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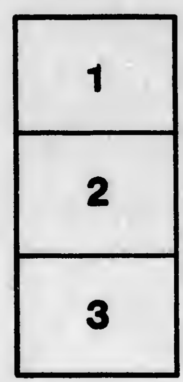

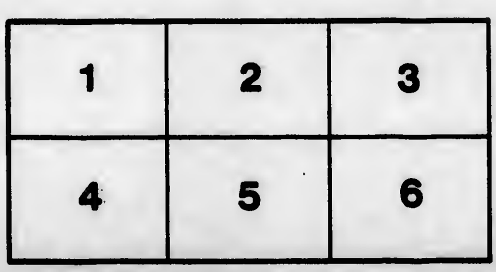

426.

ECONOMIC MINERALS OF THE PROVINCE OF ONTARIO, CANADA.

A PAPER READ BEFORE THE FEDERATED INSTITUTION OF MINING ENGINEERS.

BY

WM. HAMILTON MERRITT.

ANNUAL GENERAL MEETING AT HANLEY,
SEPTEMBER 18TH, 1895.

EXCERPT FROM THE TRANSACTIONS OF THE FEDERATED INSTITUTION OF MINING ENGINEERS.

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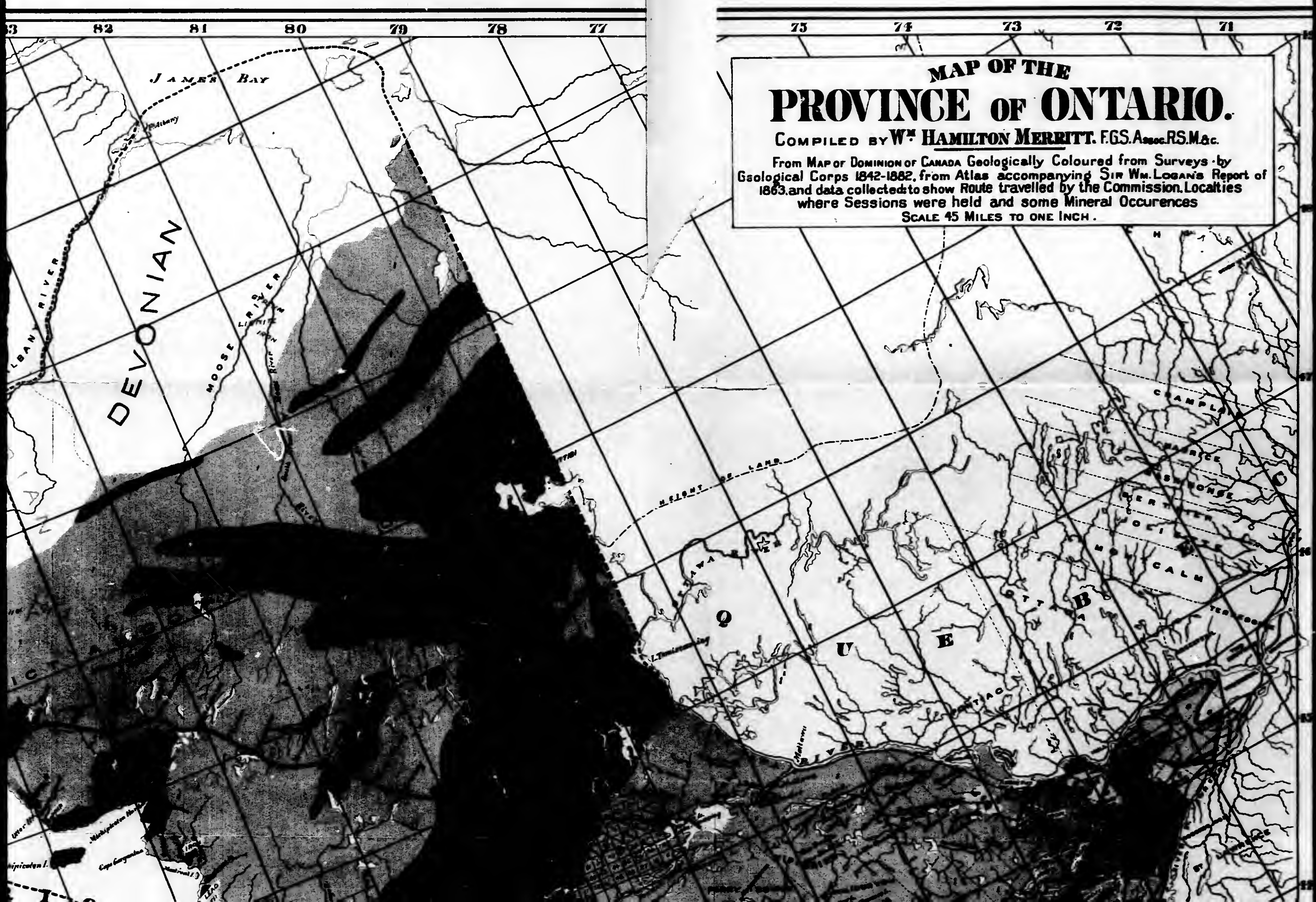
MAP OF THE
PROVINCE OF ONTARIO.
COMPILED BY Wm. HAMILTON MERRITT. F.G.S. Assoc. R.S.M. &c.
From Map of Dominion of Canada Geologically Coloured from Surveys by Geological Corps 1842-1882, from Atlas accompanying Sir Wm. Logan's Report of 1863, and data collected to show Route travelled by the Commission. Localities where Sessions were held and some Mineral Occurences
SCALE 45 MILES TO ONE INCH.
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JAMES BAY
DEVONIAN
MOOSE RIVER
RIVER
HEIGHT OF LAND
Q
U
E
B
MONTCALM
CHAMPLAIN
OTTAWA RIVER
PONTIAC


LAKE HURON
LAKE ONTARIO
LAKE ERIE
MICHIGAN
GEORGIAN BAY
NORTH CHANNEL
SAGINAW BAY
CHIPPEWA
OSWEGO
ONEIDA
JEFFERSON
LEWIS
ST LAWRENCE
WAYNE
GENESEE
WYOMING
ALLEGANY
CATTARAUGUS
CHAUTAUQUA
STEUBEN
McKEAN
POTTER
WARREN
ERIE
CRAWFORD
ELK
YATES
CHEMUNG
ST CLAIR
LAPEER
SANILAC
TUSCOLA
BAY
SAGINAW
GRATIOT
MONTCALM
MECOSTA
NEWAYGO
OCEANA
MANISTEE
WEXFORD
CLARE
CLADWIN
MIDLAND
ISABELLA
OSCEOLA
LAKE
OGEMAW
ROSCOMMON
CRAWFORD
OSCODA
ALCONA
OTSEGO
MONTMORENCY
PRESQUE ISLE
CHEBOYGAN
EMMET
CHARLEVOIX
KALKASKA
GRAND TRAVERSE
MACKINAC
SCHOOLCRAFT
KEWAUNEE
MANITOWOC
CALUMET
DOOR
STRAIT OF MACKINAC
Manitoulin Is.
Long Point
DETROIT
Michipicoten I.
Cape Gargantua
Point Aux Mines
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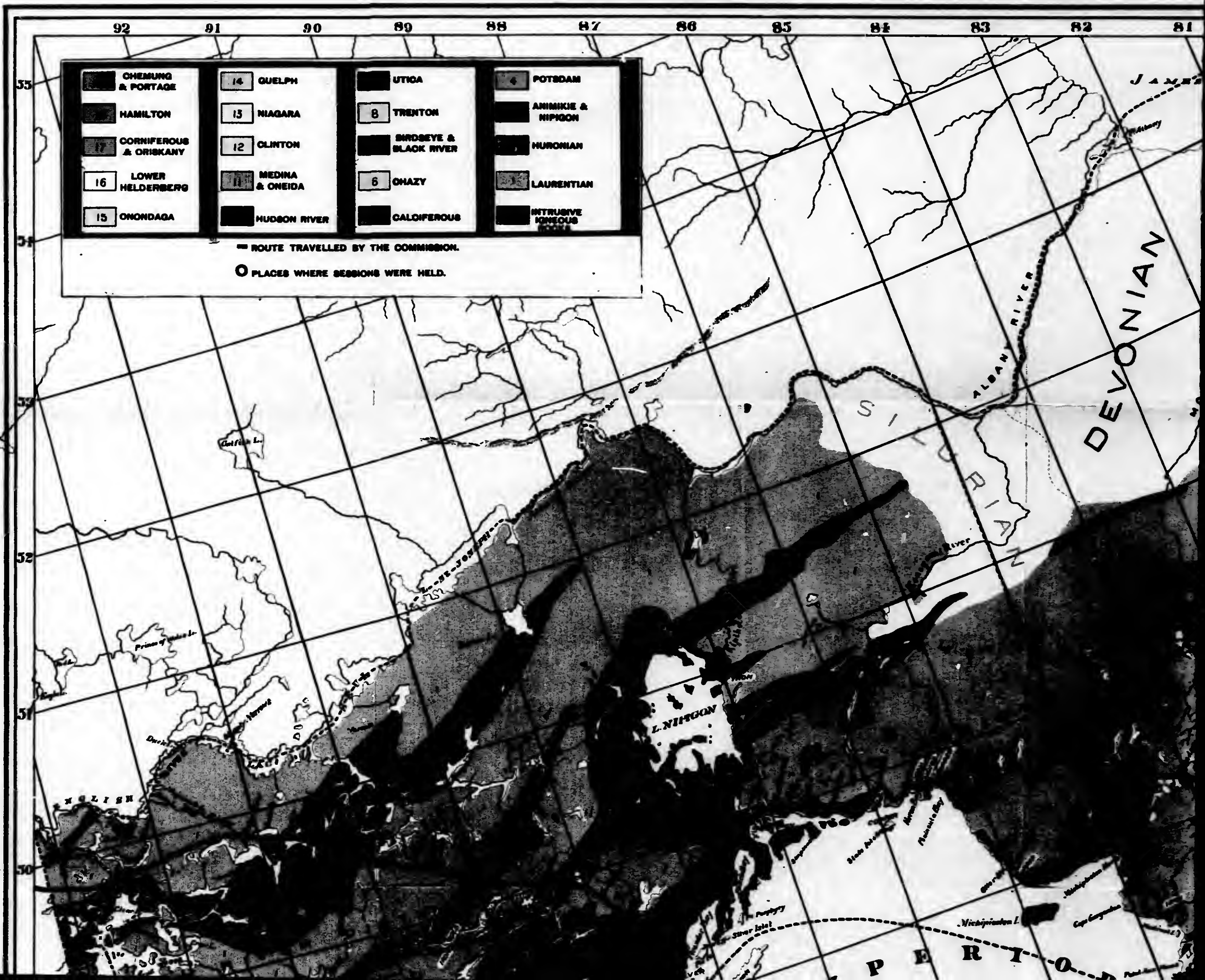
TORONTO LITHO. CO.



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CHEMUNG & PORTAGE
HAMILTON
17 CORNIFEROUS & ORISKANY
16 LOWER HELDERBERG
15 ONONDAGA
14 GUELPH
13 NIAGARA
12 CLINTON
11 MEDINA & ONEIDA
HUDSON RIVER
UTICA
8 TRENTON
BIRDSEYE & BLACK RIVER
6 CHAZY
CALCIFEROUS
4 POTSDAM
ANIMIKIE & NIPIGON
HURONIAN
LAURENTIAN
INTRUSIVE IGNEOUS ROCKS
ROUTE TRAVELLED BY THE COMMISSION.
PLACES WHERE SESSIONS WERE HELD.
DEVONIAN
SILURIAN
ALBANY RIVER
L. NIPIGON
Michipicoton I.
Nipigon Bay
Peninsula Bay

LAKE SUPERIOR
MICHIGAN
ENGLISH
PEMBINA
RED LAKE
ITASCA
BELTRAM
CASS
BECKER
OTTER TAIL
WILKIN
GRANT
DOUGLAS
STEARNS
ANOKA
AITKEN
CROW WING
MILLE LACS
CARLETON
DOUGLAS
BURNETT
POLK
BARRON
ASHLAND
CHIPPEWA
MARATHON
SHAWANAW
OCONTO
MARQUETTE
MENOMINEE
ONTONAGON
HOUGHTON
IRON RANGE
VERMILION IRON RANGE
ST CROIX
EAU CLAIRE
WOOD
KEWAUNEE
Minneapolis
St Paul
Ely
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ECONOMIC MINERALS OF THE PROVINCE OF ONTARIO, CANADA.

By WM. HAMILTON MERRITT.

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ECONOMIC MINERALS OF THE PROVINCE OF ONTARIO, CANADA.

By WM. HAMILTON MERRITT.

GEOGRAPHY.

The Province of Ontario is the most central province of the Dominion of Canada, unless the much smaller Province of Manitoba, abutting immediately on the west, can more properly claim that position.

Ontario closes around the northern shores of all the great chain of lakes, and stretches east and west (from near the junction of the Ottawa and St. Lawrence rivers to the Lake of the Woods) for a distance of about 1,250 miles.

The great extent of territory covered by this province from east to west will perhaps be more easily recognized when it is stated that it overlaps parts of the States of New York, Pennsylvania, Ohio, Michigan, Wisconsin, and Minnesota of the United States of America, bounding the Province of Ontario on the south.

From the Great Lakes the province stretches, in somewhat a wedge-shape with a broad base, to the shores of James' Bay (the southernmost bay of Hudson's Bay), a distance from Toronto (on Lake Ontario) to the mouth of the Moose river (on James' Bay) of 540 miles, and from the northern shore of Lake Superior to Fort Albany (also on James' Bay) a distance of 350 miles.

The population of the province was placed at 2,114,321 in the census of 1891, chiefly resident in the eastern portion, or the peninsula, of Ontario.

Its total area is 222,000 square miles, including 2,350 square miles of water.

Fig. 1 (Plate VIII.) is a sketch-map of the Province of Ontario, and gives an idea of its situation and area. The approximate general position of the more important economic minerals is indicated on the map.*

* Owing to the small size of the map, some of the mineral deposits have been lettered on the wrong formation, though in the immediate vicinity of where they actually exist.

Geology.

The greater part of Ontario is composed of Archæan rocks, concerning which a vast amount of work yet remains to be done. The more these older rocks are investigated the more clearly is their value recognized as the bearers of useful minerals. Especially is this the case with the Huronian, which occupies great stretches of country, lying to the north of Lakes Huron and Superior and in the Rainy river district. These rocks are similar to the great iron-bearing series of northern Michigan and Minnesota, which, in several places in Ontario (as well as near Ishpeming, Michigan), have also been proved to carry gold-bearing quartz-veins. Overlying the Archæan, the Cambrian, Silurian, and Devonian formations occur most extensively in the peninsula of Ontario, between Lakes Ontario and Erie on the south and Georgian Bay and Lake Huron on the north, and continued on to Great Manitoulin Island to the westward. A considerable area of these post-Archæan formations occurs between the Moose and Albany rivers, to the south of James' Bay, which they fringe. Patches of Cambrian rocks of economic importance occur in the vicinity of Thunder Bay, fringing Lake Nipigon, also on Michipicoten Island, and at Point Mamainse, and a small Cambrian and Silurian area forms the extreme eastern end of the province between the Ottawa and St. Lawrence rivers.

With the exception of recent clays and gravels, no formation of greater age than the Devonian is found in the Province of Ontario.

The writer has endeavoured, by shading the above-mentioned map, to designate the geological systems or epochs, but without colouring it is not possible to conveniently designate the subdivisions or groups, a designation which, however, for the purposes of this paper is not necessary.

The geological divisions of the rocks of Ontario, in descending order, are as follows:—

Systems.	Formations.
Recent	... Soils, peat, shell-marl.
	Lacustrine and fluviatile clays, sands, etc.
Pleistocene ...	... Saugeen clay, Artemesia gravel, Algoma sand.
	Sand, gravel, and shingle of the country north of the Great Lakes.
	Erie clay, calcareous and non-calcareous.
	Clays, north of the Great Lake.
	Boulder-clay, drift, or till.
Devonian ...	... Chemung and Portage.
	Hamilton.
	Corniferous.
	Oriskany.

UPPER SILURIAN ...	Lower Helderberg.
	Onondaga.
	Guelph.
	Niagara.
	Clinton.
	Medina and Oneida.
LOWER SILURIAN ...	Hudson river.
	Utica.
	Trenton.
	Black river and Bird's-eye.
	Chazy.
CAMBRIAN	Calciferous.
	Potsdam.
	Nipigon.
	Animikie.
ARCHÆAN	Huronian.
	Laurentian.

Owing to the absence of fossils considerable difficulty occurs with reference to the division of the lower series. The Laurentian is variously divided into two or three groups, and the Huronian has been divided into two divisions in different fields by some observers; but the work done so far in this direction in Ontario is not conclusive.

Considerable uncertainty also exists as to the exact ages of the Animikie and Nipigon rocks.

United States geologists now pretty generally give the name of Algonkian to the series of rocks older than the Cambrian, and younger than the fundamental complex of non-clastic crystallines for which the term Archæan is still retained. On the south side of Lake Superior, according to Messrs Irving and Van Hise, the Algonkian consists of an aggregate thickness of over 60,000 feet of rocks in which three general subdivisions, separated by great unconformities or time-breaks, have thus far been recognized. The Keweenawen or copper-bearing series, which consists of sandstones, conglomerates, lavas and tuffs, being the upper, and resting unconformably upon the two great iron-bearing series of the Upper and Lower Huronian, which include all the economically important iron deposits at present known in the region.

ECONOMIC MINERALS AND THEIR OCCURRENCES.

The mineral production of the province for the year 1894 is given by the Bureau of Mines, as shown in the table on the opposite page.

In speaking of the economic minerals, it might for some reasons have been preferable to limit the description to only such as are being worked at the present time, but the author's object is to point out minerals which

Product.		Quantity.	Value.	Workmen.	Wages.
			Dols.		Dols.
Dimension-stone ...	cubic feet	1,340,000	360,470		
Heads and sills ...	„	47,070	15,900		
Coursing-stone	square yards	22,000	36,000	854	336,700
Rubble, etc....	cubic yards	223,000	142,000		
Sand and gravel ...	„	733,500	203,450	175	61,650
Natural rock-cement	barrels	55,323	48,774	63	13,020
Portland cement ...	„	30,580	61,060	105	31,858
Lime	bushels	2,150,000	280,000	575	108,000
Drain-tiles	number	25,000,000	280,000	2,375	388,000
Common bricks ...	„	131,500,000	690,000		
Pressed bricks, plain	„	22,460,000	198,510		
Pressed bricks, fancy	„	2,896,000	34,160		
Roofing-tiles ...	„	100,000	1,200	209	95,400
Terra-cotta	...	......	52,360		
Sewer-pipes	...	......	207,000	56	23,000
Pottery	...	......	134,000	160	47,000
Gypsum ...	tons (2,000 lb.)	3,253	9,760	36	9,500
Calcined plaster, etc.	„	1,442	22,697		
Salt	„	35,215	115,551	135	43,350
Nickel	„	2,570½	612,724		
Copper	„	2,748	195,750	655	311,719
Cobalt	„	3¼	3,500		
Gold	ounces	2,022½	32,776	92	38,032
Petroleum ...	imperial gallons	34,912,360	......	......	......
Illuminating oil ...	„	14,349,472	1,337,040		
Lubricating oil ...	„	3,817,181	242,688		
All other oils ...	„	10,632,141	343,416	486	279,930
Paraffin wax ...	... lbs.	2,754,300	152,467		
Fuel product ...	...	......	71,326		
Natural gas, thousands of cubic feet		1,653,500	204,179	99	53,130
Totals		......	6,088,758	6,075	1,840,289

occur in workable quantities, geologically speaking, although through a depression of prices, as in the case of silver, or for lack of capital, as in the case of iron, they are not being worked at the present time.

The minerals which are believed to exist in the province in workable quantities will be described shortly, and some of the more important localities where they are found alluded to, with perhaps a typical example or two of the mode of occurrence.

While the writer has not hesitated to draw from the Government reports for information or illustration, most of the descriptive matter and nearly all the illustrations are taken from personal observation for nearly twenty years.

Arsenic.

Arsenic has been produced from mispickel, obtained from arsenical gold-veins, cutting syenite, in Hastings county. At present the industry is quiescent, but it will in all probability be resumed some day, as several of the veins in the above-mentioned district are heavily charged with mispickel, and the average gold content of the veins is said to be satisfactory. One large works was constructed at which the ore was crushed, rolled, concentrated, roasted, and chlorinated. The gold values were not nearly extracted and the tailings were washed with profit. The mispickel carries in places about 14 dollars of gold per ton on an average, and it has been found containing 6 ounces of gold per ton. The following are some examples of gold contents of arsenical pyrites from the Marmora district, Hastings county, collected in about one pound lots by officers of the Geological Survey and assayed by Dr. Hoffman, chemist of the Survey:—Ounces of gold per ton of 2,000 pounds, (*a*) 0·467, (*b*) 0·175, (*c*) 2·392, (*d*) 1·400, (*e*) 1·633, (*f*) 2·858, (*g*) 0·117, and (*h*) 0·117.

Antimony.

Stibnite has been found near Sault Ste. Marie. The vein is said to occur in a chloritic schist, and to comprise 18 inches of pretty solid ore with 4½ feet more of vein-matter containing stibnite, sparsely disseminated through it. Antimony has also been found in Barrie township, and is alluded to further on under the heading of *Silver*.

Building-materials, etc.

Under this heading come a great variety of substances in which Ontario is exceptionally rich, viz., ordinary building-stones, granites, marbles, sandstones, limestones, natural cement-rock, the ingredients for Portland cement, clays suitable for bricks and tiles, and clays suitable for use in the manufacture of earthenware, terra-cotta, and sewer pipes. Practically speaking, it may be said that there is an unlimited supply of all the above substances, and that it is merely the lack of demand which limits their production to almost any extent.

Granites and marbles are found in many localities, varying in structure and colour, and in freedom from joints and cracks, which conditions determine their suitability for building or ornamental purposes.

The demand for ornamental stone is small in the province, and it is imported to a considerable extent, the expenses of opening up a quarry and procuring a modern plant for extracting the stone in most cases more than off-setting the comparatively small local demand.

The only granite-quarry at present in operation is at Kingston, where a pinkish quartz-syenite is quarried and taken in barges to the mill at Ottawa, where it is cut and polished. The refuse at the quarry is broken up into blocks for pavement. The granites are of Laurentian and Huronian age, chiefly the former.

The marbles are generally highly crystalline and occur in thick beds in the Upper Laurentian, usually designated "crystalline limestone." Oftentimes they are pure white, and present a beautiful appearance when polished. In other places slabs of salmon-pink colour are obtainable, and again light grey and dark grey (almost black) coloured marbles are quarried, especially for monumental purposes.

This crystalline limestone occurs in enormous beds of 500 and 1,000 feet and upwards in thickness. It resists the weather remarkably well; edifices with this material built into them have shown little effect from the weather after from twenty to forty years' exposure. At Gouverneur, in the State of New York, where a large market is enjoyed, the operations on this marble are enormous. Fig. 2 (Plate VIII.) is an example of one occurrence in Ontario.

The Huronian marbles are not so largely crystalline as the above-mentioned, they are more homogeneous and of the close-grained texture that we are accustomed to see in marble. A great band of this marble, about 250 feet wide, occurs near Sault Ste. Marie, made up of a soft blending of green, pink, and pure white bands. The occurrence of this bed is represented in Fig. 3 (Plate VIII.).

Sandstones for building purposes are obtained chiefly from the Nipigon formation, which yields both red and white sandstones of excellent quality; from the Potsdam, which yields sandstones suitable for glass-making as well as building-stone; from the Medina (Fig. 4, Plate VIII.), which supplies the city of Toronto and vicinity with both white and brownish-pink coloured sandstone (the latter especially being highly esteemed as a building-stone), and from part of which grindstones and scythe-stones are manufactured or can be manufactured.

The sandstones of the Oriskany, at the bottom of the Devonian, are excellent for building purposes, and glass can also be made from them.

Perhaps the formation which yields the best material for glass-making, so far as purity and the absence of any colouring matter is concerned, is the Huronian, in which great thicknesses of pure white quartzite are found.

Sandstones are found in the same formation, though not yet worked, also a handsome jasper-conglomerate and ornamental argillites.

Of other ornamental stones, serpentines have been found, but they are not yet developed to any considerable extent.

Common blue-bedded limestones and dolomites abound, and are especially quarried for building purposes from the Black river and Bird's-eye, the Trenton, the Guelph, and to a less extent from the Onondaga, and the Corniferous formations.

All of the above-mentioned limestones, including the marbles of the Laurentian and Huronian, are burned into excellent lime in different parts of the province.

Lithographic stone is quarried from the Black river and Bird's-eye formation near Marmora. Much of the stone is well adapted for lithographic work, but there are other layers in which the development of small crystals of calcite detracts from its usefulness for this object.

Natural cement-rock is quarried, burnt, and ground from one of the lower beds of the Niagara formation, and also from a layer in the Trenton formation. The cement-rock in the *Eurypterus* beds of the Lower Helderberg, which is developed to a very large extent in the United States, has not yet been operated in Canada. These natural hydraulic cements stand strain-tests of from 100 to 190 pounds to the square inch in 30 days.

Portland cement is also manufactured from calcareous marl and clay in several places, and it is said to compare very favourably with imported Portland cement, tensile tests per square inch of section of 425 pounds being recorded in 6 days and of 660 pounds in 90 days.

Clays for brick or tile-making purposes are common in all parts of the province. The Erie clay burns to white bricks and tiles, while the marine clay to the east burns to a red colour. The decomposed red shales of the Medina formation furnish a red clay, from which terra-cotta work and the best quality of red pressed-bricks are manufactured. Fig. 4 (Plate VIII.) shows the mode of occurrence of this clay. The Medina formation is exposed for a very considerable distance, and the clay-bed sometimes reaches a thickness of 175 feet.

Kaolin is reported to have been found along the Missinaibi and Moose rivers, Algoma district, but it has not yet been developed.

Talc and actonolite are found in a number of places in Eastern Ontario, and are used as a lubricant, for fire-proof roofings or linings, etc.

A somewhat impure asbestos has also been found with serpentine in several places, but as yet workable veins of the fibrous serpentine (chrysotile), which is developed to such a large and profitable extent in the eastern townships in the province of Quebec, has not been found in Ontario.

Gypsum.

This mineral is found in the Onondago or gypsiferous formation of the Upper Silurian. It occurs in beds varying from 3 to 7 feet in thickness in the peninsula of Ontario, along the Grand river.

Dr. Bell reports the occurrence of beds of gypsum on the Moose river, towards James' Bay, of some 10 to 20 feet in thickness.

Along the Grand river, the beds occur in lenticular form, thinning off towards the periphery. There were different conditions during deposition as shown by argillaceous bands having been developed between the bands of gypsum. The following is a section of one of the beds:—

	Thickness.
Erie clay, or cannel clay	15 to 20 feet.
Boulder-clay, or hard pan, with nodules (often vesicular dolomite)	6 inches to 8 feet.
Blue shale	*nil* to 6 inches.
*Part mined**—	
Bluish gypsum, or "top stone" ...	*nil* to 1 foot.
White gypsum	2 to 3 feet.
Hard calcareous band...	"parting" to 2 inches.
White gypsum	1 foot.
Hard calcareous band, or "big band"	4 to 6 inches.
Greyish gypsum, sometimes absent...	average 1 foot.

Very hard calcareous band, 1 inch to 1 foot, and average 2 to 3 inches.
Mixed shale and gypsum.

The white gypsum is chemically pure gypsum, and the bands are a mixture of carbonate of lime and gypsum, with less than 2 per cent. of iron and alumina. Dr. Bell reports that

> Two grades of gypsum are found along the Grand river—the white and the grey. The latter occurs in the vicinity of Paris, and both in the beds lower down the river. The grey gypsum is used as a fertilizer, it being unsuitable in colour for alabastine, parian cement, plaster of Paris, or any kind of ornamental work. The white answers for any purpose, but should the demand increase, it will doubtless be used chiefly in the arts hereafter.
>
> The calcined plaster used in Ontario has, up to the present time, been supplied almost wholly from Nova Scotia and New Brunswick; but as an excellent article is now being made on the Grand river, at points convenient for shipment by railway, the manufacturers believe that they soon will be in a position to displace the Maritime provinces' plaster in the Ontario market.

The chemical difference between the white and grey, or pure and impure, is shown by the following analyses of the Ontario gypsums on the Grand River:—

	White.	Grey.
Sulphate of calcium	79·07	54·19
Insoluble matter	0·00	15·60
Iron and alumina	Trace	1·60
Carbonate of calcium	Trace	11·41
Carbonate of magnesium... ...	0·00	3·60
Water and loss	20·93	13·60
Totals ...	100·00	100·00

* The top is sometimes found to be grooved and polished by ice-action.

The mode of preparing stucco or plaster of Paris, as generally adopted both in the United States and Canada, varies somewhat from the methods in vogue in most European countries, where the rock is largely calcined before grinding or, where ground previously, is calcined on long stationary tables or on circular rotary tables. The practice on the North American continent is first to crush the rock through a Blake-type crusher, then to run it either through some form of disintegrator, or, in older style mills, through a cracker of the coffee-mill type, and, finally, the pulverized rock is brought to a flour fineness by the ordinary burrstone, dressed deeper than is usual in a flour-mill. The fine raw plaster is then run into a kettle of about 9 feet in diameter by about 6 feet high, which has four cross boiler-iron pipes, 10 inches in diameter, crossing through the inside. There is a heavy cast-iron ring for the bottom to rest on, and the bottom is composed of a heavy convex cast-iron casting. The top is covered with sheet-iron, and in it is a manhole for feeding in the plaster. In the centre is a wrought-iron shaft, with stirrers, which are kept in motion and prevent the plaster from being unequally calcined. When operating, the plaster boils violently inside this large pot and, with experience, the calciner can tell, by looking in the manhole, just when to stop and leave the desired amount of water in the plaster, thereby affecting its setting time. When finished the plaster runs out of a spout into a cooling bin. After calcining, the finest qualities are bolted through screens of 80, 60, and 40 mesh respectively. A kettle of the size mentioned above will calcine about 12 tons a day.

Salt.

Rock-salt occurs in very thick beds below the gypsum horizon in the Onondaga (salt-rock) formation. It is reached by borings in the western part of the peninsula of Ontario. The beds of salt run uninterruptedly into the States of Michigan and Ohio. In the borings which have been made, one or more beds are met with at a depth of about 1,000 feet from the surface, varying in thickness from 20 to 100 feet. The quantity is practically unlimited, and the quality is excellent.

The salt is obtained altogether in solution and then evaporated. The brine is generally about 100 degs. (one-fifth) salt, the maximum of saturation.

The overlying beds of gypsiferous rocks cause a certain amount of gypsum to be present in the brine, but most of it is got rid of in the process of manufacture.

As an example of a borehole, the following log is given. It was sunk by Mr. Attrill at Goderich:—

	Feet.	Inches.
Clay, gravel, and boulders...	78	9
Dolomite, with thin limestone-layers	278	3
Limestone, with coral, chert, and beds of dolomite	276	0
Dolomite, with seams of gypsum...	243	0
Variegated marls, with beds of dolomite ...	121	0
Rock-salt, first bed	30	11
Dolomite, with marls towards the base	32	1
Rock-salt, second bed	25	4
Dolomite	6	10
Rock-salt, third bed	34	10
Marls, with dolomite and anhydrite	30	7
Rock-salt, fourth bed	15	5
Dolomite and anhydrite	7	0
Rock-salt, fifth bed	13	6
Soft marls, with anhydrite	135	6
Rock-salt, sixth bed	6	0
Soft marls, with dolomite and anhydrite ...	132	0
Total depth bored ...	1,467	0

The following analysis of brine made by Dr. Sterry Hunt is a fair indication of its average quality:—

	Grains per Gallon.
Chloride of sodium	236·410
Chloride of calcium	0·190
Chloride of magnesium	0·410
Sulphate of calcium	4·858
Total	241·868
Specific gravity	1·187
Degrees of the salometer	92

The ordinary mode of raising the brine is by a pump making about 30 strokes a minute, lifting about 18,000 gallons per day of 10 hours. The brine is pumped into large vats or tanks, whence it can be directed at will into the evaporating-pans. The size of the ordinary pan is about 100 feet long by 26 feet wide, and it produces about 100 barrels of salt a day (280 lbs. to the barrel). The evaporation is produced by means of a fire placed underneath the pans.

The manufacture of salt is most largely developed in the counties of Huron, Bruce, and Lambton.

Nickel.

Nickel ore is worked only in one section of the country, about Sudbury, lying partly in the Nipissing and the Algoma districts. It occurs as nickeliferous pyrrhotite in greenstone of Huronian age. A greater or lesser quantity of copper pyrites is associated with the pyrrhotite in the different ore-bodies, varying from 7 to 0·75 per cent. or less of copper. The nickel content of the pyrrhotite averages from 1·5 to 3 per cent., but in some ore-bodies 30 per cent. of nickel ore (pentlandite) has been mined, and ore running about 10 per cent. of nickel has been shipped. Sometimes the pyrrhotite is found to carry little or no nickel. The remaining contents (besides nickel and copper) of the average ore runs about 63 per cent. of pyrrhotite and 30 per cent. of rock. Of nickel minerals, pentlandite, gersdorffite and niccolite are found.

The ore occurs irregularly in large lenses, dipping (south-east) and striking (north-east) with the formation. The ore is also found disseminated through the greenstone with which it has undoubtedly been brought up. The greenstone hills can be traced for long distances through the country, and the ore-deposits, occurring at uncertain intervals, are distinguished by the red colour given to the soil by the decomposed ferruginous matter or gossan. The ore is hard, and the ore-lenses as a rule form hills or mounds.

While differentiation explains the formation of perhaps most of the ore-bodies, yet examples of secondary action are quite clear in certain cases, such as at the Vermilion shaft where chalcopyrite forms veins and masses, with breccia of greenstone. Flucan and native copper in leaf form also point to leaching or segregation from the greenstone.

The section shown in Fig. 5 (Plate VIII.) will give a general idea of the occurrence of these ore-bodies. The ore is roasted in heaps after being passed through a Blake-crusher and hand picked. The heaps are usually about 6 feet high, and from 400 to 600 tons are put into a heap. The fuel used is dry pinewood, and when once thoroughly ignited the ore calcines readily. The heap burns from 30 to 50 days.

An average analysis of a roasted coppery ore is:—5·40 per cent. of copper, 2·43 per cent. of nickel, 7·92 per cent. of sulphur, 25 per cent. of iron, lime, magnesia, etc., and the residue chiefly consists of hornblende. In a non-coppery ore the copper is about one-half the nickel content.

The furnace used in smelting is a water-jacketed cupola of the Herreshoff pattern. It is nearly elliptical in form, having a longer diameter of 6½ feet, and a shorter of 3¼ feet at the twyers, increasing in size upwards, and is 9 feet in height to the charging-door. It is made of rolled steel with a water-space of 2 inches between the outer and inner plates, and has for its bottom a cast-iron plate protected by fire-brick, the whole resting on strong iron supports. The well, fore-hearth, or settling-pot is made of double plates of cast-iron, having a water-space of 6 inches, and rests upon four wheels for convenience of moving it whenever repairs are necessary, a second well standing ready to be put in its place. The blast is furnished by a Baker rotary blower and enters the furnace through eleven twyers under a pressure of 8 to 10 ounces per square inch. The charge consists of a mixture of calcined ore, raw ore and coke, the proportion being about 8 of ore to 1 of coke, and the slag takes off about 10 per cent. of the nickel in the ore and most of the cobalt, the slag often containing equal quantities of nickel and cobalt. The furnace smelts 120 to 150 tons per day, the proportion of slag to matte being about 8 of slag to 1 of matte. The slag is constantly discharging into pot trollies, in which it is rolled to the waste-heap. The matte is drawn at intervals through a lower tap-hole.

The matte of a coppery ore is:—

	Per Cent.
Copper	26·910
Nickel	14·140
Iron	31·235
Sulphur	26·950
Cobalt	0·235
Slag	0·935
Total	100·405

In a non-coppery ore, the nickel will run about 14 per cent., and copper 7 per cent., or where it is proposed to Bessemerize it further, the matte will be made to run about 9 per cent. of nickel and 4·5 per cent. of copper.

For shipment abroad, the matte is sometimes further concentrated by being Bessemerized in a Manhee converter, and it then runs about 40 per cent. of nickel and 20 per cent. of copper in ores which are of the non-coppery class.

No refining-works have been erected in Ontario, all matte being shipped abroad for treatment. The three principal companies operating are:—the Canada Copper Co. (who refine at Cleveland, Ohio, U.S.A.), the Vivian Co. (who refine at Swansea, Wales), and the Dominion Mineral Co., who sell their matte.

Cobalt is obtained to a small extent in association with the nickel extracted from the nickeliferous pyrrhotite.

Copper.

Copper-ores in Ontario come under three classes:—(*a*) Those connected with the large masses of nickeliferous-pyrrhotite in greenstone in the Sudbury and adjacent districts, of Huronian age. These are described above under nickel ores, with which they are associated. The deposits were opened up, at first, entirely on account of their copper-contents, the fact that they contained nickel not having been discovered. The copper production given in the provincial statistics has entirely been derived from this source and in connexion with the nickeliferous matte. (*b*) Quartz-veins cutting Huronian rocks, chiefly greenstones, are often found to carry copper pyrites. The vein worked some years ago at the Bruce mines in the Algoma district might be taken as an example of this class of deposit. At this place, quartz-veins, varying from 6 to 20 feet wide, cut greenstone, they carry about 4½ per cent. of yellow copper pyrites and a very little iron pyrites. The section (Fig. 6, Plate VIII.) shows the occurrence of these veins. In some veins in the same district, as in the township of Gould on the Mississaba river, there is a notable quantity of copper glance, with some bornite as well as chalcopyrite. (*c*) Native copper is found in conglomerate-beds of the Nipigon series on Michipicoten Island, in Lake Superior, and at Mamainse Point, on the same lake, in the district of Algoma. The occurrence is very similar to that of the famous mines of Calumet on the southern side of Lake Superior, but no such rich beds of copper have yet been opened up on the Ontario side of the lake, though there is every reason to expect that they may be found.

The rocks consist of reddish trap (sometimes porphyritic), amygdaloidal beds, volcanic tuffs, cherts, sandstones, and coarse conglomerates.

Generally speaking, the series consists of eruptive sheets and of sandstones and conglomerates, largely made up of a detrital eruptive material. The eruptives are mostly basic rocks, which were poured out as lavas upon the surface; but there are some eruptions of the acid type. The lavas and sedimentary beds are interstratified. These rocks have experienced intense and long-continued metamorphic action or alteration, which has produced amygdaloidal structure, and in certain parts has resulted in an entire change in the mineral composition of the rock.

The occurrence of native copper in the conglomerates is of peculiar interest. The copper occurs both in red and green conglomerates in small veins traversing the beds at right angles to the strike and the dip, in the amygdules, and in the interstices of the conglomerate. On Michipicoten, it occurs more as shot, barrel-copper, and irregular masses in the amygdaloid, in the grain form in the volcanic sandstone, and as stringers or metallic veinlets in the conglomerate, which is frequently bound together by them, especially where jasper nodules predominate.

The copper occurs in the beds in shoots dipping to the south-west, and the percentage varies from 2½ in sandstone, where it runs pretty regular, to 10 in the best ore-shoots in the amygdaloid. Fig. 7 (Plate VIII.) illustrates the mode of occurrence at Michipicoten. It is taken from a paper by Messrs. Herrick, Tight, and Jones, on that island.

At Mamainse, the copper chiefly occurs in the form of straggling masses and thin sheets in calcspar veins crossing the formation. The conglomerate-beds are much wider, and of coarser character than at Michipicoten.

It has been demonstrated that the copper had been deposited from wet solution in the process of rock-alteration, and as a pseudomorphous replacement of certain minerals in the rocks. It is assumed that these deposits are a concentration of copper salts once minutely disseminated through the centre series, and it is probable that the original form of the mineral in these rocks was sulphide. Copper glance is found with the native copper and small veins of carbonate at Point Mamainse. The deposits are remarkable for the comparative absence of other metallic minerals except silver, which occurs to a limited extent, in the native state.

Iron.

Iron ores are developed over a very considerable extent of country, both in eastern and western Ontario. In the eastern part, the ores occur in the so-called Upper Laurentian formation, in crystalline limestones, or at their junction with other rocks, such as greenstones, and hornblendic gneisses; or again, the ores are found in greenstones. Most of the deposits discovered up to the present have been found not far to the north of the Silurian fringe.

In the western part of the province, the great iron-ranges (Vermilion and Mesabi) of Huronian age, which have been so largely developed in northern Minnesota, continue into the Thunder Bay district of Ontario, to the south-east of Port Arthur. These ore-bodies give promise of very considerable extent. At present, on the Ontario side of the international boundary, they have been only prospected in a comparatively small extent of country, and no development work to speak of has yet been done.

In the northern part of the province, Dr. R. Bell reports the occurrence of an important bed of spathic iron-ore, partly altered to limonite (containing 52·42 per cent. of iron), in the Corniferous formation, exposed on the Mattagami river towards James' Bay.

Western Iron-ores.—The ores so far discovered in the Ontario western ranges consist of magnetite and hard blue specular-ore. In Minnesota, the very best grades of Bessemer hæmatite also abound, and so favourable is their occurrence in the Mesabi range that steam-shovels are used to extract the ore and dump it on the railway-cars, at an expense of from 50 to 75 cents per ton. As the Ontario continuation of the Vermilion and Mesabi ranges is not sufficiently developed to give satisfactory sections the author gives, from personal observation, a typical section (Fig. 8, Plate VIII.) of a deposit in the Vermilion range.

Fig. 9 (Plate VIII.) shows a section of a deposit on the Mesabi iron-range, and is taken from a paper on that subject by Mr. H. V. Winchell.

With regard to the percentage of iron in these western ores and their freedom from impurities, it will suffice to say that some of the ore-bodies already found in the Thunder Bay district are well within the Bessemer grade, one deposit of magnetite on Gunflint Lake showing a bed of 25 feet of ore which ran 68 per cent. of iron, 0·028 per cent. of phosphorus, sulphur *nil*, and very little silica. Dr. Robert Bell described a large deposit of magnetite on the Antler river lying about 100 miles west-north-west of Port Arthur, which is said to average 64 per cent. of iron, and of which he reports:—"In the widest part there are three beds, each about 50 feet in width, separated from each other by only narrow bands of rock, running with the general course of the belt to which they belong. The deposit shows workable quantities of ore at intervals for about 3 miles, and is traceable for about 5 miles."

Great interest attaches to the formation of these immense ore-bodies. There is generally an impervious bed below, and the filtration of ferruginous solution, with replacement, is the generally accepted theory. The observations of geologists of the United States Geological Survey indicate that the source of the iron has been largely the result of oceanic desposition, both chemical and mechanical, and the present ore-bodies are simply concentrations. Some of the ore-beds that have been worked in Minnesota are upwards of 100 feet thick, and from the above-mentioned facts, it would appear that there is every probability of developing as large or larger bodies on the Ontario continuation of the ore-ranges.

Tributary to Sault Ste. Marie, indications exist on the eastern shores of Lake Superior and to the north of the Ste. Mary river (which joins Lakes Superior and Huron) and Lake Huron of iron-ranges similar to the Menominee and Marquette ranges of northern Michigan. The ores are, for the most part, high grade, soft specular, and red hæmatite, in association with jasper.

Eastern Iron-ores.—In the eastern part of the province, about 500,000 tons of ore have been mined in all from time to time, but at present there is no ore being extracted. One blast-furnace is now under construction in the province and another is contemplated, and there seems a probability of a revival in the iron industry in the near future, especially as no more favourable opportunity exists anywhere for manufacturing the best grades of charcoal-iron. Geologically speaking, there is little question that large and persistent ore-bodies will be opened up when there is a steady demand. The rocks and the iron-ores in them are both altogether similar to conditions which exist in Sweden, where the same sort of ores, in identical rocks, have been mined for several hundred years over a tract of country extending for some 180 miles.

In Sweden, as in Ontario, a certain amount of hæmatite (about one-tenth) is found, but the majority of the ores in both countries found in the Archæan (Laurentian) rocks are magnetites.

Moreover, the same rocks which carry the iron-ore in Eastern Ontario cross the St. Lawrence river near the eastern end of Lake Ontario, continue through part of northern New York State, and are also continued into the State of New Jersey.

The development in New York State and in New Jersey has proved that on this continent, as well as in Sweden, the iron-ore deposits in these Archæan (Laurentian) rocks are capable of development to an enormous extent. The following extract from the *Annual Report* of the Geological Survey of the State of New Jersey for the year 1882* gives a very satisfactory idea of the experience gained in connexion with the permanency of the iron-mines:—"Their permanent withdrawal and final abandonment has come not so much from the lack of ore, or the exhaustion of the veins, but from the heavy expenses attending the working of them at a greater depth," etc.

The output in 1890 was:—

	Tons.
New York State	1,253,393
New Jersey State	495,808
Total	1,749,201

And of this amount 202,035 tons were red hæmatite.

In the iron-bearing Archæan rocks of eastern Ontario, it would appear that there are two principal modes of occurrence of the iron-ores:—

(1) In association with bands of crystalline limestone, either embedded in it or at its junction with gneiss, granite, syenite, or greenstone.

(2) In greenstone, in which it occurs as irregular masses. In the latter case, the ore-body has doubtlessly been formed by differentiation, or the concentration of the ore-body in the original fused magma.

In the former case, concentration by displacement probably has played the most important part in connexion with ferruginous solutions.

* Page 70.

In certain cases, however, some of the deposits bear the character of beds deposited with the enclosing rocks, the lie of the ore-bed and the intercalated minerals being the same as that of the country rock. This would correspond with the deposits of lake-ore which are now being formed to a considerable extent in the Province of Quebec.

A large amount of hornblende or augite almost invariably accompanies the iron-ores.

The annexed section (Fig. 10, Plate VIII.) of one of the magnetic ore-beds of eastern Ontario will give an idea of the mode of its occurrence.

The grade of the ore naturally varies in different deposits. Some are very high grade and pure. In others as much as 12 per cent. of titanic acid is found. As a rule the ores are somewhat free from phosphorus, but many contain sulphur.

The following analyses of eastern Ontario ores will give an idea of a good grade of magnetite and hæmatite, the former having been shipped as a Bessemer ore, and the assay being taken from a report on the ore-body by the writer :—

	Magnetite. Per Cent.	Hæmatite. Per Cent.
Ferric oxide	63·56	82·250
Ferrous oxide	27·00	—
Silica	3·89	16·050 (Silica and Alumina)
Alumina	0·93	
Lime	2·59	Traces
Magnesia	1·97	—
Sulphur	0·06	0·000
Titanium	0·00	—
Phosphorus	Trace	0·026
Totals	100·00	100·000
Metallic iron	65·39	57·600

Platinum.

Platinum has not yet been found in any workable amount in Ontario, but a notable quantity of a hitherto unknown compound of this and other metals of the same group with arsenic has been produced at the Vermilion mine in the Sudbury district. The compound is a heavy white metal of the following composition :—

	Per Cent.
Arsenic	4·98
Antimony	0·50
Platinum	52·57
Rhodium	0·75
Paladium	Traces
Iron	0·07
Oxide of tin	4·62
Total	99·49

The mineral has the formula $PtAs_2$, being amorphous with FeS_2, and the name sperrylite has been given to it. The mineral is found as small silver white crystals among a decomposed greenstone, which has been milled for the free gold contained in it.

Gold.

Gold has been discovered in a great many places in the ancient rocks of the province, in veins cutting syenites, granites, greenstones, and Huronian green schists, for the most part. The places where gold has been found extend from the extreme east to the extreme west of the province. Development is at present going on in only three districts, one in the east, one in the centre, and the third in the extreme west.

All of the gold occurrences are in the Huronian system, unless the measures in the east, in the Marmora district, are correctly classed as Upper Laurentian, in which case that division of the Archæan formation can claim veins of this precious metal. Another exception may also be quoted, where a quartz vein containing bornite, occurring in the Laurentian near Parry Sound, is found to yield coarse gold.

From the small amount of development which has taken place up to the present time, it would appear that disappointment in not finding an equal amount of free milling ore in depth at, or near, the surface has largely been the factor in discouraging operations. With the great advance in modern methods for treating ores of a refractory nature, we may look forward to gold-mining operations being permanently established in the province on a scale which has not hitherto been attempted.

Free milling ores, however, are by no means lacking.

The character of the arsenical gold-bearing veins in eastern Ontario, in the Marmora district, has been described under the remarks on arsenic. In the same locality, veins carrying gold in association with iron pyrites and no mispickel are also found, one of which is being developed at present. The mispickel ores appear to be more particularly associated with veins in syenite, while those veins whose chief mineral is iron pyrites seem more generally associated with diorites and talcose or chloritic schists, the latter generally as a lining to the vein.

Confusion frequently arises as to the rock in which the gold veins occur. Mining engineers, and even geologists, have failed to recognize that sometimes the schists forming the walls of the veins are the product of the chemical decomposition of the true walls, along the fissure in which the vein has formed, and this schistose lining, sometimes extending on one or both sides for some distance, is spoken of as the true wall or country rock of the vein.

The gold-bearing veins of central Ontario—the Sudbury, Wahnapitæ, and Bruce mines districts—occur in the Huronian belts for the most part in rocks of the greenstone type.

In the west, in the Lake of the Woods, Seine river, and Rainy Lake districts, the gold-carrying veins cut syenites, granites and green schists, termed Keewatin Schists, which are generally hornblendic and chloritic. Where the veins cut syenite, syenitic gneiss or diorite, there is generally a strong development of talcose schist-lining in this district. It may be said that the gold veins in the Huronian formation in Ontario are intimately connected with eruptive rocks.

The general character of the gold-bearing quartz-veins in this province is what is termed "bedded veins." The writer has, however, observed instances which would seem to point to the fact that the stratification of the formation, with which the veins run, may be a secondary or false-bedding due to pressure and metamorphic influence, and at right-angles to the pressure. This false-bedding has been caused after the vein was formed, or more probably during its formation, and the opening in which the vein has formed has also taken place at right-angles to the pressure, therefore parallel to the false-bedding. This would give the appearance of a bedded vein, even though the first crevice, in which the vein subsequently formed, was across the original bedding of the rocks or through a massive rock. In this case the designation bedded vein would be in reality a misnomer and discredit an actual fissure.

With regard to the gold-contents of the vast number of veins, which are found to carry that metal in Ontario, to a greater or less degree, a good deal could be said owing to the fact that there is naturally a great variation in richness or poverty. The arsenical ores of eastern Ontario have had examples given under arsenic. The iron pyritic ores of the same district have in one or two instances been tested pretty extensively. A good average of them may be said to be 10 dols. a ton, while one mill-test of 3 tons of ore by Messrs. Ricketts & Banks, of New York, was said to yield 25·40 dols. per ton, and assays of iron pyrites gave from 90 dols. to 326 dols. per ton.

In central Ontario, in the Bruce mines district, the milling operations at the Ophir mine are said to be profitable, but the true yield is not generally known. Three lots of ore (presumably picked) were treated at the Houghton School of Mines and gave an average of 9·7 ounces of gold and 6·15 ounces of silver per ton.

In western Ontario, in the Lake of the Woods and Rainy Lake districts, extremely rich samples of ore have been found near the surface, but until lately no veins had been developed which did not become refractory in a very short distance down, in some cases running into mispickel. Recently, however, mining and milling operations indicate that the free milling stage continues to a considerable depth in some of the veins, and that a yield of 10 dols. and upwards per ton is obtained from the mill.

In one instance, however, the Sultana mine has been producing ore from below 200 feet in depth, which has recently been milling as high in free gold as from 15 dols. to 25 dols. per ton, with concentrates running from 40 dols. to 80 dols. per ton. The ore is taken from a vein running with the formation, and the quartz occurs as lenses in a belt of talcose-lining. When one lens is worked out, another is opened up by sinking or drifting. The country rock in this case is a porphyritic quartz-syenite in which mica is also developed, and the felspar greatly preponderates. It shows signs of considerable pressure, a fissile or schistose structure, and elongation from squeezing being abundantly visible.

The gold-belt which is exciting the greatest interest at present is situated on the Seine river, Rainy river district. Though no mines have yet been opened, extensive prospecting and preliminary works are being carried on with encouraging results. The chief area, so far discovered, shows a great number of strong auriferous quartz veins cutting a granite which varies in different parts of the area from true granite to binary, hornblendic and protogenic types. So far as worked out the richest veins seem to be connected with the protogene in which chlorite and talc, in the place of mica, gives the rock a greenish hue; iron pyrites is also common in this granite. The gold is very coarse and the higher grade ore gives excellent panning results. The concentrates in some instances run very high. Iron pyrites, galena, and zinc blende are the chief minerals in the veins, and the gold is apparently more often intimately associated with the occurrence of the blende than with either of the other minerals.

The strike of the veins is generally from north and south to east and west, and often north-westerly. Fig. 11 (Plate VIII.) gives a rough section and general idea of the belt above described.

In the western part of the Thunder Bay district, a vein in a dioritic rock was worked for sylvanite, but though the ore was said to run 21 dols. to the ton, the enterprise was not a success. This is mentioned, as it is the only place where this mineral has been obtained in the province. In the township of Marmora, Hastings county, bournonite is found carrying 1·45 ounces of gold and 4·37 ounces of silver per ton.

In conclusion, it may very properly be said that there is every reason to believe that with the requisite amount of capital invested in judicious development, and in some cases with the best modern methods and machinery for extracting gold from refractory ores, gold-mining will become a very important and remunerative industry in Ontario.

Silver.

Silver-ores have only been produced to any extent in one district in Ontario. Near Port Arthur, in the Thunder Bay district, well defined fissure-veins cut the black Animikie (Cambrian) shales and trap overlying (and in places forced in between) the shales. These veins carry silver-ore in irregular shoots and ore-bodies, varying from mere traces up to several thousands of dollars per ton. The crevice in which the vein has formed has generally faulted the series. The line of fault, and presence of a vein, may often be noticed by an indentation in the escarpment, visible for miles away, but it is only where a capping of trap has prevented the weathering down of the soft shales that an escarpment has formed and the veins have been made visible thereby. Sometimes, however, the veins cross intrusive vertical dykes, as at Silver Islet, and they are there visible. Figs. 12 and 13 (Plate VIII.) are examples of these conditions.

The veins strike in different directions, but the majority run east and west. None appear to have any decided advantage over the others on account of the direction of their course, although, of the richest developed thus far, Silver Islet strikes north and south, and the Beaver and Badger north-easterly. For the most part the veins are very strong and persistent. As an example the Walbridge or Trowbridge vein is known to run from 12 to 15 miles, and in places it widens to some 50 feet. The veins not only cut the Animikie formation and the overlying trap, but they extend down into the Archæan below. This is shown in one case at the Shuniah mine, where the vein cuts into a granitic syenite in the lower levels; and again at the Silver Mountain West-end mine where the shaft followed the vein into the underlying Huronian jasper. In neither of these cases has the Archæan proved a prolific wall-rock.

The components of the veins are chiefly calcspar, quartz (commonly as amethysts), fluorspar, heavy spar, and breccia of wall-rock. The minerals which they carry are iron pyrites, galena, zinc-blende, with native silver near the surface and argentite below. The galena is not argentiferous as a rule, but the zinc-blende is often rich in silver, which is held in leaf-form through the blende. The rarer silver minerals which were found, more particularly at Silver Islet, contain nickel, cobalt, and arsenic, and are known as macfarlanite, huntalite, and animikite, the latter having also a little antimony. It is also said that arsenical silver-ore has been found on Edwards Island in Black Bay, antimonial silver-ore on an island at the mouth of Pine Bay, township of Pardu, and tetrahedrite in another locality. The silver-contents of the veins occur in very irregular pockets in some mines and in shutes in others. In the Silver Islet mine, the ore was associated with the occurrence of graphite, the presence of which was constantly watched for. In this mine there were pockets of gas, which sometimes became ignited. Ore was shipped from the mine of a value of 1,000 dollars, 3,000 dollars, and up to 5,000 dollars a ton. While in operation, the mine produced over 3,000,000 dollars in silver, but, after the prospectors had been unsuccessful in striking a new pocket of ore for some time, a gale on the lake flooded the mine, and it has not been since pumped out and worked. The best ore from the other mines has been shipped running 1,000 dollars and 1,500 dollars a ton. Lower grade ores are stamped and concentrated. No smelting has yet been done in the district, and at present, owing to the low price in silver, no mines are worked.

There is no question that silver-mining will be carried on profitably in the future, as has been the case in the past, and on a very much increased scale in this district.

A silver-ore of an unusual character has been discovered and prospected to a limited extent in eastern Ontario. The ore appears to be an argentiferous meninghenite, the silver being more probably associated with the lead than with the antimony, for it is stated that specimens of stibnite found with the ore were devoid of silver. This ore appears to occur in veins or stringers in connexion with a strong bed of crystalline limestone, of Upper Laurentian age, which can be followed for miles.

Lead.

Lead ores have been worked in both eastern and central Ontario, but the ventures were not successful. In the east, veins carrying galena, considered at one time to be in paying quantities, cut the Upper Laurentian, and also the Calciferous formations. In the former, the country rock is gneiss and crystalline limestone, and in the latter a dolomitic limestone. In both cases the silver-contents of the ore was low. The vein-matter consists of calcspar, and on an average about 5 per cent.

of galena, containing some 4 dollars in silver per ton, is scattered in irregular bunches through the vein-matter. A little barytes, iron, and copper pyrites and blende are also found in small quantities in the vein-matter.

In the central part of the province, near Sault Ste. Marie, veins of argentiferous galena were worked to a depth of 400 feet. The ore is said to assay, on the average, 20 dollars of silver and 60 per cent. of lead per ton. The galena occurs in veins and stringers in a belt of green schists, which lies between granite and a siliceous felsite, with hornblende-rock, of Huronian age. Zinc-blende and copper and iron pyrites occur with the galena.

In the west, the silver-carrying veins of the Animikie contain sometimes considerable quantities of galena, but no mine has been worked for the latter mineral. Galena-bearing veins occurring in Laurentian and in the Nipigon series, are also found in the Thunder Bay district, opposite the head of Black Bay (Lake Superior), south of Lake Nipigon. One of these veins, with a width of 6 to 8 feet, was worked for the galena. It was said to carry 17 dollars of gold and 2 dollars of silver per ton. The gangue is quartz, calcspar, and barytes. It is not now worked.

Zinc.

Zinc-ores are not worked in the province, either for export or for the extraction of the zinc. Zinc-blende is reported to have been found to a considerable extent in the Huronian formation, in a hornblende-rock or diorite, occurring in large veins or lenticular masses at the Zenyth location, Black Bay, near Thunder Bay. It gave an assay, according to the records of the Geological Survey, of 54 per cent. of zinc. The same ore in large crystals is found in an 8 feet vein of coarse calcspar, which occurs at the contact of the Huronian and Animikie rocks. The blende occurring in the silver-carrying veins of the Animikie has been alluded to.

Apatite.

Phosphate of lime or apatite has not been found in Ontario in as large deposits as in the sister province of Quebec, but as regards similarity of occurrence and quality of produce (dependent largely upon intelligent dressing of the rock) identical conditions appear to prevail on both sides of the Ottawa river. Apatite averaging 84 per cent. of phosphate of lime has been shipped from Ontario mines.

At present the low price of phosphate of lime, owing to the development of the Florida high-grade rock, has been the cause of the temporary cessation of this industry in Ontario. The apatite-bearing formation is found so far only in the extreme eastern portion of the province.

The apatite occurs in veins, usually bedded veins, in pyroxenite and gneisses in the Laurentian system; hornblende or pyroxene and mica invariably are present with the apatite, and the former is sometimes mistaken for it. Sometimes the apatite is found in the form of crystals in veins of calcspar, but these deposits are not usually so remunerative as the more massive occurrence, though the uncertainty and irregularity of all phosphate-veins is exceptionally great. The following sketch (Fig. 14, Plate VIII.) of a phosphate-vein gives an example where it cuts across the formation, though it is usually found running with it.

Much of the mining in Ontario is in reality quarrying, and is done by means of open-cuts. Where this is the case, the apatite is taken out in fairly solid condition, but when a great depth is reached the force of the strong explosives, that it is necessary to use in the very hard rock in which the apatite occurs, breaks the apatite into a powder, in which form much of the high grade is shipped from deep mines. The product is dressed and sorted into three grades usually, only the first two being shipped. Grade No. 1 runs over 80 per cent. of phosphate of lime.

Mica.

Mica-mining may properly be said to be in its infancy, and until quite recently had nowhere arrived at the dignity of mining, the operation consisting for the most part in making irregular surface-pits where the mica-crystals were discovered at the surface. This condition was chiefly due to the fact that the consumption of the mineral was very small. Electricity has, however, brought about a much larger demand for mica, and it is expected that mica-mining will assume considerable importance in the near future.

The mica-bearing formations of eastern Canada occur in the Laurentian. Nearly all of these old crystalline rocks carry more or less mica, but only in certain belts is mica found in large enough crystals to be of commercial value. Mica occurs in two classes of rocks:—

(1) *Granite.*—In granite the mica is associated with quartz and felspar, and is usually present as muscovite or white mica. Other minerals, such as tourmaline, garnet, apatite, and common emerald, are very often found in a crystalline form associated with this class of deposit.

It is evidently where the crystallization of the rocks has been slowest that we find the merchantable mica, for the other components of the rock accompanying it are also more or less equally well-developed, and we not only find larger crystals of mica but the crystals of the other minerals composing the rock are of a correspondingly increased size. It is therefore advisable to note the general crystalline character of the rock-masses when mica-crystals appear at the surface and mining operations are contemplated.

(2) *Hornblendic or Pyroxenic Rock.*—The largest quantity of mica, however, is obtained from hornblendic syenite, often gneissic, but in cases graduating from a pyroxenic syenite to a diorite or gabbro. In this latter class of deposit, the mica is either found associated with hornblende or pyroxene and apatite, or in veins or irregular masses of calcspar or felspar (with more or less quartz) cutting hornblendic or pyroxenic syenite.

The mica is chiefly found as phlogopite or amber mica, but sometimes biotite or black mica is found. It may be remarked that where the hornblende contains a larger quantity of iron (typical black hornblende) the mica is darker, and when the mica is associated with the lighter coloured actinolite it is found to be amber-coloured or almost white.

Fig. 15 (Plate VIII.) is a section showing a large deposit of the second class of occurrence worked in the Kingston district. Crystals 6 feet across were to be seen in the zone marked *a*.

It may correctly be inferred from the above description that the occurrence of the larger (or merchantable) crystals is somewhat irregular and precarious, and such is found to be the case. Indeed, in most formations, the crystals are much twisted, broken by joints, with embedded crystals of quartz or calcspar, and sometimes spotted with iron or manganese stain, or minute crystals of tourmaline, magnetite, apatite, calcite, etc.

It is perhaps more difficult to put a price upon the cost of mining mica than upon any other mineral, though it be conceded that all mineral occurrences vary greatly in the cost of their yield. When the mica is associated with apatite, as is very often the case, that mineral yields a good price, and the felspar, which is in other cases largely developed in association with the mica, has been exported; but the extensive use of this mineral at remunerative prices to the producer, remains for further developments. Under exceptionally favourable cases, 20 tons of rock may yield a ton of merchantable uncut mica, and it in turn gives a very good result if from 4 to 10 tons of the uncut mica yield 1 ton of cut mica. In one case in a yield of 23 per cent. of cut mica, 7 per cent. was No. 1, and 16 per cent. was No. 2. Sizes run from 6 by 7 inches down to

$1\frac{1}{2}$ by $2\frac{1}{2}$ inches, the smaller sizes being much the most numerous. It is a somewhat strange coincidence that 23 per cent. is the exact yield of a well-known Indian mine.

Graphite.

Graphite or plumbago is not at present mined in the province, but a deposit in eastern Ontario was worked somewhat extensively many years ago.

The plumbago is found in the Laurentian formation, occurring, where worked, in thickly disseminated scales in a sandy, calcareous and quartzose rock (gneissic in structure), which in some places graduates into an impure limestone. Large amounts of this graphite-rock are obtainable at a low cost, but the presence of the lime probably accounts for its now being unworked. The rock was stamped in a 10 stamp mill, and the plumbago washed out on 3 revolving buddles. The resulting powder was dried and bolted.

Natural Gas.

Natural gas has been found in important quantities in two places in Ontario, both on the northern shore of Lake Erie. The first place, where it was found by boring, was at the extreme western tongue of the peninsula of Ontario. Here it was found in the Clinton formation, and the flow occurred from a vesicular limestone. It is well established that one of the principal reservoirs of the gas is in spaces which have been caused by dolomitization of limestone. However, the cause which led to the search for gas at this place, was because it was in the line of the continuation of the great anticlinal of Ohio, which had been proved to be such a wonderful reservoir for gas in that state. The flow when first struck went as high, in different holes, as from 2 to 10 millions of cubic feet of gas per day, with a pressure of 400 lbs. per square inch. The holes are bored about 1,000 feet deep in this gas-field.

The second place, where large quantities of gas were found, was at the eastern end of the southern part of the peninsula of Ontario, no great distance from where the Niagara river flows out of Lake Erie. In this district, the gas was found also in the Clinton rocks, but the main supply is derived from still lower down, from the Medina shales and sandstones. Here the pressure amounted to 500 and 560 lbs. per square inch, and the yield reached from 2 to 3 millions, and upwards, of cubic feet of gas per day. The depth of the holes are, to reach the Clinton about 680 feet, and the Medina formation about 750 feet, and this latter is penetrated generally to some 850 feet.

To give an idea of the cost of drilling, a fair average price down to a depth of 850 feet would be about 2 dollars per foot, including casing, and a completed well in all respects.

The great pressure of the gas of the wells is reduced by regulators down to 4 or 5 ozs. per square inch at the consuming point. Unfortunately, the gas is being rapidly exhausted, especially in the eastern field which supplies the large city of Buffalo, in the United States, and the pressure is getting less and less, so that it has become necessary to use pumps to force the gas, instead of being obliged to call into play considerable ingenuity to control it.

This natural gas is an object lesson of the different policies which animate the two Anglo-Saxon races of the North American continent.

The Ontario gas-field is being exhausted for the benefit of the people of New York State, without let, tax, or hindrance on the part of the people of Canada, while a washerwoman, and much less a miner, is not allowed to cross the international line and seek work in the United States while domiciled in Canada.

Petroleum.

Petroleum is found in two areas in the western part of the peninsula of Ontario in the county of Lambton. The rock which furnishes the oil is the Corniferous limestone (Devonian) which is very fossiliferous. The oil is struck at between 465 and 475 feet from the surface in a porous dolomitic limestone, which is from 1 to 6 feet thick, brown in colour (probably from the petroleum), and very soft. The holes are drilled 4⅝ inches in diameter, and where casing is put down it is rimed out ½ or ¾ inch more, the casing being 4⅝ inches inside and 5⅛ inches in outside diameter. The hole is put down in about five or six days, and costs, for drilling, from 150 to 160 dols. Wooden rods are used as drill-rods, in place of the rope used in the United States oil-districts, a steel drill 3½ inches in diameter and 25 to 30 feet long being attached to the lowest section. These Petrolea drillers are very expert, and are called for all over the world, much work being done by them in Europe, Asia, and Australia. The oil was at first free-flowing, but in this field it is now pumped and run into tanks. The crude-oil is distilled in large sheet-iron retorts, and the various products are :—Gasoline, naphtha, illuminating-oil, intermediate and wool oils, and, lastly, lubricating-oils; while an incrustation of carbonaceous matter or coke, which makes a good fuel, is left in the retort.

All the grades of distillation are divided at will, either by stopping the process at various stages or by subsequent re-distillation and treatment into an almost endless variety of lighter and highly combustible intermediate illuminating and lubricating-oils, and also into such solids as vaseline, paraffin, etc. Tars and asphalts might be produced from an oxidized matter which is thrown away.

The products of evaporation may be roughly divided into 40 per cent. of illuminating-oils, and 60 per cent. of the above-mentioned articles; or more exactly, burning oil 38 to 39 per cent., gas oil 17 per cent., tar 18 per cent., waste 10 per cent., water 6 per cent., and coke 9 per cent.

The fire-test of 95 degs. Fahr., at which the oil ignites, is common to all grades of illuminating-oil.

The process of refining the illuminating-oil is to agitate it with 2 per cent. of sulphuric acid to remove the free carbon or tarry materials which are drawn off below; then, after washing it with water, caustic soda and litharge are added. The litharge combines with the sulphur present in the oil and forms lead sulphide. Flowers of sulphur is then added, which precipitates the lead and other impurities, and the oil is left cleared, but some sulphur generally remains. This sulphur gives the oil a smell in burning, and it is removed by some refiners by re-distilling the oil after the litharge and caustic soda have been added, and before the flowers of sulphur has been put in. Most of the sulphur is then left in the retort in combination with the lead. The rest of the process is then carried on with the re-distilled product as above described. Finally, in all processes the product is bleached in the light in an open vat.

The tar, or residue after the illuminating-oils have come off, is re-distilled, from which about 70 per cent. of gas oil, used in making illuminating gas, and 30 per cent. of paraffin oil are obtained, according to the grade required. The paraffin oil is put into a freezing-vat, and from 8 to 10 per cent. (or one pound to the gallon) of paraffin wax crystallizes out from it. This wax has all the oil squeezed out by pressure and is refined, one part of the resulting yield being made into wax candles, and the other smaller portion into a wax which is used as chewing-gum and for various other purposes. The residual oils, after the paraffin has been crystallized, are made into lubricating-oils.

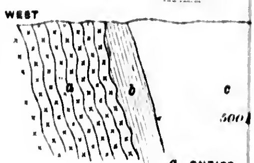
Illuminating-oil can be distilled from the Utica shales, which, in places, contain 3 to 4 per cent. of tarry oil. This industry, however, cannot compete with the petroleum oil-fields.

Lignite.

Lignite has been found in unproved quantity in the north on the Missinaibi and Mattagami rivers, branches of the Moose river. It has also been met with on Rainy river. All the occurrences so far have been in the drift.

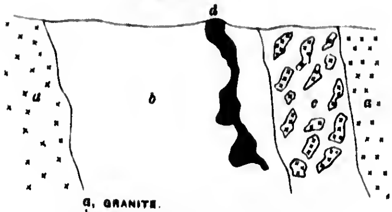
The writer now concludes a condensed and necessarily incomplete description of the economic minerals of Ontario. As will be gathered from his remarks immense possibilities exist for enormous future development.

Fig. 2.

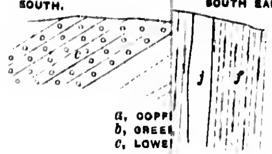


a, Gneiss.
b, Schist.
c, Marble.
d, Syenite.

Fig. 5.

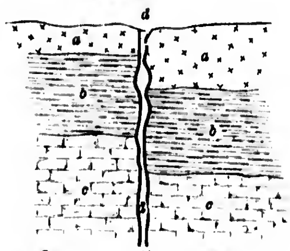


a, Granite.
b, Greenstone.
c, Mixed granite and greenstone.
d, Ore-body.



a, Copp…
b, Gree…
c, Lowe…

Fig. 12.



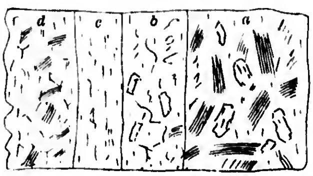
Section of a Vertical Fault.

a, Trap.
b, Black shales.
c, Cherty limestone.
d, Vein.

Fig. 10.

…one.
…d hornblendic schist (green).
… with ore-streaks.
…dy, banded structure with
…tz.
…ic rock, quartzose in places.
…gneiss.

Fig. 15.



a, Zone of larger crystals of mica and hornblende.
b, Apatite and hornblende.
c, Chiefly hornblende.
d, Mica rock.

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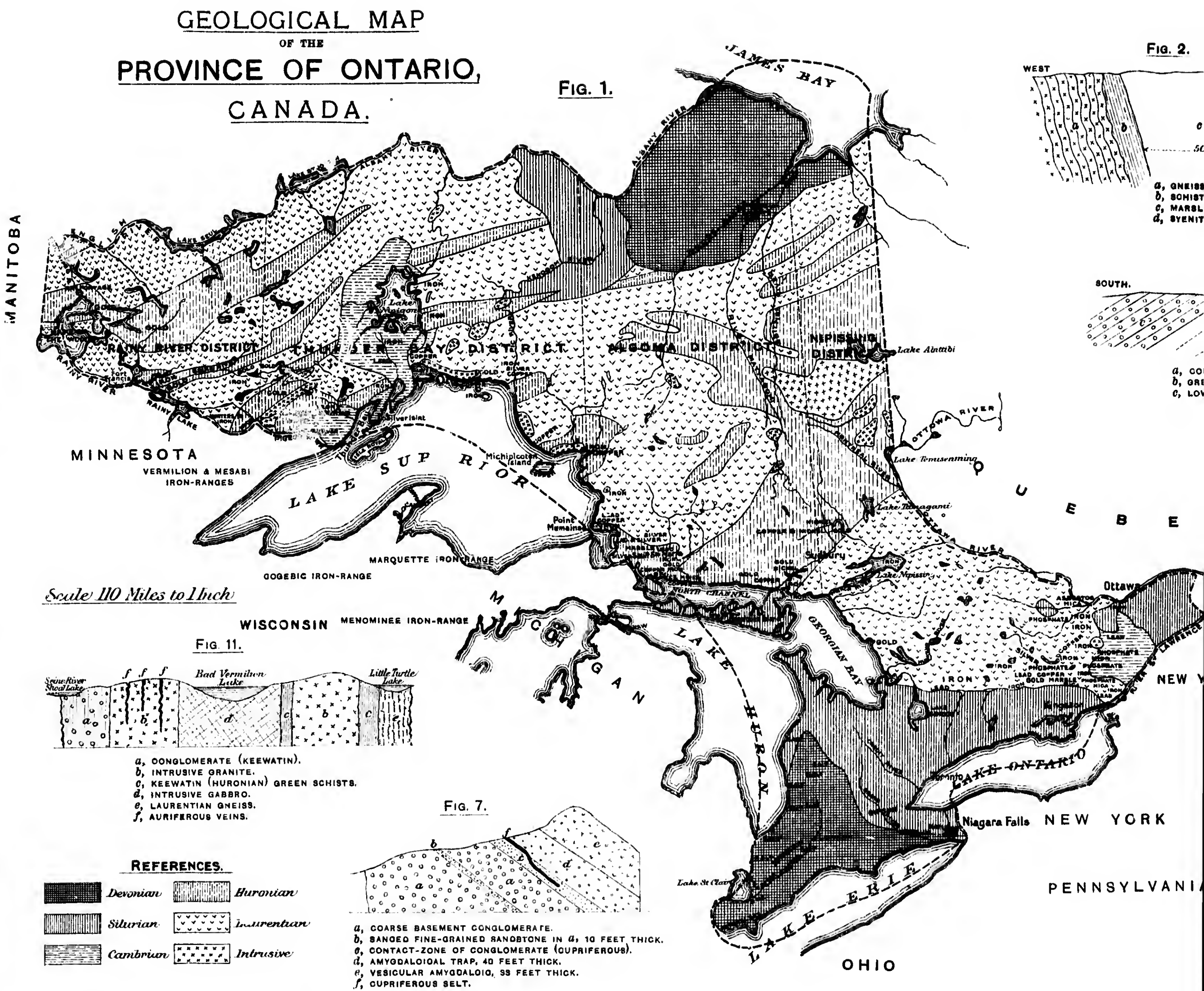

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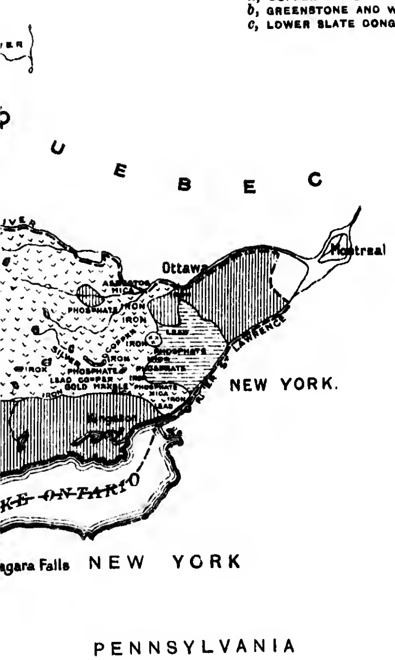
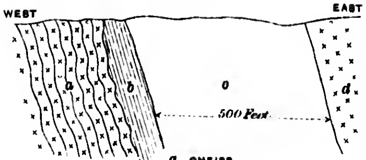
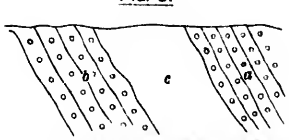


FIG. 2.



a, GNEISS.
b, SCHIST.
c, MARBLE.
d, SYENITE.

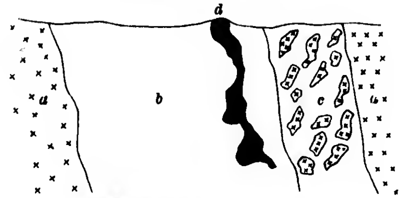
FIG. 3.



a, UPPER SLATE CONGLOMERATE.
b, LOWER SLATE CONGLOMERATE.
c, MARBLE.

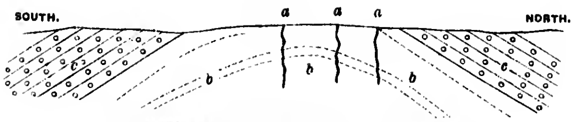
FIG. 4.

FIG. 5.



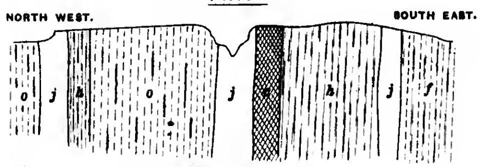
a, GRANITE.
b, GREENSTONE.
c, MIXED GRANITE AND GREENSTONE.
d, ORE-BODY.

FIG. 6.



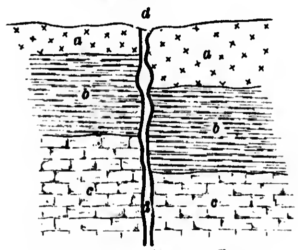
a, COPPER VEINS.
b, GREENSTONE AND WHITE QUARTZ CONGLOMERATE.
c, LOWER SLATE CONGLOMERATE.

FIG. 8.



c, JASPER.
f, JASPER AND SHALES.
h, SHALES.
j, ORE.
o, JASPER WITH ORE-STRINGERS.

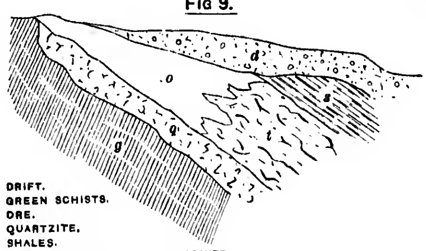
FIG. 12.



SECTION OF A VERTICAL FAULT.

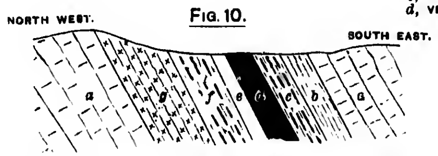
a, TRAP.
b, BLACK SHALES.
c, CHERTY LIMESTONE.
d, VEIN.

FIG 9.



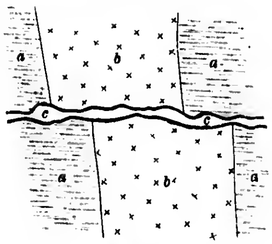
d, DRIFT.
g, GREEN SCHISTS.
o, ORE.
q, QUARTZITE.
s, SHALES.
t, BANDED ORE AND ROCK TACONITE.

FIG. 10.



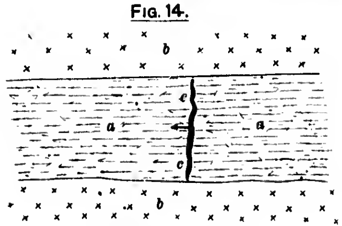
a, CRYSTALLINE LIMESTONE.
b, MIXED LIMESTONE AND HORNBLENDIC SCHIST (GREEN).
c, HORNBLENDIC SCHIST WITH ORE-STREAKS.
d, HIGH-GRADE ORE BODY, BANDED STRUCTURE WITH CALCITE STREAKS.
e, THIN BAND OF QUARTZ.
f, ORE AND HORNBLENDIC ROCK, QUARTZOSE IN PLACES.
g, GREY AND REDDISH GNEISS.

FIG. 13.



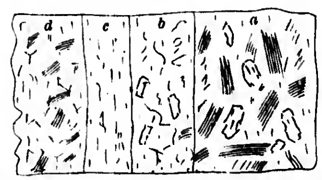
a, SHALES.
b, DIORITE DYKE.
c, VEIN.

FIG. 14.



a, HORNBLENDE-ROCK.
b, GRANITE.
c, VEIN OF APATITE.

FIG. 15.



a, ZONE OF LARGER CRYSTALS OF MICA AND HORNBLENDE.
b, APATITE AND HORNBLENDE.
c, CHIEFLY HORNBLENDE.
d, MICA ROCK.

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