ore leads for considerable distances and sinking a few shallow test pits. The present occupants have made several new openings, one shaft reaching the depth of 47 feet, and have continued uncovering the vein of ore on the surface for the distance of 350 feet. One hundred and fifteen tons of ore have been shipped to Hollidayburg, Pennsylvania, for treatment, showing a grade of 61 per cent. About 800 tons of similar grade ore were on the dump at the time. Recently test borings have been made to the depths of 100, 70, 62, 60 and 30 feet respectively on the vein matter, which extends from 20 to 150 feet in width, and is free from impurities. The working force at the mine is under the management of Mr. G. L. Woodworth, and since the new company has held the property averages twelve men.

A railway at the cost of $5,000 per mile is being constructed from the mine to the Central Ontario railway, a distance of nine miles. The road has been graded to the village of Marmora, six and a half miles. The remaining part of the road will be graded and the rails laid early in the spring. Work will then be pushed forward vigorously at the mine. A commodious frame boarding-house was nearly completed, and other buildings erected suitable for working the mine on a large scale.

Other Locations.

On lot 16 in the seventh concession of Marmora the Crescent Gold Mining Company has opened an iron mine during the year. Development work comprised stripping the vein of ore for a considerable distance, and sinking several test pits ; from one, which was sunk 20 feet, some excellent Bessemer ore, free from impurities, has been taken. Tests by analysis have shown the grade to be 62 per cent. On the adjoining lot is the Dufferin iron mine, owned by the Bethlehem Co. of Pittsburgh. A large quantity of ore is lying on the dump, but the mine has been idle for the past eight years.

Mr. H. M. Powell of Marmora owns the east half of lot 24 in the fifth concession of Marmora, on which he has done prospecting work with encouraging results. Four or five men were employed for six months in opening test pits and stripping the vein of arsenical ore. About 100 tons of hematite ore have been taken out. The property is nine miles northeast from Marmora village.

Several of the iron mines in eastern and central Ontario which have been extensively worked in former years and were largely productive, and in many cases with large quantities of ore on hand, are now lying idle.

No work has been done during the year in the mines along the line of the Kingston & Pembroke Railway.

Causes which affect the Industry.

Speculations as to the cause of the collapse of iron mining enterprise in eastern Ontario assign various causes for it. When investment was active about ten years ago the duty on ore imported into the United States was 50 cents a ton. Several New York and New Jersey mines about this time ceased to be producers. The increase of the duty to 75 cents was not effectual to lessen importation from Spain, Africa, England or Cuba. The importation from these sources has grown with the increasing demands of the furnaces along the Atlantic coast to an average of 800,000 tons a year, and the recent reciprocal relations established between the United States and Cuba leave untouched the duty on iron ore from the important mines in that island. The increased duty had no effect to reopen those mines of New York and New Jersey, whose ores were either of inferior quality or costly by reason of the great depth of the mines. Processes for roasting ores objectionable on account of sulphur and for crushing and separating by magnetic attraction the iron oxides from the accompanying rocky material with which the phosphorus is confined have been greatly improved within the last five years, and are now economically used at mines which but for them could not be successfully operated. The use of concentrated ore in the United States foots up some 90,000 tons yearly, the output of twenty-five mills.

A paper by W. H. Hoffman, M.E., read before the American Institute of Mining Engineers at its meeting in October last gives the results attained at the Croton mines, New York, in the roasting and concentration processes. The ore, broken to pass through a 2¾-inch ring, is roasted in Davis Colby kilns at a cost of 8½ cents a ton for fuel gas ; the cost of filling and discharging the kilns is 3 cents a ton ; the average temperature of the roasting process is 1,250° Fah., which is reduced to 350° by sprinkling water on the ore as it leaves the kiln. A 94 h.p. steam engine operates a Sturtevant crushing mill, which brings the roasted ore into the crushed condition at the rate of 22 tons an hour. By means of the magnetic separator the ore is removed from the accompanying gangue and the metallic iron ore raised from 38 per cent. to 70.6, with .018 phosphorus and 0.22 sulphur. In twenty-four hours 580 tons treated in this plant turned out 215 tons of concentrate at a cost inclusive of cost of mining amounting to $1.95 a ton.

The importance of this process to many Canadian mine owners is evident in view of the large charge on the shipping output involved in the rejection to the dump of fully one-third of the ore raised. The analyses have been shown me made by the furnace chemist of an American company who mined in eastern Ontario some 40,000 tons of ore for its own furnaces and then withdrew from the business with considerable loss of abandoned machinery. The mean contents shown by forty-two analyses are: metallic iron ore, 48.8; phosphorus, .013; silica, 9.34; lime carbonate, 5.8; magnesia carbonate, 9.012; manganese oxide, .45; pyrites, .442. It is altogether probable that this ore could have been materially improved by treating one-third of the quantity shipped for concentration and removal of sulphur and phosphorus, but at the time when the mine was surrendered these processes had not reached their present economic development. Doubtless some of our ores are sufficiently rich to render the process referred to unnecessary.

Iron mining in the United States within the past five years has not only shown enormously increased production, but has taken in new fields, calling for capital for development to such a degree that the question arises, Can any immediate development of the iron mining industry of Ontario be hoped from American enterprise?

In my former report mention was made of opinions in favor of appropriations for diamond drill boring as a means of testing the depth and value of our iron ores. This method is adopted by the government of Victoria, Australia, for promoting enterprise in gold and coal mining. The report of the Secretary of Mines of that colony gives plans of the borings and statements of cost. During the year 1890 the number of bores put down was 145, at a cost of $2.70 per foot; the total appropriation amounted to $105,000. The work could be done much cheaper in this country, and if directed by an expert would afford exceedingly valuable information as to the depths and disturbances of our magnetic ore and other ore deposits.

It has been suggested that the owners of mining properties make the cost of borings which result in important discoveries a first lien on the land.

A recent report announces that borings show an abundance of ore in the Norrie and Ashland iron mine in Michigan at 1,500 feet vertical depth.

PHOSPHATE OF LIME.

A number of phosphate properties have been lying idle during the year, or but limited operations carried on. High freight, a depressed market and heavy duties have severely checked the phosphate industry for the present.

The drop in the price of phosphate last year, which was attributed by some to the effect on the English market of a considerable importation of Florida phosphate, resulted in the suspension of mining operations at many points. The resources of the province in this mineral might be profitably investigated with the diamond drill. The late Mr. Vennor of the Geological Survey recommended the use of the drill along part of the south boundary of Bedford township in Frontenac, and since his death other promising fields have become known. The irregularity of phosphate veins or deposits and the great cost of raising the accompanying hard rock, and in some cases the expense of moving the output of the mine, have interfered with the development of this industry. Yet there is ground for believing that careful exploitation of certain known areas would result in revealing large deposits of high grade phosphate which could be profitably mined with the application of machinery, and from which an extensive output would repay improvement in the means of transportation.

The amount brought into Kingston by the Kingston & Pembroke Railway during 1891 was 73 car loads, 1,200 tons; from Loughborough and Storrington, 2,550 tons; in all 3,750 tons. Thirty-five tons were shipped to the United States, and the remainder to Montreal.

Montreal Mining Co's. Mine.

A phosphate property owned by the Montreal Mining Co. is situated on lot 3 in the sixth concession of Bedford, at Bob's lake. Nine men were employed at the time of my visit in June who were working on royalty. A large number of pits were open, varying from a few feet to fifty in depth, and extending over an area of about forty acres. The work of this year had been but recently commenced, and in consequence only a small quantity of phosphate had been taken out. This company owns in all 600 acres of phosphate lands. Edward Nolan had charge of the work.

Properties in Bedford.

Hon. Peter McLaren and Mr. Edward Watts own the phosphate mines on lots 27, 28 and 29 in the tenth concession of Bedford. This property has been worked for the past two years with a force of a few men. Six men were employed for about three months of the present year, and about 500 tons of phosphate had been taken out and hauled to Westport wharf for shipment. Four pits had been opened following the vein of phosphate, the deepest being 25 feet.

Opinicon Mine.

Opinicon or Rock Lake mine is situated on lot 21 in the fifth concession of the township of Storrington, county of Frontenac. This property is leased jointly by the Kingston Phosphate Co. of Montreal and Mr. James Bell of Arnprior, and is owned by the Canada Company. It is worked on royalty at $2 per gross ton. The work is carried on day and night with two shifts of men, a total force of 30 men being employed. Two openings were made about the middle of the lot; the larger one extends 40 feet in length and is sunk on the vein of phosphate to the depth of 150 feet. The vein increases in width from a few feet at the surface to 100 feet at the bottom of the cutting. The deepest workings of the mine had reached the level of the lake The hanging wall, which is limestone, was well supported by rock pillars which had been left. The output from this opening averages about four tons daily of 75 per cent. phosphate. It is sorted, washed and then hauled half a mile to a landing on the lake, loaded on scows each holding about 100 tons, and thence taken to Kingston. Steam power is used for drilling, hoisting the ore and pumping the water from the mine.

The second opening has reached a depth of 35 feet; the opening at the surface is 20 by 30 feet and widens as it goes down. About 1½ tons of ore of 75 per cent. phosphate is taken out daily and treated in a similar way to that taken from the other works. A whim is used for hoisting at this pit. From 6 to 8 men were employed at the working.

Mr. Neal Cochrane, a graduate of a mining school in the west of Scotland, had the immediate charge of the work at the mine, and Mr. Gorman of the Foxton mine was general manager.

Several other openings have been made on the property with excellent showing of phosphate, but they have not been extensively worked.

The whole of the work on this property was conducted in an economic and satisfactory manner.

Foxton Mine.

Work has been continued on this mine since my visit in December, 1890. The drift 60 feet below the surface has been run in 70 feet west and intersects the stopings made from the level below. The second drift commences 100 feet from the surface and runs in west 75 feet. The stoping was still following the vein upward and had reached within 25 feet of the surface. The mineral is in a well defined vein, varying from 6 to 10 feet in width. About 30 hands were at work, drilling in the stope being done by hand. A description of the plant was given in my former report.

The Concession Mine.

The pit opened at a distance of 200 feet from the Foxton has been sunk to a depth of 50 feet, the opening at the surface being 20 by 40 feet and narrowed at the bottom to 10 by 15 feet. Three or four men were employed opening a test drift in the bottom of the pit in a northerly direction by the use of a steam drill driven with the power at the Foxton mine, which is also used for hoisting the rock.

During the winter about 600 tons of good grade phosphate were hauled to Kingston, a distance of 21 miles. About 400 tons were on hand at the mine. A more direct road of easier grade to Kingston is being opened via Eel and Sydenham lakes, over which ore will be hauled to the market.

The Johnson Mine.

Lomer, Rohr & Co. have commenced work recently on the old property known as the Johnson lot, in the sixth concession of Loughborough, with a force of 12 men and have taken out 40 or 50 tons of high grade phosphate. These properties and the Foxton are under the management of Mr. F. M. Gorman.

The Fleming Company's Mine.

The Mining Review of Ottawa, referring to the Fleming Phosphate Company's mine in the fourth range of Portland township, (October No., p. 195) says :

It is expected 1,000 tons of high grade ore will be taken out during the winter ; it is said to be one of the most remarkable phosphate deposits in Canada.

Eagle Lake Mine.

Work had been suspended on this mine during the months of November and December owing to the dulness of the market. The work done during the year has been in the old openings of the mine. About 250 tons of No. 1 and 500 tons of No. 2 phosphate had been mined. An average staff (for about six months) of 15 men were employed. Part of the time, however, the men were employed at the saw mill. The old stock of lumber has been marketed.

Shaft No. 1 has now reached a depth of 175 feet ; the rock is more eruptive, but the same grade of ore is maintained. Considerable stoping has been done in the opening and the vein matter has increased in size.

A new shaft 50 feet in depth has been opened on the lead of phosphate, and the mine is in good condition for working. The iron deposits in connection with this mine have not been worked largely. About 800 tons of 65 to 70 per cent. magnetic iron ore is ready for shipment.

St. George Lake Mine.

This mine has been worked with 12 men for three months during the year and 220 tons of high grade phosphate shipped to London, England, with the first grade ore from the Eagle Lake mine. Work has been done chiefly in the easterly pit which has reached the depth of 60 feet. The ore is still raised with a whim.

Silver Lake Mine.

This mine has been worked with a force of 15 men for four months during the year. The work has been confined to surface openings, some of which have reached the depth of from 15 to 30 feet. Two hundred and fifty tons of 80 to 85 per cent. phosphate have been taken out. The siding of the Canadian Pacific Railway has not yet been completed.

Frontenac Mine.

Shaft No. 1 has been sunk an additional depth of 20 feet, making a total depth of 70 feet. The vein of ore which has been followed averages from one to two feet in width and 20 feet in length. The vein in the stope averages two feet in width. Ten tons of 85 per cent. have been taken out. Six men were employed a month and a half during the year. Mr. T. T. Hampton of Sharbot Lake has charge of the works.

Gypsum or Plaster of Paris.

Gypsum as defined in the glossary of the Commissioners' Report is "Sulphate of lime, usually white and crystalline, granular. Selenite is the pure crystalline form, and splits into plates which are very transparent. It is very soft and is the mineral which constitutes the second degree of hardness, talc being the first" Gypsum occurs in beds on the Grand river in southern Ontario, and on the Moose river in the northerly part of the province, a distance of 500 miles north of Toronto. Plaster of Paris is a plaster made of gypsum by grinding and calcining it, so called from its manufacture near Paris in France. In Canada this term has been adopted for gypsum in any form.

The Excelsior Mine.

The Excelsior gypsum mine which I visited recently is on lot 2 on the Grand River road, Jones tract, three miles east of the village of Cayuga, county of Haldimand. The property consists of 65 acres and has been worked for the last 15 years and large quantities of gypsum removed. In September, 1890, it was purchased by the Adamant Manufacturing Company of Syracuse, New York. This company has offices at 71 Genesee street, East Syracuse, and 100 Esplanade street east, Toronto. The supply for use at the mill in Syracuse is obtained chiefly from the Nova Scotia and New Brunswick gypsum beds. The mill in Toronto is supplied from this mine.

The mine was worked from the beginning of the year until June with a force of 5 or 6 men and 1,300 tons of gypsum were taken out, most of which had been carried over the tramway to the mill a distance of a quarter of a mile. A drift has been run in from the level surface in a northerly direction at an incline of a foot in ten to the distance of 175 yards. At a distance of 150 yards from the place of entrance the gypsum was reached in a layer of 4 feet in thickness lying between shale above and limestone underneath. The drift has been extended to a total distance of 400 yards following the continued bed of plaster from the place where it was first reached. At the foot of the incline in this drift a level has been run in east 125 yards and the gypsum removed to the width of 100 yards, the open space being filled in with waste rock as the work progresses, an opening of about 8 feet for the tramway and convenience of work being left. In this drift an air shaft 4 by 4 feet has been opened to secure ventilation and provide a way for going in and out of this part of the mine. Also from the bottom of the incline another level has been run in southwest a distance of 100 yards, from which large quantities of gypsum had been taken out. In this level an air shaft was opened 4 by 4 feet; 125 yards from the bottom of the incline another short level of 10 yards has been opened. Near the extremity of the main drift a small air hole one foot square has been opened to the surface, which is 60 feet above the workings.

The plaster is taken out of the mine on a horse-car carrying about 2,500 pounds per load and conveyed by tramway to the company's mill. The mill was idle at the time of my visit.

Some parts of the interior of the mine require additional timbering. Mr. John A. Nelles, who has charge of the work, informed me this would be properly done before work was recommenced. He has had the direction of the work at the mine from the time it was first opened.

Glenny Mine.

The gypsum quarry on lots 1, 2 and 3 in the township of Cayuga, in the county of Haldimand, is about one mile east of the Excelsior mine and has been worked for forty years past. The Grand River Plaster Co. purchased this property about ten years ago, and has constantly worked it since. It has offices at Cayuga and at 67 William street, New York. The paid up capital is $50,000. The company holds the mining right for 300 acres and the surface right for 15 acres. The working force for ten years last past has varied from 10 to 35, averaging 15 men annually. The yearly output of gypsum reaches 2,000 tons.

The workings at this mine consist of a drift in a northeasterly direction run in at the bottom of a small elevation of 20 feet, half a mile from Grand river and about 5 feet above its ordinary level. The drift is run in 400 yards in length and follows mineral the whole distance except for 30 yards from the entrance; the bed averages 4½ feet in thickness and is said to extend laterally over an area of 35 acres, of which 4 or 5 acres have been worked out. At a hundred yards from the mouth of the drift a level in a southerly direction is driven in to the distance of 30 yards. At a further distance of 200 yards from the mouth of the drift a second level is run in for fully 100 yards and was the principal place of work in the mine at the date of my visit. Two other extensive openings have also been made at a still further distance from the mouth of the drift. Two air shafts are opened which afford good ventilation to the mine.

The gypsum is mined and loaded into dump cars by contract for 70 cents per ton. It is then hauled out at the expense of the company by a pony mule employed for that purpose over a well laid track by means of which two or three car loads of 2,500 pounds each can be taken at a trip. The company furnishes the explosives and timber for the mine. The mill in connection with this mine is capable of grinding 15 tons of land plaster in ten hours and is run only in the daytime. It has been fitted up for manufacturing calcined gypsum, which is used largely for hard finish for walls. The pure white plaster is selected for this purpose.

The rock is treated as follows: It is first sorted, then passed through a Kelly crusher and falls into the disintegrator, and thence it is elevated to a hopper which feeds the buhr-stones for grinding. When ground it is again elevated into a bin and shoveled into the kettle for roasting. A batch of 35 or 40 barrels is treated in about three hours, being actively stirred with mullers during the time of roasting. After roasting it is again screened and put into sacks or barrels for the market.

This property is in good working condition, being under the control of Mr. Robert Glenny who owns the surface right and from whom the company purchased the mining right. He has had charge of the work for the last nine years.

The Merritt Mine.

Another gypsum mine known as the Merritt mine is situated on lot 3 of the Jones tract. The mineral right embraces 106 acres. The property belongs to the Grand River Co. and was opened 16 years ago by Mr. Glenny; 10,000 tons of plaster at least have been taken out of it. The company purchased it from Mr. Glenny about the time that it acquired the Glenny mine, but it has been lying idle for the last seven years. Mr. Glenny informed me that the quarry yet contains a very large quantity of excellant white plaster.

The Teasdale Mine.

A gypsum mine is being opened on lot 1 on the Huffman tract, and is owned by Mr. Thomas Teasdale. Work was begun about a year ago. About 100 tons of plaster have been taken from the mine. Two men were employed in the work. The gypsum lies only a few feet above the ordinary level of the waters of the Grand river and serious difficulty sometimes occurs in working the mine on account of the inflow of water from the river; this difficulty is common to most of the mines situated on the banks of the Grand river.

Mount Healey Mine.

One of the oldest plaster locations is situated at Mount Healey on the Grand river, on what is known as the Cook block, and contains about 70 acres. W. Donaldson & Co. own the property and have worked it for he last 20 years (except for the last two years, during which time the property has been idle), taking out an average of 1,000 tons annually. Mr. Donaldson informed me that work would be resumed during the coming winter. An area of about 20 acres has been worked over. The layer of plaster in this mine averages three feet in thickness and is about 20 feet below the surface; the rock above being shale, and underneath limestone.

Martindale's Mine.

In November I visited the gypsum mine situated on lots 54 and 56 River range, Oneida township county of Haldimand. The mining right embraces 330 acres. Mr. Thomas Martindale is the owner of the property and has worked it continuously since 1866. The annual product until 1885 was 2,000 tons, and since it has been about 600 tons. Six men were employed until recently; about 500 tons of plaster were on hand in

November. The plaster is mined by contract and removed by horse tramway to the rock house in cars capable of carrying about 2,500 pounds each. The mill, which is capable of grinding 2,000 tons yearly, is situated on the opposite side of the river, in the village of York: it is run only part of the time. The plaster, which is ground for fertilizing uses only, is usually hauled to Deans and Cayuga stations, Canada Southern railway, and Caledonia on the Hamilton and Port Dover railway, for shipment.

The gypsum extends over an area of about 200 acres, about 20 of which have been worked; the layer averages four feet in thickness and is from 25 to 40 feet under the surface. The inside workings of the mine are very extensive, reaching a distance of three-quarters of a mile from the opening on the bank of the river.

Some parts of the works I found in excellent shape, while other parts were in an unsafe condition for the workmen and others who had occasion to enter the mine. I required some of the older workings to be fenced off to prevent persons from entering them, as the hanging rock roof was liable to fall away at any time. I also directed the manager, Mr. George Millward, to construct a couple of stone pillars to support the roof at the place of present working, and to sink a shaft from the surface at a place which I indicated for the purpose of ventilation and to provide a way of escape in case of an accident, whereby exit by the usual passage from the mine might be barred.

The Garland Mine.

This mine is on lot 13 in the sixth concession of Oneida township, county of Haldimand, and comprises 29 acres: it is owned by L. H. Johnson of Caledonia. The property has been worked for about 20 years, and not less than 20,000 tons of gypsum have been obtained from it. It has been held by the present owner for nine years and about 800 tons of gypsum have been mined annually. A working force of from four to six men has been usually employed. A drift due south was started on a plain surface and run in on an incline of one foot in ten, and at a distance of 86 yards the plaster was reached, averaging four and a half feet in thickness. The vein is overlaid with a thin layer of argillaceous shale, above which is clay to the surface. Underneath the layer of plaster is a conglomerate of lime, gypsum and clay. The drift is continued in the same course a further distance of 36 yards, then turns an angle to the southwest and is continued 28 yards to its terminus. The present workings are at the end of the drift.

The ore is removed from the mine by means of a horse tramway; the car when loaded contains 2,500 pounds. Frem the mine it is hauled to a mill in Caledonia a distance of three miles and there is ground as a fertilizer. I gave directions to the foreman, Wm. Smith, to replace some of the old timbers used as supports with new, to construct a siding or man-hole along the tram-way, and to open at or near the end of the drift a shaft for ventilation and egress from the mine in case of accident.

The Paris Plaster Mine.

The Paris plaster mine has been purchased recently by the Alabastine Co., of Paris, of which Mr. B. Church of Grand Rapids, Michigan, is a principal shareholder. He is also the general manager of the Alabastine Co. of Michigan. Mr. J. W. Wheeler, who has the management of the company's works at Paris, accompanied me in a recent visit to the mine, which is situated one mile and a quarter east of the town of Paris, on the south side of the Grand river. The mining right comprises 140 acres, and has been constantly worked for the last seven months by a few men who mine the gypsum and deliver it at the mouth of the shaft by contract at $1 per ton. It is taken out of the mine on a small hand car. The company provides the timber for the mine. A drift, starting at the foot of the hill a few feet above the level of the waters of Grand river, has been run in 400 feet in a southwest direction, passing most of the distance through the old workings of the mine, done in former years, but radical changes are required to make it safe and convenient for working the mine. Along the front of the bank of the river the gypsum has been worked out for a considerable distance; further back under the hill, at a depth of 130 feet from the surface, where it is now being taken out, there is apparently a large body of mineral still. The bed is composed of gray interstratified with layers of pure soft white gypsum, and averages 5 feet in thickness. A slate roof a few feet only in thickness overlies the gypsum with clay and boulders above to the surface; and to render it secure and safe requires additional supports at the place of working. I gave instructions for this to be done. In places in the old workings the rock roof was left in a dangerous condition. The air was foul in the mine and at times the men were unable to continue work on this account. Another drift should be opened about 75 yards west of the present one and driven in to the present workings. It should be made sufficient in size and securely walled up so as to render it a convenient way for carrying on the work of the mine with safety and economy. The present drift should be abandoned for working purposes, but left open to secure proper ventilation in the mine.

I was informed by the manager that it was the intention of the company to renovate the workings. This being done the property will probably become a large producing one, notwithstanding the removal already during thirty years of immense quantities of gypsum.

MICA.

The export of cut mica entered at the American Consulate at Kingston for the past year was of the value of $5,723. In addition to this a considerable trade was done in supplying the requirements of the home electrical and stove trades. White mica has been raised in the townships of Miller and Palmerston and county of Frontenac, and resumption of the industry is likely to happen. The importance of this mineral appears from the increasing demand for electrical purposes, along with the diminution of the supplies from the producing mines in the United States. The following figures are taken from the recent annual statistical review of the New York Engineering and Mining Journal of cut mica produced in and imported into the United States:

Year.	Imports.	Home production.	
		Quantity.	Value.
		lb.	
1881	$5,839	100,000	$250,000
1882	5,175	100,000	250,000
1883	9,884	114,000	285,000
1884	28,284	147,410	368,525
1889	97,351	49,500	50,000
1890	161,740	....	32,569
1891	132,744	....	....

The manufacture of ground mica, which is said to be profitable, has not yet arisen in this province, and it must be stated in this connection that a large trade in grinding low grade phosphates, actinolite, talc, ochres and mica apparently is waiting for development at Sydenham village in Loughborough, or at any one of the many points in the region referred to where cheap water power may be had.

The Sydenham Company's Works.

The mica mine owned by the Sydenham Mining and Mica Co. near the lake at Sydenham has been lying idle throughout the year. The same company owns a property yielding pure white mica situated in the township of Effingham, in the county of Addington, respecting which Mr. Lacey says that "the output has been satisfactory and of high grade as to quality, and a ready sale has been found for it in the home market for stove purposes." A force of 12 men was employed for eight months during the year, but work has been suspended for the winter. The company's cutting works are in the village of Sydenham.

Foxton's Mine and Works.

The mica cutting works of Mr. Fred. Foxton are in Sydenham, and he owns a mica property two miles west of the town, on lot 7 in the eighth concession of Loughborough. This property was not being worked at the date of my visit; it had been extensively worked during the former part of the year, and work will be resumed again with a force of 6 or 8 men in about ten days. A good return of amber mica had been obtained from this mine.

Mr. Foxton owns another mica property 16 miles north of Sydenham, in the township of Bedford, known as the Devil Lake mine, situated on the shore of a lake bearing the same name The property had been worked with 18 men for the last six months in two shifts, day and night. They had been laid off for a couple of days at the time of my visit, but I was informed work would be resumed in about two weeks with the same force of workmen. This property has yielded a large quantity of colored mica.

Wakefield Mica Mine.

A note appears in the August number of the Canadian Mining Review of Ottawa, as follows: "Mr. T. J. Waters has some forty men working day and night on his mica property recently purchased from Messrs. Skead & McVeity, and this mine is doing better than ever, producing about 30 tons rough per week. A cutting plant will shortly be put in." In the October number of the same publication mica properties are reported in the Kingston district: "Mica in large crystals, white and of tough, strong quality, has been obtained on lots 11, 12 and 13 of the southwest range on the colonization road in Abinger township and on lot 7 in the fifth concession of Effingham township."

Bedford Mills Mine.

Pine & Co., of Boston, Mass., have leased an old phosphate property near the new Bedford mills on Blue lake, and were engaged in sorting over some of the old phosphate dumps and opening some new leads. A tunnel had been run into the hill for a distance of 150 feet, starting about 12 feet above high water mark on the lake; a good yield of phosphate had been obtained. About 20 rods from the opening of the tunnel, and on the summit of the elevation, a shaft had been sunk to the depth of 65 feet and a considerable quantity of amber mica had been taken out.

The Godfrey Mine.

Mr. V. P. Day of Harrowsmith, on the Kingston and Pembroke railway, writes of recent date respecting the Godfrey mica mine: "This property is on lot 2 in the first concession of the township of Hinchinbrook, county of Frontenac, on the line of the Canadian Pacific railway, a quarter of a mile from the track and one mile from Godfrey station. The property is owned by Mr. O. H. Godfrey, but has been worked only six months during the year. Eight prospect pits have been opened, averaging 14 feet in depth. Of the output 60 tons of mica in the rough as selected at the mine have been sold from $120 to $200 per ton. There is still a large quantity of valuable material on hand. The quality is very superior light amber, very hard and flexible. As yet the leading vein has not been discovered. In all the pits opened mica has been found in paying quantities, and is on a second ledge supported by a heavy slide of gray spar extending fully a quarter of a mile. It is intended to prosecute the work vigorously next season."

The Frontenac Region.

Amber and brown mica are generally found with the phosphates of Loughborough, Storrington and Bedford in Frontenac. It may be here incidentally stated that a line drawn from Sydenham village in Loughborough to Sharbot Lake in Oso would be the axis of a mineral region in which have been found magnetic and hematite ores, galena, baryta, phosphate of lime, mica and graphite. The same region affords excellent sandstone, marble and soap-stone. The bands of crystalline schists in which mica is found are numerous, and but few have been developed. This region has been the only producer in Ontario for several years.

ASBESTOS.

The Engineering and Mining Journal of New York, giving the statistics for 1891, says (page 7): "Asbestos of inferior quality is found in a number of localities in the United States, but these have never become very important. The chief source of the fibrous asbestos suitable for weaving formerly was Italy, but since 1879 the Canadian mines near Thetford, province of Quebec, just north of Vermont, have become the chief source. The mineral occurs in veins with fibres perpendicular to the walls. Four grades are made. No. 1 has fibres one inch long and upwards, and sells now for $170 or more per ton; No. 2 has fibres under one inch but still good for weaving; No. 3 has bits of gangue mixed with the fibres; and No. 4 is the waste material good only for grinding. The American market is principally supplied with the Canadian asbestos."

The total production of asbestos for the Dominion of Canada for the year 1890 was 8,000 tons, valued at $1,039,661, equal to nearly $130 per ton.

On lot 13 in the ninth concession of Marmora, containing 100 acres, Mr. J. C. Boyne of Marmora has opened an asbestos mine by sinking several test pits of a few feet in depth over an area of two acres, from which a small quantity of excellent asbestos has been obtained. It is found on a hill ranging from 50 to 70 feet in height, and has been worked to only a limited extent. It is the intention of the owner to work the property with a strong force in the spring. The property is two miles from Rowan station on the Central Ontario railway, adjoining the public road.

THE METALLURGICAL INDUSTRY.

Without some development of the metallurgical industry the future of mining enterprise in this province will always fluctuate with the varying changes of opinion as to the value of mining investments, with the changes of tariffs, with the cost of transportation to manufacturing centres and with the competition of foreign mines. I communicated in my last report some opinions given me by persons interested in the mining industry as to the best means of developing the mineral resources of the province. An article on the subject of the metallurgic department of the Sheffield (Eng.) Technical School, in the Canadian Mining Review for November last, may be permitted insertion here.

To Prof. Arnold's laudable ambition of establishing a metallurgic workshop-school that should be an actual copy of the appliances and practical methods of the very best systems of steel manufacture and iron founding is due the creation of this institution, for which it is claimed that it will "enable a student to perfect himself in the actual art of manufacture and permit him, with a confidence born of actual experience, to take a prominent position amongst the supervising and controlling staff of a steel-manufacturing establishment." If in the very cradle of steel-manufacture an institution of this kind is necessary and meets with the approval of the highest technical authority, how much more should the necessity for a still more complete equipment for instruction in metallurgy impress itself on the people of this country, [who have a wider range of mineral resources awaiting development, and the necessity before them of either educating their youth in metallurgical knowledge of the first order or of remaining ignorant and inept as a people in these industrial enterprises which withdraw year after year millions upon millions for metal manufactures within the scope of native resources, and more lamentable loss still—withdraw yearly a considerable portion of the industrious youth of the land.

Passing from the description of the engineering shops, physical laboratory and woodworking departments, the following is an outline of the equipment of the metallurgic department, given with plans in an extra edition of the London Ironmonger of the 10th ult.:

The open-hearth steel furnace—of 25 cwt. capacity—with a complete gaseous fuel plant and hydraulic machinery; a 50-ton testing machine; a crucible steel house, with two melting holes, pot house and pot-making tools; a flame and ore-annealing furnace for malleable iron castings; an iron foundry equipped with belted cupola, drying stove and green sand castings. The laboratory is equipped with the most modern apparatus for rapid and accurate chemical examination of iron and steel, fuel and refractory materials. Apertures are provided at various parts of the furnace for testing temperature, for aspiring gases for analysis and for the spectroscopic examination of combustion and oxidation. By means of glycerine vacuum gauges the pressure and velocity of the gases in any part of the furnace can be ascertained. It is therefore possible to obtain a complete diagnosis of the furnace—both thermic, physical and chemical—at any stage of its operation. The hydraulic plant in connection with the furnace consists of a compressor, accumulator, ladle crane, centre crane and ingot breaker. The iron foundry has a cupola for melting half a ton of metal. The gaseous fuel generating plant is fitted for demonstrating the various different characters of useful combustible gases from solid and liquid hydrocarbons.

Amongst the donors to this institution are the dukes of Norfolk and Devonshire, Sir T. Mappin, the town trustees and Thomas Jessop, for a total of £8,000. Some ancient guilds and trading companies have assumed a yearly liability of £1,750 for five years, and Sir T. Mappin has given £1,000 towards a prize fund. The endowment fund is not fully quoted, but it is altogether likely that the above statement comprises the principal part of the equipment and sustentation fund.

An institution sufficiently comprehensive to take in the whole field of metallurgic operations, designed "to be an actual copy of the appliances and practical *modus operandi* of the best systems of iron and steel manufacture," with the addition of the Bessemer process, and also with a plant for the reduction of gold, silver, copper, nickel and lead ores, and for refining these métals, "such as to enable a student to perfect himself in the art of manufacture and to permit him with a confidence born of actual experience to take a prominent position amongst the supervising and controlling staff of a steel manufacturing or indeed any metallurgical establishment," was submitted in outline to the consideration of the Ontario Government last year in Inspector Slaght's report. Time will conclusively show that no other system for placing the foundation of mining as well as metallurgical enterprise on a sure basis can compare with this. But time is in this country the element which costs, although there is an oriental wealth of it everywhere. So many others get ahead. Even Russia in the midst of her hunger-stricken peasants, is devising well-laid plans for great iron manufactures which command the attention of western Europe, and will no doubt draw to her large sums for investment. Illustrations just like this will continue as the years go by until our forests become huckleberry jungles and our mines the property of foreign enterprise, reaping wealth in fields of industrial activity which we seem unwilling to learn how to occupy. All this will come to pass unless our Governments, Federal and Provincial, will wake up.

TRANSMISSION OF POWER.

The extensive application of electricity for the transmission of power from waterfalls to mining sites for running mining machinery may call for legislation to enable parties to run their wires over the property of neighboring owners. The erection of systems of wire rope transmission for carrying ores from mines to railways and navigable streams may also require to be facilitated by extending to them the operation of the Act which enables mining concerns to construct tramways and expropriate property therefor.

A. SLAGHT, Inspector.

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MAP OF PARTS OF THE DISTRICTS OF
NIPISSING AND ALGOMA
EXHIBITING THE COUNTRY AROUND SUDBURY AND EASTWARD TO THE OTTAWA RIVER.
Compiled from plans of survey by the Department of Crown Lands, Toronto, and plans of survey by the Geological Survey Department, Ottawa
1892.
SCALE, 4 MILES TO AN INCH.
EXPLANATION OF COLORS.
D
LOWER SILURIAN.
Consisting of reddish and greenish marls at the base, followed by limestones of the Trenton group, and the black shales of the Utica formation.
C
CAMBRIAN.
Consisting of dark colored sandstones, black slates and volcanic breccia.
B
HURONIAN.
Consisting of Greywackes, quartzite, clay-slate, crystalline-schists, etc.
Dia
GREENSTONES.
Including diabase, diorite, and gabbro.
A
LAURENTIAN.
Consisting of gneiss, granite, quartz, syenite, mica-and hornblende-schists, quartzite, etc.
LAKE NIPISSING
LAKE HURON
LAKE KEEPAWA
MANITOULIN ISLAND
FIRST REPORT B EAU OF MINES.
DEPARTMENT OF OWN LANDS ARDY.
The Copp, Clark Co. Lim^{ted} Lith. Toronto