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TWENTY-SEVENTH ANNUAL REPORT

OF THE

ONTARIO BUREAU OF MINES, 1918,

BEING

VOL. XXVII

AND CONTAINING PARTS I, II AND III

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1918

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GEOLOGICALLY COLOURED MAP

(*In pocket on inside of back cover*)

No. 27*a*.—Matachewan Gold Area, District of Timiskaming. Scale, 1 mile to the inch.

LETTER OF TRANSMISSION

To His Honour Sir John Strathearn Hendrie, C.V.O.,

Lieutenant-Governor of the Province of Ontario.

Sir,—I have the honour to transmit herewith, for presentation to the Legislative Assembly of the Province of Ontario, the Twenty-seventh Annual Report of the Bureau of Mines.

I have the honour to be, Sir,

Your obedient servant,

G. H. Ferguson,

Minister of Lands, Forests and Mines.

Department of Lands, Forests and Mines,
Toronto, 1918.

INTRODUCTORY LETTER

To the Honourable George Howard Ferguson, K.C.,

Minister of Lands, Forests and Mines.

Sir,—I have the honour to submit to you herewith, for transmission to His Honour the Lieutenant-Governor in Council, the Twenty-seventh Annual Report of the Bureau of Mines, being for the year 1917.

The Report consists of three Parts. Part I contains the customary Review of the Mining Industry of Ontario for the past year, with statistics of production for the several metallic and non-metallic substances, and a variety of tables giving particulars regarding them. The Review shows that the aggregate value of the output in 1917 was the greatest yet recorded; also that the tendency noted in previous Reports, towards the establishment of refining processes and facilities for manufacturing secondary products, is steadily becoming more marked. With the advantages of ample supplies of raw materials, cheap electric power, and efficient transportation, there is no reason why Ontario should not speedily develop a full-bodied metallurgical and chemical industry, and good progress has already been made to this end.

The Statistical Review is followed by a chapter on Mining Accidents in 1917 by T. F. Sutherland, Chief Inspector of Mines.

Messrs. Sutherland, Collins and Stovel report on the mines, quarries and metallurgical plants in operation during the year.

Arthur L. Parsons, who examined the Slate Islands in Lake Superior, gives an account of the geology of the Islands, and of the veins which attracted considerable attention a number of years ago, but failed to realize the hopes of mineral wealth entertained regarding them.

Mr. Parsons also deals with Mineral Developments in Northwestern Ontario, including the working and opening up respectively of copper deposits at Tip Top mine and near Mine Centre, also with diamond drilling on the titaniferous iron ores of the so-called Fetiva range on the northwest shore of Bad Vermilion lake.

Ogahalla to Collins on the National Transcontinental Railway is the title of a descriptive account by Percy E. Hopkins of the geology of a section of that railway line 175 miles in length from Kenogami river westward to Trout lake, about 35 miles west of Lake Nipigon. The line thus examined connects the great Clay Belt of Northern Ontario where it thins out on the west, with the rocky region into which it merges on the way to the Manitoba boundary. In addition, Mr. Hopkins made some reconnoitering trips into the unexplored territory in the vicinity of Armstrong, a divisional point on the railway.

Mr. Hopkins also contributes Notes on Lake Abitibi Area, having during the latter part of the field season of 1917 examined a considerable part of the shore line of that lake and many of the islands therein, as well as the country adjacent to several of its tributaries, and an area in Rickard township, in all of which localities the rock formations are favourable for mineral deposits and at a number of points have disclosed promising shows of gold.

The Matachewan Gold Area, where gold was found in the autumn of 1916, is described by A. G. Burrows, and the geology of the neighbourhood of the discovery is shown on the map accompanying his Report. For the convenience of prospectors and others interested in the development of this field, an advance edition of Mr. Burrows' Report was issued early in 1918, as Bulletin No. 34.

In Part II, under the title, Sand and Gravel in Ontario, there is a description by counties of many of the detrital deposits which play so useful a part for road and other construction purposes. The author, Auguste Joseph Gaston Ledoux, was professor of mineralogy at the University of Brussels, Belgium, when the great European war broke out. Enlisting in the Belgian army, Professor Ledoux assisted in defending his country against the invading Germans, and was seriously injured in action. Forced to retire from military service, he came to Ontario was taken on the staff of the University of Toronto in 1915 as special lecturer in mineralogy, and was subsequently employed by the Bureau of Mines in investigating these surface deposits. Prof. Ledoux spent the field season of 1917 in southern or older Ontario, to which the account in Part II is mainly confined. It was proposed also to cover the sands and gravels of northern or newer Ontario, in so far as present transportation facilities and knowledge of the territory made this possible. Professor Ledoux had begun work on the northern areas and had made some headway, when further progress was stopped by his sudden death at Sudbury on 7th August, 1918. His treatment of the subject, Sands and Gravels, deals not only with the occurrences, but with the quality and availability of the various deposits for economic uses, such as building, glassmaking, moulding, etc.

Part III, Cobalt; Its Occurrences, Metallurgy, Uses and Alloys, presents the results of an investigation into the properties of the metal cobalt, by C. W. Drury, Professor of Metallurgical Research, Queen's University, Kingston, Ontario. Section I deals with cobalt deposits, the metallurgical processes for recovering the metal from its ores, and the various uses in which it is or may be employed. In Section II there is a study of the effects of cobalt when alloyed with a variety of other metals. In view of the fact that at present the silver-cobalt ores of Ontario furnish the greater part of the world's supply of this metal and the probability that they will continue to do so for some time to come, it seems appropriate to add the results of Professor Drury's researches to the present stock of available information on this subject.

I have the honour to be, Sir,

Your obedient servant,

THOS. W. GIBSON,

Deputy Minister of Mines.

BUREAU OF MINES,
DEPARTMENT OF LANDS, FORESTS AND MINES,
Toronto, 1918.

STATISTICAL REVIEW

of the

MINERAL INDUSTRY OF ONTARIO FOR 1917

By Thos. W. Gibson, Deputy Minister of Mines

In money value the output of the mineral industry of Ontario in 1917 exceeded that for 1916 by 10.3 per cent., being $72,093,832, as compared with $65,303,822. This is the highest figure yet reached for any year. Examination of the statistics makes it plain that the increased value is due more largely to higher prices than to greater production. The effect of the war has been to raise the price of practically every mineral product, with the solitary exception of gold. Increased demand and higher cost of production, both in the main due to the war, have combined to enhance the value of all the items on the list, especially of those substances required for direct use in warfare. In the case of an essential such as copper, the government of the United States deemed it necessary to intervene in order to prevent the price rising beyond all bounds. On the other hand, gold, though sharing to the full in the greater expense of production, was, because of being itself the standard of value, denied the benefit of an increase in price. The natural effect upon the gold mining industry has been to decrease the output, the number of ounces won in 1917 being 76,940 less than in 1916. Silver offers a strong contrast. A small diminution in output was more than offset by a decided advance in price, in consequence of which the mining companies of Cobalt received $16,183,208 for 19,479,692 fine ounces, while in 1916 their return for 20,007,367 ounces was only $12,703,591. Of the other items in the metallic list, cobalt, nickel, iron ore exported, pig lead and molybdenite show substantial increases in value as compared with 1916, while copper, "other" nickel and cobalt compounds, and pig iron from Ontario ore, as well as gold, show decreases due to smaller output. The net result, so far as metallic substances are concerned, is an increase of $1,828.939.

Non-metallic products show in the aggregate a heavy increase in value, amounting to $4,961,071 or 48 per cent., compared with 1916, and in most of the items the larger value was accompanied by an increased production. This is true of arsenic, feldspar, fluorspar, iron pyrites, lime, natural gas, quartz, salt, stone, and talc. For this enlarged output the war was in the main directly or indirectly responsible. Iron pyrites, for instance, was in strong demand to take the place of native sulphur, the supply of which from Sicily to this continent was entirely cut off. The requirements of the steel-making trade for fluorspar brought the Madoc deposits into active operation. More natural gas was used by the munition manufactories of southwestern Ontario. Salt for essential chemical products; arsenic for insecticides to protect precious supplies of growing vegetables and fruit; lime for metallurgical use; talc to take the place of the hitherto imported product; all these and other materials were required in increased quantities, both on this side and on the other side of the boundary line in carrying on the essential work of winning the war.

Table I, which follows, summarizes the statistics of mineral production for 1917, including the number of employees engaged in the several branches of the industry, and the wages paid them:—

TABLE I.—MINERAL STATISTICS OF ONTARIO FOR 1917

Product.		Quantity.	Value.	Employees.	Wages.
METALLIC.			$		$
Gold	ounces	420,893	8,698,735	2,939	3,588,983
Silver	"	19,479,692	16,183,208	2,692	3,011,680
Copper	lbs.	539,540	118,772	115	84,653
Copper in matte (a)	tons	21,197	7,842,890	3,356	5,570,587
Nickel in matte (a)	"	41,887	20,943,500		
Iron ore (exported) (b)	"	136,343	483,690	475	493,078
Pig iron (c)	"	49,485	1,016,699	2,895	4,339,136
Cobalt (metallic)	lbs.	396,395	589,290		
Cobalt oxide	"	418,703	533,489		
Nickel "	"	23,748	6,533		
Nickel (metallic)	"	225,480	91,923	391	542,925
Other Nickel and Cobalt compounds	"	393,036	42,026		
Molybdenite (concentrates)	"	77,517	108,501	196	116,382
Lead (pig)	"	1,772,512	172,601	121	85,528
Total metallic			56,831,857	13,180	17,832,952
NON-METALLIC.					
Actinolite	tons	120	1,320		
Arsenic (white, grey and other forms)	lbs.	5,183,145	608,483	(d)	(d)
Asbestos	tons	10	2,150	18	3,000
Brick (sand-lime)	M	9,079	87,159	71	37,110
" (fancy and pressed)	"	36,233	474,614	407	206,844
" (common)	"	68,214	713,824		
Tile (drain)	"	15,940	546,040	909	473,375
" (building)	"	3,933	301,688		
Cement (Portland)	bbls.	2,063,231	2,934,271	589	538,355
Corundum	tons	188	31,213	46	33,817
Feldspar	"	18,334	81,802	136	67,182
Fluorspar	"	4,327	66,474	56	29,582
Graphite (refined)	"	3,173	296,587	156	120,053
Gypsum (crushed, ground and calcined)	"	48,943	130,138	70	59,966
Iron pyrites	"	286,049	1,111,264	580	583,819
Lime	bush.	2,820,507	657,364	325	262,132
Mica	tons	435	92,453	88	48,490
Natural gas	M. cu. ft.	20,026,000	3,220,123	783	537,946
Petroleum (crude)	Imp. gals.	7,104,700	475,000	(e) 79	(e) 75,670
Pottery			94,501	41	35,318
Quartz	tons	176,993	358,674	217	165,032
Salt	"	138,909	1,047,707	312	234,925
Sand and gravel	cu. yds.	1,187,973	431,597	417	232,971
Sewer pipe			378,923	202	168,421
Stone, (building, granite, trap, etc.)			939,052	652	475,794
Talc (crude and ground)	tons	16,076	179,554	56	49,734
Total non-metallic			15,261,975	6,210	4,439,536
Add metallic			56,831,857	13,180	17,832,952
Grand total			72,093,832	19,390	22,272,488

(a) Copper valued at 18½ and nickel at 25 cents per pound in the matte.
(b) Total production of iron ore 176,833 tons.
(c) Production from Ontario iron ore only. Total pig iron production 691,233 tons, value $14,201,695.
(d) Included with cobalt and nickel compounds.
(e) Employees and wages for proportion of domestic crude petroleum distilled in Ontario oil refineries.

Table II gives for the last five years the value of the production of the various metals, minerals, and mineral products. The figures show that the metallic output has increased in value during the period by 51 per cent., while the non-metallic production in 1917 was a little less in value than in 1913. The latter fact is due to the very heavy falling off in the manufacture of construction materials which followed the outbreak of the war. There are symptoms that this depression of the building and allied trades is beginning to be lifted, and in the meantime the expansion of other branches of non-metallic mining has practically made good the loss.

TABLE II.—VALUE OF MINERAL PRODUCTION, 1913 TO 1917.

Product.	1913	1914	1915	1916	1917
METALLIC:	$	$	$	$	$
Gold	4,558,518	5,529,767	8,501,391	10,339,259	8,698,735
Silver	16,579,094	12,795,214	12,174,312	12,703,591	16,183,208
Cobalt	420,386	546,479	(a) 379,657	(a) 762,327	(a) 1,122,779
Copper	1,840,492	2,081,332	3,926,018	8,365,255	7,961,662
Nickel	5,250,803	5,136,804	(b)17,042,230	(b)20,685,564	(b)21,041,956
Other Nickel and Cobalt compounds	.....	45,189	9,227	60,956	42,026
Iron ore (exported)	138,750	169,427	171,345	342,700	483,690
Pig iron	8,719,892	7,041,079	(c) 1,891,400	(c) 1,646,010	(c) 1,016,699
Lead (pig)	.....	.....	.....	70,863	172,601
Molybdenite	.....	.....	14,099	26,393	108,501
Metallic production	37,507,935	33,345,291	44,109,679	55,002,918	56,831,857
NON-METALLIC:					
Actinolite	.....	.....	.....	.....	1,320
Arsenic	64,146	116,624	148,379	200,103	608,483
Asbestos	.....	.....	.....	100	2,150
Brick, common and sand-lime.	3,452,352	2,336,207	763,591	509,559	800,983
Brick, paving, fancy, etc. ...	243,119	237,440	158,515	318,942	474,614
" pressed	919,741	656,944	217,350		
Calcium carbide	123,100	142,883	(d)	(d)	(d) .....
Cement, Portland	4,105,455	2,931,190	2,534,537	2,242,433	2,934,271
Corundum	137,036	65,730	31,398	8,763	31,213
Feldspar	67,142	55,686	47,031	42,159	81,802
Fluorspar	.....	.....	.....	10,146	66,474
Graphite	93,054	87,167	115,274	249,586	296,587
Gypsum	92,627	221,175	190,422	116,206	130,138
Iron pyrites	171,687	264,722	353,498	471,807	1,111,264
Lime	390,600	333,407	244,953	265,356	657,364
Mica	55,264	40,402	33,490	55,407	92,453
Natural gas	2,362,021	2,346,687	2,622,838	2,404,499	3,220,123
Peat fuel	1,750	2,100	.....	.....	.....
Petroleum (crude)	398,051	337,867	300,219	387,846	475,000
Phosphate of lime	.....	3,150	.....	.....	.....
Pottery	52,875	25,720	49,387	87,025	94,501
Quartz	130,860	82,544	142,354	223,514	358,674
Salt	474,372	498,383	585,022	700,515	1,047,707
Sand and gravel	233,567	151,909	178,288	470,963	431,597
Sewer pipe	600,297	571,756	361,283	216,749	378,923
Stone, building, crushed, etc.	1,137,153	1,088,862	651,593	755,313	939,052
Talc, crude and ground	125,340	74,583	85,325	111,489	179,554
Tile, drain	292,767	277,530	321,253	275,471	546,040
" building	.....	.....	.....	(e) 176,953	(e) 301,688
Non-metallic production	15,724,376	12,950,668	10,136,000	10,300,904	15,261,975
Add metallic production	37,507,935	33,345,291	44,109,679	55,002,918	56,831,857
Total production	53,232,311	46,295,959	54,245,679	65,303,822	72,093,832

(a) Cobalt oxide and metallic Cobalt.
(b) Nickel in matte, oxide and metallic Nickel.
(c) The product of Ontario ore only.
(d) Raw materials not all produced in Ontario.
(e) Included in former years with fancy and paving Brick.

The steady growth of the mineral industry of the Province is seen by comparing the value of the production by five-year periods since 1891, the date at which the Bureau of Mines was brought into existence. Following are the figures:—

Year.	Value Production. $	Growth per cent.
1891.....	4,705,673	
1896.....	5,235,003	.....11.2
1901.....	11,831,086	.....125.9
1906.....	22,388,383	.....89.2
1911.....	41,976,797	.....87.4
1916.....	65,303,822	.....55.5

As the figures show, the growth was continued into 1917, the total production being worth $72,093,832, or 10.3 per cent. above that of 1916.

Table III shows the value of the various metals and metal-bearing substances produced in Ontario from the time mining began down to the end of 1917. As will be noted, silver holds the first place, followed by nickel, pig iron, gold and copper, in the order given. Owing to a change in the method of compiling these statistics, pig iron since 1914 comprises only the pig product of Ontario ore smelted in the Province, and iron ore only ore exported. Including all pig iron produced in the Province regardless of the place of origin of the ore, and in iron ore all the domestic ore mined, whether smelted here or exported, the totals for pig iron and iron ore respectively would be $102,859,096 and $9,869,864.

TABLE III.—TOTAL PRODUCTION OF METALS IN ONTARIO.

Metal.	To end of 1916.	1917	Total Production.
	$	$	$
Gold	33,663,648	8,698,735	42,362,383
Silver	151,428,500	16,183,208	167,611,708
Platinum and Palladium (*a*)	290,755	.....	290,755
Cobalt (*b*)	3,180,990	1,122,779	4,303,769
Nickel (*c*)	89,128,164	21,041,956	110,170,120
Other Cobalt and Nickel Compounds	115,372	42,026	157,398
Copper	33,452,628	7,961,662	41,414,290
Iron Ore (*d*)	8,193,881	483,690	8,677,571
Pig iron (*e*)	76,544,482	1,016,699	77,561,181
Lead	188,153	172,601	360,754
Zinc	92,410	.....	92,410
Molybdenum	42,167	108,501	150,668
Total	396,321,150	56,831,857	453,153,007

(*a*) Figures incomplete.
(*b*) Includes metallic contents of Cobalt oxide.
(*c*) Includes metallic contents of Nickel oxide.
(*d*) From and including 1915 only ore exported.
(*e*) From and including 1915 only product of domestic ore.

The War and the Mineral Industry

The influence of the war on the mineral industry of the Province was discussed in the last Report of the Bureau, and it will now suffice to say that the effects there mentioned are still in evidence, and are in some directions becoming even more marked. For instance, the margin between profit and loss in gold mining is growing narrower, and in some properties has disappeared altogether. The high cost of labour, the difficulty of obtaining it in sufficient quantity and of the proper quality, and the steadily increasing prices of supplies, have united in raising the cost of production to a point where self-interest suggests that it would be better to suspend operations until more normal conditions return. In mines of lower grade, considerations of this kind have become very urgent, and some of the owners have felt impelled to close. They have not seen the wisdom of continuing to operate at a loss, and have decided that the prudent course is to leave the ore in the mine in the hope of being able to extract it at a profit some time in the future. How far this process will extend, it is impossible to say. So long as gold remains the basis of our monetary system, so long will it be essential to maintain a sufficient supply, and in sacrificing some part of their profits in remaining in operation, those companies which do so are acting a patriotic part.

In another and quite different direction, the war is telling against the mining industry. Assiduous and intelligent prospecting for new mineral areas and ore bodies is essential to the maintenance, not to say the progress, of mining. Now, very many of the best and most capable prospectors have gone overseas to fight the King's enemies, and their absence is being felt. Gold and silver mines are not like farms, and cannot be worked for ever, or even for many years. There must be a constant succession of new properties to take the place of those being exhausted, otherwise the industry will languish. The pre-Cambrian formations of northern Ontario have already given such proof of their mineral riches that there can be no doubt many valuable metal deposits remain undiscovered. It is to be hoped that when the victory for freedom and civilization has finally been won, many of the gallant men who laid down the prospector's pick for the rifle will return to their native heath and once more fare forth into the wilderness to find the treasures which it hides.

On the other hand, the demands of the war have greatly stimulated the production of certain minerals, and practically given rise to new mining industries. An essential in the manufacture of explosives, as, in fact, of chemicals of almost any kind, is sulphuric acid. Since the stoppage of supplies of free sulphur from Sicily, the product of Louisiana and Texas has not been sufficient for the tremendous demand for sulphuric acid from the munition plants of the United States, and the lack is being in large part supplied by the importation of iron pyrites from Ontario. The principal producer is the Nichols Chemical Company, Limited, whose mines are at Northpines and Goudreau, north of Lake Superior; also at Sulphide, in the county of Hastings, where it operates an acid plant. The production of pyrite rose from 145,315 tons in 1916 to 175,593 tons in 1917, most of which was exported to the United States. It is expected that about one-third of the total requirements of pyrite in the U.S. for 1917, or, say 400,000 tons, will be obtained in Ontario.

Another mineral which has sprung suddenly into active demand is fluorspar, which is used as a flux in steel-making. There are a number of deposits near

Madoc, in Hastings county, and as the price has risen from $4 or $5 to about $30 per ton, strenuous efforts are being made to meet the demand, and a considerable proportion of the known deposits have been opened and are being worked.

Molybdenite, to take the place of tungsten in the manufacture of special steels for tool-making and other purposes, has also come into prominence during the past four years. A number of molybdenite showings have been developed and a considerable quantity of concentrates produced. Ferro-molybdenum has also been made at Orillia and Belleville in the electric furnace. An account by A. L. Parsons was given in the Bureau's last Report of the principal occurrences of molybdenite in the Province.

Nickel and copper are, of course, prime requisites in modern warfare, and the capabilities of the Sudbury mines were taxed during the past year to supply the demand. Production had reached its maximum in 1916, and the output last year was practically on the same level, being 41,887 tons of nickel and 21,197 tons of copper in the matte, as against 41,299 tons of nickel and 22,430 tons of copper in 1916.

The conditions under which the mining industry is at present being carried on are perhaps more difficult than at any previous time. The extreme scarcity of labour caused by the withdrawal of so large a proportion of working miners and labourers continues to hamper operations, and there is little relief in sight except what may result from the slackening of operations in the gold fields. The bulk of the labour actually employed in mining is of foreign origin, not a little of it indeed alien enemy in character. It does not appear that any large proportion of this enemy labour is actively hostile, but the presence in our mines and mills of so many workmen who, technically at least, are the enemies of our country, cannot be regarded as a satisfactory feature. The mining industry is essential to the carrying on of the war, since it provides the raw materials for weapons and munitions, and the metals required for financing the struggle. No doubt a recognition of this fact reconciles a good many people to a spectacle which would otherwise be intolerable—that of enemy workmen employed at large wages while patriotic Canadians are risking their limbs and lives at very much smaller pay.

It will be remembered that in May, 1917, on account of the dearth of labour, and to enable prospectors and claim-holders to remain at work in the mines, an Order-in-Council was passed permitting the postponement of assessment work on mining claims for twelve months. The provisions of this order were largely taken advantage of, and the result was that in 1918 two instalments of assessment work fell due on many claims, namely, the instalment for 1917 and also that for 1918. To ease the situation, in June, 1918, another Order was passed declaring it unnecessary in such cases to do more than the work postponed from last year, and also moving forward for twelve months the period for performing any subsequent instalment or instalments of work.

The high and steadily mounting cost of supplies of all kinds, and the delays attendant upon the procuring of machinery, are also embarrassing the mining industry in common with others. The peremptory and enormous demands of the war for steel and iron must first of all be met, and only what remains can be diverted to peaceful industries. While so large a proportion of the manufacturing plants both of Canada and the United States are engaged in making munitions of war, this difficulty of obtaining mining machinery and plant will necessarily

continue. Coal is also required at many mining properties for heating and at some for power, and the coal situation is certainly not all that could be desired. However, electric energy generated hydraulically is now so generally used for the operation of mines and works in Ontario that the scarcity of fuel is not so serious in mining as in many other industries.

The operation of the taxation laws, Dominion and Provincial, has not borne with undue harshness upon mining. In both cases profits are the basis of the tax, and if no profits are realized no taxation is imposed. In addition, the Dominion taxing regulations permit allowance to be made for exhaustion of the mine, which materially reduces the amount of the tax. Except in the case of nickel-copper mines, and also where profits exceed one million dollars per annum, the Ontario tax remains at 3 per cent. of the net profits. The Canadian Copper Company contested the constitutionality of the amendments of 1917 to the Mining Tax Act of Ontario, and applied to the Government of Canada to disallow it. Argument was heard by the Government in the matter, but it declined to interfere.

Gold

The production for 1917 was 420,893 fine ounces, being 76,940 ounces or about 15 per cent. less than in 1916. The causes of this decrease have already been mentioned, the principal, if not the only one, being the greatly increased cost of production of an article whose price is fixed. All but about 6 per cent. of the gold was obtained from the mines of Porcupine. Here the leading producer was the Hollinger, followed by the McIntyre, Dome, Porcupine Crown, Porcupine V.N.T., and Schumacher, in the order named. Dome Lake made a small production, and there was a little gold obtained at one or two other prospects under development. At Kirkland Lake, Tough-Oakes was joined during the year as a producer by Teck-Hughes. The only other productive property of account was the Crœsus, which won some 2,837 ounces of gold from 1,541 tons of ore. In Table IV, given below, will be found particulars of the gold production for 1917:—

TABLE IV.—GOLD MINING IN 1917.

Mine.	Tons Ore milled.	Gold Product.		Silver Product.		Total Value.	Extraction per ton	Dividends in year.
		Fine ounces.	Value.	Fine ounces.	Value.			
Porcupine—			$		$	$	$ c.	$ c.
1. Dome.....	359,570	71,193	1,471,705	10,659	8,469	1,480,174	4 12	300,000 00
2. Dome Lake..	16,388	2,166	44,291	176	143	44,434	2 61	.....
3. Hollinger....	514,301	204,810	4,233,777	34,886	28,161	4,261,938	8 29	738,000 00
4. McIntyre	175,893	81,827	1,696,126	17,536	14,078	1,710,204	9 73	541,542 45
5. Newray.....	340	70	1,440	9	7	1,447	4 26	.....
6. Porc. Crown.	39,111	18,180	375,766	2,637	2,138	377,904	9 66	120,000 00
7. " V.N.T.	34,971	10,416	208,350	1,705	1,388	209,738	5 99	.....
8. Schumacher..	37,323	9,551	197,413	1,491	1,192	198,605	5 32	.....
9. Tommy Burns & Gold Reef	31	44	876	1	1	877	.....	.....
Kirkland Lake—								
10. Teck-Hughes	11,257	3,181	65,753	1,155	969	66,722	5 44	.....
11. Tough-Oakes.	38,695	16,384	338,593	5,257	4,237	342,830	8 86	.....
Miscellaneous—								
12. Cordova	860	29	593	.....	.....	593	(a)	.....
13. Crœsus.....	1,541	2,837	59,820	281	226	60,046	38 97	.....
14. Rognon.....	40	14	279	.....	.....	279	6 97	.....
15. St. Anthony.	.....	94	1,944	26	23	1,967	.....	.....
16. Small Producers....	3	43	884	404	242	1,126	5 89	.....
17. Copper Ore ..	.....	54	1,125	.....	.....	1,125	.....	.....
Total	1,230,324	420,893	8,698,735	76,223	61,274	8,760,009	7 12(b)	1,699,542 45

(a) Over $3,000 in gold lost in fire.
(b) Average of 1 to 16 inclusive, omitting Nos. 12 and 15.

Development work is going on in several of the newer gold areas, and the prospect is that ere long some of these properties will contribute to the output of gold. At Boston Creek, the Patricia syndicate took over the Boston-Hollinger claim in August 1917, and by the end of the year had power plant installed and the necessary buildings erected. Two shafts had been sunk, 110 and 90 feet respectively in depth, and it was proposed to erect a 40-stamp mill. In this camp also the Miller Independence Mines, Limited, installed a standard Ball mill, with amalgamation and oil-flotation treatment of concentrates.

At Kirkland Lake there was a good deal of activity. Lake Shore Mines, Limited, built a mill of approximately 60 tons per day capacity, and expected to have it in operation in March, 1918. It is of the ball-and-tube grinding type, with continuous counter-current decantation process for gold recovery. Kirkland Lake Gold Mining Company, Limited, also had a gold mill in course of construction. The Wright-Hargreaves Mines, Limited, continued sinking and developing operations, employing a force of about 50 men.

The mill at the Dome mine, Porcupine, operated for most of the year, but closed down at the end of November, the cost of production having risen to a point where operations were unprofitable. Underground work, however, was continued.

The Canadian Exploration Company, at Long Lake, did some diamond-drilling in the early part of the year, and a little experimental work on tailings, but later closed the mine entirely.

Following is a list of the producing gold mines, with the post-office address of the manager, etc.:—

PRODUCING GOLD MINES, 1917.

Name of Company.	Name of Mine.	Locality.	P.O. Address of Manager, etc.
Cordova Mines, Limited	Cordova	Eastern Ontario	Toronto.
Crœsus Gold Mines, Limited	Crœsus	Munro tp.	Matheson.
Crown-Newray Company	Newray	Porcupine	Timmins.
Dome Mines Co., Limited	Dome	Porcupine	
Dome Lake Mining and Milling Company, Limited	Dome Lake	Porcupine	South Porcupine.
Hollinger Consolidated Gold Mines, Limited	Hollinger	Porcupine	Timmins.
McIntyre-Porcupine Mines, Limited	McIntyre	Porcupine	Schumacher.
Porcupine Crown Mines, Limited	Porcupine Crown	Porcupine	Timmins.
Porcupine V. N. T. Gold Mines, Limited	Vipond-North Thompson	Porcupine	Timmins.
Rognon Gold Mines, Limited	Rognon	Wabigoon Lake	Dryden.
Schumacher Gold Mines, Limited	Schumacher	Porcupine	Schumacher.
Teck-Hughes Gold Mines, Limited	Teck-Hughes	Kirkland Lake	Kirkland Lake.
Thunder Mining Company, Limited	St. Anthony	Sturgeon Lake	St. Anthony Mine.
Tough-Oakes Gold Mines, Limited	Tough-Oakes	Kirkland Lake	Kirkland Lake.

The gold production of the Province and of the Porcupine area respectively, for the last seven years, are given in the table appended. As the figures show, the Porcupine mines have supplied very much the larger share of the total.

GOLD PRODUCTION, 1910-1917.

Year.	Total Production. $	Porcupine. $	Percentage from Porcupine.
1910	68,498	35,539	51.8
1911	42,637	15,437	36.2
1912	2,114,086	1,730,628	81.8
1913	4,558,518	4,294,113	94.1
1914	5,529,767	5,190,794	93.8
1915	8,501,391	7,536,275	88.6
1916	10,339,259	9,397,536	90.8
1917	8,698,735	8,229,744	94.5

On a later page will be found Table V, which shows the dividends which have been declared by the gold mining companies in Ontario up to the end of 1917. It will be seen that for last year the amount so declared was $1,699,542.45, and for the full period, $11,486,167.45.

The Case of the Gold Mining Industry

For the immediate future the outlook is for a diminution of the gold yield of the Province, but this by no means reflects upon the capability of the producing areas, new or old. It is simply the result of economic conditions, a suspension, not a cessation, of activity, and at the worst only partial. In the long run the expenditure of money in operating an unprofitable enterprise must result in lessening the stock of capital employed in the industry, and from this point of view is economically unsound.

But there is little room to doubt that with the return of peace there will come a renewal of vigorous life in the gold mining camps of the North. The colossal expenditures of the belligerent nations during the period of the war have far outstripped the ability of the gold reserves of the world to finance them, measured by any customary pre-war basis. These reserves have been computed roughly to amount to $10,500,000,000, or, say, 17,000 tons of gold. Practically all the combatant nations, Italy excepted, have a single standard for their financial basis, namely, gold. Hence the debts which all have so lavishly contracted, and are still contracting, are nominally payable in this metal. But the entire gold reserves of the world, instead of representing about 35 per cent. of the total indebtedness of the warring nations, as they did before the beginning of the conflict, now amount to only about 8 per cent. Consequently, the ability of any nation to obtain funds for war expenditures now depends much less than formerly upon the amount of gold which it possesses or controls, and rests in fact almost wholly on its credit. This in turn is based upon its previous financial record, and its present and potential resources. Yet all the borrowings, and the interest annually accruing upon them, are payable in gold, and hence the necessity imposed upon the borrowers to provide themselves with this essential metal. As gold is the article in demand, among the most important assets of a nation is its gold fields, and it is reassuring to remember that Great Britain and her Allies control over 90 per cent. of the world's gold production. The gold mines of the British Empire alone annually provide about 62 per cent. of the entire yield, which in 1917 is estimated at about £96,700,000.

The favourable trade position occupied by the United States after the war began and up to the time when she too was constrained to throw her sword into the

scale, enabled her to increase her share of the world's monetary stock from about one-fifth to nearly one-third; the coin and bullion used as money in that country on November 1, 1917, being estimated at $3,041,500,000. As a matter of practical experience neither the world stock of gold or of silver, nor both combined, has proven sufficient to meet the necessities of trade and finance occasioned by the war, and the strain upon these metals has had in every country to be relieved by the issue of paper currency. One of the first war acts of the British Government was to print, in August, 1914, one-pound and ten-shilling notes, nothing of smaller denomination than the five-pound notes of the Bank of England having previously been in circulation in England.

Unless the changes which everyone is predicting are to follow the war, include the overthrow of our present systems of exchange and the substitution of some other basis for that of gold, the demand for that metal will continue, and will probably become greater than ever. Should the cost of labour and supplies fail to drop to a level at which low grade mines again become profitable, the nations may have to face the question whether, on the ground of public necessity, they should not come actively to the aid of the gold mining industry.

Silver

There was a slight falling off in the quantity of silver mined and marketed last year as compared with 1916, the quantities respectively being 19,479,692 and 20,007,367 fine ounces, a decrease of 2.6 per cent. In value, however, there was a large increase. In 1916 the return to the mining companies was $12,703,591, while in 1917 it was $16,183,208, or 27.3 per cent. more. Thus, while in 1916 the average price per fine ounce received by the mine owners was 63.49 cents, last year it was 83.07 cents. For the entire year 1917 the average price for silver in New York was 81.417 cents, as compared with 65.661 cents in 1916. The lowest monthly average price was 73.861 cents in March, and the highest 100.740 cents in September. On September 21 the price rose to $1.08 per ounce, and on September 28 the Mining Corporation of Canada is stated to have sold 200,000 ounces of silver on a basis to net the company in Toronto $1.16 7-16 per ounce. On the same day the New York price was $1.085 per ounce. These are the highest figures for silver that have been quoted for forty years. The price in London on September 21 rose to 55d. standard, the highest figure since March, 1878. It remained four days at this point, and then began to fall in a spectacular fashion, until October 23, when it reached 41⅞d., a drop of 13⅛d. in less than a month. On October 30 a rise of 3d. occurred from 43d. to 46d., the largest variation in a single day on record. Since the close of the year the United States Government has decided to melt into bullion as much as is necessary of some $400,000,000 it holds in silver dollars, and to fix the price for purchase of silver to replace them at $1.00[1] per fine ounce, thus ensuring a firm and high market for the output of the Cobalt mines.

The rapid rise in the value of silver last year was in the main due to the demand for coinage purposes by the belligerent nations, including China. The European armies are paid in silver, and huge disbursements are constantly being made to the millions of men under arms.

[1] Since increased to $1.01½.

Influence of the East

The Chinese demand arose from an effort by that country in the latter part of the summer to replace part of its currency, of which large amounts had earlier in the year been shipped abroad, chiefly to India which imported from China some 39 million ounces. China's policy of alternate buying and selling silver was largely responsible for the rapid fluctuations of price during the year. The monetary system of that country, if system it can be called, being based on silver, the rise in price of that metal greatly helped the revenue of the Chinese Government, especially in relation to payments of foreign indebtedness which had to be made in gold. In China gold is a commodity, just as silver is in other countries, and the enhanced value of silver led to an increased purchase of gold in the form of objects of art and jewellery. A large part of the imports of silver, amounting to 25 millions of ounces, came from San Francisco; London, for the time at any rate, being unable to compete with Western ports on account of the greater cost of carrying silver across the Atlantic owing to the high rates of insurance against war risk. This considerable diversion of silver from the London market contributed largely to the remarkable rise in price to 55d. per standard ounce in September.

The increased cost of commodities, which was as marked in the East as in the West, the large war expenditures and consequent stimulation of business demanded an increase in the amount of currency, and accordingly the Indian mints became very busy. During the twelve months ending March 31, 1917, the coinage of rupees,[1] half-rupees and quarter-rupees amounted to 307¾ million rupees, the equivalent of nearly 106 million fine ounces of silver. The net imports into India during this period were a little less than the silver coined, or 104,069,101 ounces, but the Government

[1] The rupee is the standard measure of value in India, and it also circulates largely in Mesopotamia, Egypt, etc. It is a silver coin weighing 180 grains, of which 165 parts are pure silver and 15 parts alloy. There are 16 annas in a rupee, and one anna equals 12 pies (or pice); 8-anna and 4-anna pieces are struck in silver, 1-anna pieces in nickel, ¼-anna, ⅛-anna and 1-12-anna pieces in bronze. The value of a rupee is one-fifteenth part of one pound sterling, or 1s. 4d., hence one anna is the equivalent of a penny. The gold standard was introduced into India in 1899, but as yet no sovereigns have been minted there. A lac (or lakh) is 10,000 rupees, and a crore is 10,000,000 rupees.

The extreme poverty of the majority of the Indian people is illustrated by an example from life given in Benjamin White's "Silver, its History and Romance" (Hodder and Stoughton, London, New York and Toronto, 1917). An agricultural labourer's family in Bengal consisted of himself (aged 18), two younger brothers aged 8 and 6 years respectively, a sister of eleven, and his wife and mother, six persons in all. The head of the household and his 8-year old brother were the breadwinners, earning 2d. per day each, the wages being paid sometimes in cash, but generally in kind. The family possessions consisted of 3 cows, value £4 10s., and some goats; their furniture of three brass dishes, a few kitchen utensils and a grindstone (flour mill), total 8s. The entire expenditure of this family for one year was £6 sterling, of which £4 15s. went for food, 15s. for clothing, and 10s. for other purposes, including 8d. for celebration of the sun-god festival. It is evident that among the 300,000,000 people whose standard of living sinks to so low a level, coins of small denomination are required in the myriad transactions of daily life, hence the circulating media are largely confined to the rupee and smaller coins. Since the war began, however, even the Hindu labourer's wages have materially increased.

In explanation of the almost uninterrupted disappearance from view of much of the silver imported into India, Mr. White says: "The Indian native is a born hoarder. Generation after generation of unrest has passed in India. Great empires in succession have risen and fallen, and the coming and going of each ruling power has been bad for the peasant. So, throughout the ages, he sank his little pile in mother earth, to be disinterred in another and perhaps happier time. 'Will the British Raj last any more than the others?' he says. 'It is true we are not ground and taxed to death as in the past; so much the better for our underground reserves.' For this operation nowadays, he prefers to secrete a portion in gold. He can better afford it; it is handier for hoarding, and it is less bulky for carrying."

was able to procure an additional £1,000,000 worth in the local bazaars. The exceptional promise of good crops in India in 1917, which promise was fulfilled, required the mints to remain at work, and coinage to the extent of 207,737,326 rupees was turned out during the year. For the six months ending September 30, 1917, the net imports into India were 42,915,610 ounces. The internal demand for silver in India for use in the arts, usually large, became very great, and to a considerable extent was met by "country bars," *i.e.,* bars made by melting down old stocks of jewellery, etc. The existing high prices tempted many people who had bought their silver jewellery in the years when prices were very much lower, to realize a profit by re-selling it as bullion. Later in 1917 the export of silver from India was prohibited, and imports were regulated by providing that none should be brought in except under license. To supplement the very large coinage of silver, the Indian Government decided upon an issue of rupee notes, thus falling in line with many of the Western nations. The prohibition by the British Government of shipments of gold to India, with the view of reducing the drafts on the all-important stocks of that metal held in England necessitated settlement of the balance of trade in favour of India to be made in silver, and this fact, together with a somewhat similar situation in China and Japan has no doubt assisted in maintaining the high level to which the price of silver has risen. The action of the United States Government in resolving to melt into bullion $400,000,000 worth of silver dollars held in reserve against silver certificates, and to place the bars upon the market as required, was very opportune in relieving the strain thrown upon the financial functions of silver in the East, where perhaps 75 per cent. of the production of the world is annually consumed.

In Europe and America, the principal feature of the silver industry was the purchase by Great Britain, France, and the United States of large quantities to be coined for payment of their troops. The continent of America being the source of over 80 per cent. of the silver annually produced in the world, and the continent of Asia absorbing over two-thirds of it, it would seem that the direct route from the Pacific coast to China and India would even in normal times offer advantages over Atlantic shipments with transfer at London. Insurance rates were high during 1917, and much more silver than usual was exported from San Francisco and Vancouver. The currents of trade once firmly established are, however, very persistent, and the control that London exercises over Eastern exchange will probably be strong enough to ensure a restoration of former conditions when peace returns.

Silver Largely a By-Product

The events which in any quarter of the world have a bearing upon the demand and price for silver, have a special interest for that branch of the mining industry in Ontario, by reason of the fact that the mines of this Province are among the comparatively few which are worked primarily for their silver contents. Probably two-thirds of the silver production of the world is obtained as a by-product of lead, copper, and zinc mines, in the ores of which silver is present in quantity worth saving, yet not usually sufficient to warrant their being worked for the silver alone. The lead, copper, or zinc would continue to be produced if the market price of the metal or metals warranted, whether silver were high in price or low,

and fluctuations in the price of the by-product metal are of comparatively little significance. In the case of Cobalt, however, silver is the paramount product, and consequently the ruling price of silver is the fact of prime importance. Because of silver being in this sense subsidiary to other metals, even a decided advance in value, such as occurred in 1917, has not the effect of increasing the output to the same extent as if it were in the main worked for its own sake only. Hence it is unlikely that the present value of silver will be reduced by a sudden and large increase of the world's output, and so long as the present urgent demand continues, it may reasonably be expected that the price will remain high.

The production of silver in the world last year is estimated at about 167,000,000 fine ounces. Of this, the United States contributed 74,244,500 ounces, and Canada 22,150,680 ounces. Mexico, which a few years ago led all the countries with a yield of over 70,000,000 ounces, has now fallen to about half that quantity, and the policy of hostility towards foreign capital invested in mining being pursued by the Government in power renders it unlikely that her former position will be soon resumed.

The production of silver in the Province last year, according to camps, was as follows:—

	Ounces.
South Lorrain	10,000
Gowganda	1,064,635
Cobalt proper	18,327,258
Silver recovered from gold and copper ores	77,799
Total	19,479,692

The mines sending out more than one million ounces of silver were:—

	Ounces.
Mining Corporation	4,546,065
Nipissing	3,794,242
Kerr Lake	2.302,466
Coniagas	1,273,853
O'Brien	1,064,335
Miller-Lake O'Brien	1,050,149
McKinley-Darragh-Savage	1,013,602

Those shipping less than a million ounces, but more than a quarter of a million were:—

	Ounces.
Temiskaming	887,122
Buffalo	645,915
La Rose Consolidated	478,639
Beaver Consolidated	462,723
Chambers-Ferland	330,063
Trethewey	311,324
Crown Reserve	309,420
Hudson Bay	277,091
Penn-Canadian	259,784

Silver and Gold Dividends

Table VII, which is appended, gives a list of the silver and gold mining companies which have paid dividends, and shows the amounts so paid, etc. In 1917 the distribution of dividends and bonuses amounted to $5,586,946.80, and in the entire period to $70,821,829.34.

TABLE V.—DIVIDENDS AND BONUSES BY GOLD AND SILVER MINING COMPANIES TO DECEMBER 31, 1917.

Name of Company.	Date of Incorporation.	Authorized Capital.	Capital Stock Issued.	Par value per share.	Amount of Dividends and Bonuses paid to end of 1916	Amount of Dividends and Bonuses paid during 1917.		Total of Dividends and Bonuses paid to Dec. 31st, 1917.	Last Dividend or Bonus. Date declared.
GOLD COMPANIES.		$	$	$ c.	$	$ c.	%	$	
Dome Mines Company, Ltd.	Mar. 23, 1910	5,000,000	4,000,000	10 00	1,200,000 00	300,000 00	7½	1,500,000 00	May 7, 1917
*Hollinger Consolidated Gold Mines, Ltd.	May 20, 1916	25,000,000	24,600,000	5 00	7,456,000 00	738,000 00	3	8,194,000 00	April 22, 1917
McIntyre-Porcupine Mines, Ltd.	Mar. 16, 1911	4,000,000	3,610,283	1 00	.....	541,542 45	15	541,542 45	Sept. 29, 1917
Porcupine Crown Mines, Ltd.	May 26, 1913	2,000,000	2,000,000	1 00	720,000 00	20,000 00	12	840,000 00	July 15, 1917
Rea Consolidated Gold Mines	April 5, 1911	1,000,000	200,000	5 00	12,000 00	.....	....	12,000 00	.....
Tough-Oakes Gold Mines, Ltd.	July 15, 1913	3,000,000	2,657,500	5 00	398,625 00	.....	....	398,625 00	Dec. 27, 1916
Total by Gold Companies	.....	.....	.....	.....	9,786,625 00	1,699,542 45	....	11,486,167 45	
SILVER COMPANIES.									
Aladdin Cobalt Company, Limited	Aug. 23, 1912	500,000	500,000	5 00	.....	75,000 00	15	75,000 00	April 30, 1917
Beaver Consolidated Mines, Ltd.	Mar. 1, 1907	2,000,000	2,000,000	1 00	650,000 00	.....	....	650,000 00	April 8, 1916
Buffalo Mines, Ltd., The	April 27, 1906	1,000,000	1,000,000	1 00	2,787,000 00	.....	....	2,787,000 00	May 28, 1914
Casey Cobalt Silver Mining Company, Ltd.	Dec. 19, 1906	100,000	100,000	1 00	203,249 33	.....	....	203,249 33	April 22, 1914
Cobalt Comet Mines, Ltd.	April 16, 1913	1,000,000	1,000,000	1 00	230,000 00	.....	....	230,000 00	April 1, 1915
Coniagas Mines, Limited, The	Nov. 24, 1906	4,000,000	4,000,000	5 00	8,440,000 00	300,000 00	7½	8,740,000 00	Aug. 8, 1917
Crown Reserve Mining Co., Ltd.	Jan. 16, 1907	2,000,000	1,999,957	1 00	6,190,849 00	.....	....	6,190,849 00	Dec. 28, 1916
Kerr Lake Mining Company, Ltd.	Aug. 9, 1905	40,000	40,000	100 00	7,128,000 00	662,000 00	....	7,790,000 00	Oct. 9, 1917
La Rose Mines, Ltd.	May 31, 1908	6,000,000	6,000,000	5 00	6,030,546 84	240,000 00	4	6,270,546 84	Sept. 11, 1917
McKinley-Darragh-Savage Mines of Cobalt Ltd.	April 17, 1906	2,500,000	2,247,692	1 00	4,943,930 46	269,723 04	12	5,213,653 50	Nov. 6, 1917
†Mining Corporation of Canada, Ltd.	Mar. 20, 1914	2,075,000	2,075,000	1 00	1,348,750 00	1,556,296 86	18¾	2,905,046 86	Dec. 15, 1917
Nipissing Mining Company, Ltd.	Dec. 16, 1904	250,000	250,000	100 00	16,288,297 25	1,935,000 00	....	18,233,297 25	Dec. 6, 1917
Penn-Canadian Mines, Ltd.	April 24, 1912	1,500,000	1,349,705	1 00	67,485 25	148,467 55	11	215,952 80	Sept. 10, 1917
Peterson Lake Silver-Cobalt Mining Co. Ltd.	April 11, 1906	3,000,000	2,401,820	1 00	420,031 50	42,031 85	1¾	462,063 35	Jan. 2, 1917
Seneca-Superior Silver Mines, Ltd.	Sept. 29, 1911	500,000	478,884	1 00	1,579,817 20	.....	....	1,579,817 20	Dec. 15, 1916
Temiskaming Mining Co., Ltd.	Nov. 5, 906	2,500,000	2,500,000	1 00	1,684,156 25	300,000 00	12	1,984,156 25	Oct. 5, 1917
Wettlaufer Lorrain Silver Mines, Ltd.	Nov. 30, 1908	1,500,000	1,416,590	1 00	637,465 50	.....	....	637,465 50	Sept. 22, 1913

Trethewey Silver Cobalt Mines, Ltd.	May 30, 1906 June 1, 1911	2,000,000	1,000,000	1 00	1,111,998 50	50,000 00	5	1,161,998 50	Aug.	20, 1917
Right of Way Mines, Ltd.	Sept. 11, 1909	2,000,000	1,685,500	1 00	244,397 50	8,427 50	½	252,825 00	.....	
Right of Way Mining Co., Ltd.	July 13, 1906	500,000	500,000	1 00	324,643 93	.....	....	324,643 93	.....	
**City of Cobalt Mining Co., Ltd.	Oct. 5, 1906 Jan. 7, 1909	500,000 1,500,000	1,500,000	1 00	145,000 00	.....	....	145,000 00	April	15, 1909
Cobalt Central Mines Co., Ltd.	Dec. 13, 1906	5,000,000	5,000,000	1 00	192,845 00	.....	....	192,845 00	Aug.	25, 1909
**Cobalt Lake Mining Co., Ltd.	Dec. 22, 1906	3,000,000	3,000,000	1 00	465,000 00	.....	....	465,000 00	May	29, 1914
Cobalt Silver Queen, Ltd.	April 1, 1906	1,500,000	1,500,000	1 00	315,000 00	.....	....	315,000 00	Dec.	31, 1908
**Cobalt Townsite Mining Co,. Ltd.	May 8, 1906	100,000	45,011	1 00	1,042,259 61	.....	....	1,042,259 61	Nov.	11, 1914
Foster Cobalt Mining Co., Ltd.	Feb. 14, 1906	1,000,000	915,588	1 00	45,000 00	.....	....	45,000 00	Jan.	1, 1907
Temiskaming and Hudson Bay Mining Co. Ltd.	July 29, 1903	25,000	7,761	1 00	1,940,250 00	.....	....	1,940,250 00	Nov.	10, 1914
Hudson Bay Mines, Ltd.	July 16, 1909	3,500,000	3,200,050	5 00	778,909 42	.....	....	778,909 42	Aug.	31, 1913
Total by Silver Companies	.....	.....	.....	.....	65,234,882 54	5,586,946 80	....	70,821,829 34		
Total dividends	.....	.....	.....	.....	75,021,507 54	7,286,489 25	....	82,307,996 79		

* Hollinger Consolidated Gold Mines Limited is a consolidation of the Acme Gold Mines Limited, Millerton Gold Mines Limited, and Hollinger Gold Mines Limited. Dividends include $160,000 paid by the Acme prior to amalgamation with the Hollinger.

† Mining Corporation of Canada, Limited, owns and operates the City of Cobalt, Cobalt Lake and Cobalt Townsite mines.

** Now owned and operated by Mining Corporation of Canada, Limited.

Table VI, which follows, shows the shipments of ore, concentrates and silver bullion from the Cobalt silver mines since they were opened in 1904. The figures take no account of inter-camp movements, but include all shipments to outside points, whether in Ontario or the United States. The diminution in raw ores sent out, and the increase of concentrates and bullion will be noted:—

TABLE VI.—SILVER PRODUCTION, COBALT MINES, 1904 TO 1917.

Year.	No. of Producing Mines.	Shipments and Silver Contents.								
		Ore.			Concentrates.			Bullion.	Total.	
		Tons.	Oz.	Av. per ton. Oz.	Tons.	Oz.	Av. per ton. Oz.	Oz.	Ounces.	Value. $
1904....	4	158	206,875	1,309	.....	.....	.....	.....	206,875	111,887
1905....	16	2,144	2,451,356	1,143	.....	.....	.....	.....	2,451,356	1,360,503
1906....	17	5,335	5,401,766	1,013	.....	.....	.....	.....	5,401,766	3,667,551
1907....	28	14,788	10,023,311	677	.....	.....	.....	.....	10,023,311	6,155,391
1908....	30	24,497	18,022,480	736	1,137	1,415,395	1,244	.....	19,437,875	9,133,378
1909....	31	27,729	22 436,255	809	2,948	3,461,470	1,174	.....	25,897 825	12,461,576
1910....	41	27,487	23,581,714	821	6,945	7,082,884	1,030	980,633	39,645,181	15,478,047
1911....	34	17,278	20,318,636	1,176	9,375	8,056,189	858	3,132,976	31,507,791	15,953,847
1912....	30	10,719	15,395,504	1,436	11,214	9,768,228	871	5,080,127	30,243,859	17,408,985
1913....	35	9,861	13,668,079	1,386	11,016	8,489,321	770	7,524,575	29,681,975	16,553,981
1914....	32	4,302	6,504,753	1,511	12,152	8,915,958	733	9,742,130	25,162,841	12,765,161
1915....	24	2,865	6,758,286	2,359	11,996	10,001,548	834	7,986,700	24,746,534	12,135,816
1916....	28	2,177	4,672,500	2,146	8,561	7,598,011	887	7,644,579	19,915,090	12,643,175
1917....	28	2,288	3,271,353	1,429	13,720	6,445,243	469	8,053,318	19,401,893	16,121,013
Total ..	.....	151,568	151,712,958	1,001	88,964	71,234,197	801	50,145,038	274,724,172	151,950,561

In Table VII is shown the quantity and value of all the constituents, recoverable and recovered, in the ores of the Cobalt camp from the beginning. Until 1913 an estimate was made of the nickel, cobalt, and arsenic contents, since in few cases only were these substances paid for, and consequently no assays were made for them, but since 1914 only the actual recoveries and their money values are given. Beyond doubt in past years only a small proportion of these by-products was extracted from ore shipped to the United States, but the volume of such shipments has since been greatly reduced.

TABLE VII.—TOTAL PRODUCTION, COBALT SILVER MINES, 1904 TO 1917.

Year.	Copper.(a)		Nickel.		Cobalt.		Arsenic.		Silver.		Total Value.
	on.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Ounces.	Value.	
		$		$		$		$		$	$
1904..	.....	.....	14	3,460	16	19,960	72	903	206,875	111,887	136,217
1905..	.....	.....	75	10,00	118	100,000	549	2,693	2,451,356	1,360,503	1,473,196
1906..	.....	.....	160	.....	321	80,704	1,440	15,858	5,401,766	3,667,551	3,764,113
1907..	.....	.....	370	1,174	739	104,426	2,958	40,104	10,023,311	6,155,391	6,301,095
1908..	.....	.....	612	.....	1,224	111,118	3,672	40,373	19,437,875	9,133,378	9,284,869
1909..	.....	.....	766	.....	1,533	94,965	4,294	61,089	25,897,825	12,461,576	12,617,580
1910..	.....	.....	504	.....	1,098	54,699	4,897	70,709	30,645,181	15,478,047	15,603,455
1911..	.....	.....	392	.....	852	170,890	3,806	74,609	31,507,791	15,953,847	16,199,346
1912..	.....	.....	429	14,220	934	314,381	4,166	80,546	30,243,859	17,408,935	17,818,082
1913..	.....	.....	377	13,326	821	420,536	3,663	64,146	29,681,975	16,553,981	17,051,839
1914..	.....	.....	(b) 90	28,978	(b) 351	590,406	2,030	116,624	25,162,841	12,765,461	13,501,469
1915..	.....	....	(c) 35	28,353	(c) 206	383,261	2,490	148,379	24,746,534	12,135,816	12,695,809
1916..	.....	.....	(c) 79	59,330	(c) 400	805,014	2,160	200,103	19,915,090	12,643,175	13,707,672
1917..	53	28,840	(c) 155	125,071	(c) 337	1,138,190	2,592	608,483	19,401,893	16,121,013	18,028,597
Total.	53	28,840	4,058	283,969	8,950	4,388,400	38,789	1,524,569	274,724,172	151,950,561	158,176,339

(a) Copper is recovered from certain silver ores and concentrates shipped to United States refineries.
(b) Metallic contents of Nickel and Cobalt oxides respectively.
(c) Metals and metallic contents of all Nickel and Cobalt compounds.

Following is a list of the productive silver properties in operation at Cobalt in 1917:—

PRODUCING SILVER MINES IN 1917.

Company or Owner.	Mine.	P.O. Address of Manager, etc.
Adanac Silver Mines, Limited	Adanac	Haileybury.
Aladdin Cobalt Company, Limited	Chambers-Ferland	Cobalt.
Angus, D. H.	Nipissing Reduction Mill clean-up	Cobalt.
Beaver Consolidated Mines, Limited	Beaver	Cobalt.
Buffalo Mines, Limited, The	Buffalo	Cobalt.
Cobalt Comet Mines, Limited	Drummond	Giroux Lake.
Cobalt Provincial Mining Co., Limited	Provincial	Cobalt.
Cobalt Silver Queen, Ltd.	Silver Queen	Cobalt.
Coniagas Mines, Limited	Agaunico	Cobalt.
	Coniagas	
Crown Reserve Mining Company, Limited	Crown Reserve	Cobalt.
Hargrave Silver Mines, Limited	Hargrave	Cobalt.
Hudson Bay Mines, Limited	Hudson Bay	Cobalt.
Kerr Lake Mining Company, Limited	Kerr Lake	Cobalt.
La Rose Mines, Limited	La Rose	Cobalt.
McKinley-Darragh-Savage Mines of Cobalt, Limited	McKinley-Darragh, Savage	Cobalt.
Mining Corporation of Canada, Limited, The	Cobalt Lake, Townsite-City	Cobalt.
National Mines, Limited	National	Cobalt.
Nipissing Mining Company, Limited	Nipissing	Cobalt.
O'Brien, M. J., Limited	O'Brien	Cobalt.
do	Miller-Lake O'Brien	Gowganda.
Penn-Canadian Mines, Limited	Penn-Canadian	Cobalt.
Pittsburg Lorrain Syndicate	H.R. 105, or Currie	Silver Centre.
Reeve-Dobie Mines, Limited	Reeve-Dobie	Gowganda.
Right-of-Way Mines, Limited	Right of Way	Cobalt.
Temiskaming Mining Company, Limited	Temiskaming	Cobalt.
Trethewey Silver-Cobalt Mine, Limited	Trethewey	Cobalt.

Refining the Silver

Much the larger part of the ore raised from the silver mines of Ontario is now treated and refined in the Province. The silver mining industry at Cobalt has undergone a normal course of development since the opening of the mines in 1904. At the beginning the entire output, consisting mainly of high-grade ore and metallic slabs and nuggets, was sent to smelters in the United States; then, as the deposits were opened up and low-grade ore and milling rock began to be encountered, concentration methods were introduced. This was followed by the establishment of refineries in the Province itself, not at Cobalt, but in other parts of Ontario, where plants already in existence could be made use of, or where there was cheap electric power. At a number of the mines themselves, smelting and cyanidation processes were introduced for the production of merchantable bars; and custom concentration and reduction plants were erected. As at the Nipissing mine, specialized methods of treating both high grade and low grade ores were devised and installed, and lastly the introduction of the flotation process for the concentration

of low grade rock and ore gave value to dump piles and large quantities of material that were previously regarded as worthless. The substitution of hydraulically generated electrical power for the steam engine at an early date materially lessened the cost of mine and mill operations. The working of the Mining Tax Act gave the local municipalities a large share of the revenues derived from mines, and enabled a first-class system of automobile roads to be constructed connecting the mines with the railway at Cobalt, and from the outset the Government railway itself, running as it did to the very collars of the mine shafts, effectually averted all transportation difficulties.

The southern Ontario refineries under the encouragement afforded by the Metal Refining Bounty Act not only produced refined silver bars, but also cobalt and nickel oxide, subsequently extending the list of products to include cobalt sulphate, carbonate and hydroxide, nickel sulphate, metallic cobalt and nickel, and stellite, an alloy of cobalt, tungsten and chromium, useful for the making of high-speed tools. Quantities of arsenic are obtained, sold chiefly as white arsenic or arsenious acid, a smaller proportion being disposed of as crude. A little metallic arsenic is also produced. It can thus be seen how large a part in the industrial growth of the Province the silver mining industry has played and continues to play, for the mines are by no means exhausted, and will continue to produce silver for years to come.

The statistics exhibiting the operations of the silver-cobalt refineries of Ontario show that over and above the value of the silver refined, there were produced and marketed from the ores and concentrates treated during 1917 no less than $1,872,744 worth of by-products. This total is exclusive of stellite, of which only one component, cobalt, is derived from these ores.

The refineries in operation were those of the Coniagas Reduction Company, Limited, Thorold; Deloro Smelting and Refining Company, Limited, Deloro, and Metals Chemical, Limited, Welland. The number of workmen employed was 391, and the amount paid out as wages for labour $542,925. Of the material treated, 5,719 tons were ore and concentrates, and 2,245 tons residues. To refineries in the United States there were consignments from Cobalt amounting to 6,307 tons, from which 2,914,267 fine ounces of silver were recovered. These shipments were on the whole of considerably lower grade than those to the home refineries, averaging only 462 ounces of silver to the ton, as against 810 ounces. Much the larger quantity treated by U.S. plants was at the works of the American Smelting and Refining company, Denver, Col., and Perth Amboy, N.J. From 129 tons of gold ore and slag received from Porcupine the U.S. plants recovered 1,958 ounces of silver. Out of the total quantity of silver contained in the product of the Cobalt mines in 1917, namely, 19,401,893 ounces, 14,504,681 ounces were refined at the mines in Cobalt or in Ontario works, being about 75 per cent. of the whole.

OPERATION OF ONTARIO SILVER-COBALT REFINERIES, 1917.

Product.	Quantity.	Value.
		$
Ore, Concentrates and Residues treated.....tons	7,964	.....
Silver recovered .....fine ounces	6,451,363	5,289,782
Arsenic, White, shipments.....lbs.	4,588,793	586,096
Arsenic, Crude, shipments..... "	580,777	17,957
Arsenic, Metallic, shipments..... "	13,575	5,430
Cobalt Oxide, shipments..... "	418,703	533,489
Cobalt Carbonate and Sulphate, shipments ..... "	52,485	13,211
Cobalt, Metallic, shipments ..... "	396,395	589,290
Nickel Oxide, shipments..... "	23,748	6,533
Nickel Sulphate, shipments ..... "	335,794	26,437
Nickel, Metallic, shipments ..... "	225,480	91,923
Cobalt and Nickel Oxides, not separated, shipments.... "	4,757	2,378
Total value of products	.....	7,162,526

The plants in southern Ontario for refining silver and recovering by-products from the ores of the Cobalt camp may be enumerated as follows:—

REFINERS OF SILVER-COBALT ORES, 1917.

Name of Company.	Location of Works.	P.O. Address.
Deloro Smelting and Refining Co., Limited ...	Deloro	Deloro.
Coniagas Reduction Co., Limited	Thorold	St. Catharines.
Metals Chemical, Limited	Welland	Welland.

In Cobalt camp itself, the following mines produce bullion from their own ores: Nipissing, O'Brien and Buffalo, and the first-named also from purchased ores. There are several plants which concentrate ores purchased for the purpose, or act as custom concentrators. These are Cobalt Reduction Company, a subsidiary of the Mining Corporation of Canada, Dominion Reduction Company, and Northern Customs Concentrators, Limited. The first two of these works produce bullion, the last concentrates only. In these three plants there were treated during the year 207,127 tons of ore, of which 1,547 tons were high grade, and 205,580 tons low grade. From the high grade ores were obtained 3,716,612 ounces of silver in bullion form. Concentrates from the low grade ores amounted to 6,290 tons. Shipments of concentrates from the plants consisted of 6,410 tons, containing 4,563,442 ounces of silver, or 712 ounces per ton.

Besides the concentration works proper, a sampling plant has been carried on for a number of years by Messrs. Campbell and Deyell. The business of this firm is confined to ore-sampling (valuing), assaying, and the melting of silver metallics into base bullion. In none of these processes except the melting of metallics are any values extracted. In the sampling process the ore is usually received in 30-ton lots, is crushed in a ball mill, then passed through machines which extract samples, after which the bulk of the ore is bagged and returned to the owners.

The number of employees in the foregoing works was 229, to whom were paid wages amounting to $256,553.

CONCENTRATION AND SAMPLING PLANTS, COBALT, 1917.

Name of Company or Firm.	Location of Plant.	P.O. Address.
Cobalt Reduction Company, Limited	Cobalt	Cobalt.
Dominion Reduction Company, Limited	Cobalt	Cobalt.
Northern Customs Concentrators, Limited	Cobalt	Cobalt.
Campbell and Deyell, Limited	Cobalt	Cobalt.

Refining Bounties on Cobalt and Nickel

By the Metal Refining Bounty Act (R.S.O., 1914, chapter 23) a bounty of six cents per pound was provided on refined cobalt and nickel and the oxides of these metals produced in Ontario from Ontario ores, the bounty being calculated on the metallic contents. There was provision also for a bounty of one and a half cents per pound on refined copper or copper sulphate similarly produced, and on white arsenic made from mispickel one-half cent. per pound. The term of the Act was originally five years from April 20, 1907, but was subsequently extended for another five years from April 20, 1912. It expired in 1917, and was not re-enacted, and the bounties ceased to be payable on April 20, 1917. The Act fixed a maximum amount payable on cobalt and cobalt oxide of $30,000 per annum, and on nickel and nickel oxide of $60,000 per annum, and provided that should the production in any one year be greater than could be paid for by the maximum bounty at the rate specified in the Act, the rate should be correspondingly reduced. In 1916 the cobalt production was in excess, consequently the rate per pound of metallic contents was reduced to 3.9131 cents.

For the broken period from January 1, 1917, until the expiry of the Act on April 20 of the same year, the sum of $16,469.13 was earned by the refining companies, as follows:—

PAYMENTS UNDER METAL REFINING BOUNTY ACT, 1917

Company	Product lbs.	Metallic Contents lbs.		Bounty		Total Bounty
		Cobalt	Nickel	Cobalt	Nickel	
				$ c.	$ c.	$ c.
Deloro Smelting & Refining Co.,Ltd.						
Cobalt Oxide	6,400	4,544	.....	272 64	.....	.....
" Metal	20,240	18,225	.....	1,093 50	.....	.....
Stellite	60,736	33,204	.....	1,992 24	.....	.....
Metallic Nickel	29,510	.....	29,067	.....	1,744 02	5,102 40
Coniagas Reduction Co., Ltd.—						
Cobalt Oxide	29,573	21,219	.....	1,273 11	.....	.....
" Metal	82,702	81,122	.....	4,867 33	.....	.....
Nickel Oxide	5,495	.....	3,825	.....	229 47	6,369 91
Metals Chemical, Ltd.—						
Cobalt Oxide	51,706	37,461	.....	2,247 67	.....	.....
" Sulphate	30,366	6,225	.....	373 48	.....	.....
" Hydroxide	7,210	3,967	.....	283 03	.....	.....
Nickel Oxide	7,926	.....	5,292	.....	317 53	.....
" Sulphate	147,506	.....	30,134	.....	1,808 06	.....
" Carbonate	466	.....	201	.....	12 05	4,996 82
Total	.....	205,967	68,519	12,358 00	4,111 13	16,469 13

During the ten years the Metal Refining Bounty Act was in force a total of $170,140.95 was paid out in bounties, details of which are given in the statements which follow. The Act provides a bounty on the refined metals and oxides only. As regards the other compounds and alloys upon which bounty has been paid, it should be pointed out that in the process of refining the ore, the oxides of the metals are necessarily first produced, and are subjected to subsequent manipulation in the preparation of the secondary compounds. The bounty in all cases is calculated on the pure metallic contents only. Nothing has ever been claimed as bounty on copper or arsenic. Large quantities of arsenic were made during the continuance of the Bounty Act, but being a product of the Cobalt silver ores it was not eligible for bounty, which, under the terms of the Act, was payable on arsenic made from mispickel only.

It may fairly be said that the Act was successful in achieving the object aimed at, namely, the establishing of a refining industry in Ontario for the treatment of the Cobalt silver ores, not only for their silver contents, but also for the cobalt and nickel.

TOTAL BOUNTIES PAID UNDER METAL REFINING BOUNTY ACT.

Cobalt

Company	Oxide lbs.	Metal lbs.	Carbonate lbs.	Hydroxide lbs.	Sulphate lbs.	Stellite lbs.	Bounty $
Deloro Smelting and Refining Co., Ltd....	941,989	228,755	.....	.....	.....	118,528	48,930 93
Coniagas Reduction Co., Ltd	1,488,560	224,883	.....	.....	.....	.....	67,174 99
Metals Chemical, Ltd..	234,036	.....	5,723	5,966	84,454	.....	9,577 60
Canadian Smelting and Refining Co., Ltd....	36,137	.....	.....	.....	.....	.....	1,026 05
Standard Smelting and Refining Co., Ltd....	5,026	.....	.....	.....	.....	.....	214 92
Dominion Refineries, Limited	1,550	.....	.....	.....	.....	.....	62 59
Total.....	2,707,298	453,638	5,723	5,966	84,454	118,528	126,987 08

Nickel

Company	Oxide lbs.	Metal lbs.	Sulphate lbs.	Carbonate lbs.	Bounty $
Deloro Smelting and Refining Co.. Ltd...	140,754	69,763	.....	.....	8,166 96
Coniagas Reduction Co., Ltd.....	690,782	.....	.....	.....	27,539 01
Metals Chemical, Ltd	57,557	.....	360,215	466	6,776 04
Canadian Smelting and Refining Co., Ltd.	16,156	.....	.....	.....	681 84
Total.....	905,249	69,763	360,215	466	43,153 85

Summary of Bounties Paid

Company	Cobalt	Nickel	Total
	$	$	$
Deloro Smelting and Refining Co., Ltd	48,930 93	8,166 96	57,097 89
Coniagas Reduction Co., Ltd	67,174 99	27,539 01	94,714 01
Metals Chemical, Ltd	9,577 60	6,766 04	16,343 65
Canadian Smelting and Refining Co., Ltd	1,026 05	681 84	1,707 89
Standard Smelting and Refining Co., Ltd	214 92	.....	214 92
Dominion Refineries, Limited	62 59	.....	62 59
Total	126,987 08	43,153 85	170,140 95

The Cobalt Industry

The production of cobalt blue or smalt for use in the manufacture of fine pottery or chinaware, so far as Europe is concerned, originated in Saxony in the early part of the sixteenth century, and has remained in existence there until the present time, but in gradually lessening importance as the ore deposits, very similar to those of Cobalt, were worked out. For a number of years previous to the discoveries in Ontario, the chief source of cobalt ore was New Caledonia, an island owned by France off the eastern coast of Australia. When the mines at Cobalt began to be worked in 1904, the chief metal being silver, cobalt and other constituents were little considered. It soon became apparent, however, that the silver could not be won without at the same time raising large quantities of cobalt, nickel and arsenic, for which practically no market existed. Most of the ore being exported and refined in the United States in plants unprovided with means for the recovery of these substances, they were in the main simply wasted. On refineries for treating the ores being established here, however, they were forced to grapple with the problem of saving the cobalt, etc. This led to investigation of the technical problems involved, and presently the refining companies were in a position to place large quantities of cobalt oxide on the European market, where the principal demand existed. Notwithstanding the strenuous efforts that were made to maintain the high price at which the finished article was sold, say $2.50 per pound, the weight of Ontario competition brought it down by successive stages to 75 or 80 cents per pound. Competition from New Caledonian sources was eliminated, and the Ontario article has continued to dominate the market. So tenacious of established custom is trade that many of the European manufacturers and dealers in cobalt blue simply re-packed the oxide from Ontario in their own packages, marked them with their old labels and sold them as such to their customers to satisfy their demand for the identical article they had been in the habit of using.

The outbreak of the war put an end to the export trade to the continent of Europe, but considerable quantities continued to be sold in England. The growing scarcity of tonnage led to the system of importations being permitted only under license, and also to the prohibition of re-exports from Britain. Previously the far Eastern demand for cobalt oxide had been supplied from London, but now, owing to the conditions brought about by the war, Ontario oxide is transported across the continent by rail and shipped from Seattle or Vancouver to Japan and China. The

demand in the United States and Canada for metallic cobalt has to a large and growing extent taken the place of the former demand for the oxide as a pigment in the ceramic trade. The alloy stellite, composed of cobalt, tungsten and chromium, has been found very useful for the manufacture of high-speed tools for working steel, and is largely used for this purpose by the makers of shells and other war munitions. Although cobalt and nickel are by nature more closely allied than perhaps any other two metals, their effects upon steel seem to be quite different. The addition of cobalt makes steel very hard, a quality necessary for machining tools, such as are used in turning-lathes, planers, etc. On the other hand, nickel makes steel tough, but not hard, hence its usefulness lies in quite other directions, such as increasing the resistance to torsion or strain of any kind. This property has led to an increasing employment of cobalt in the manufacture of special tool steels, intended to be used at high speed, and the greater part of the cobalt required for this use is supplied by the Ontario silver ore refining companies. Cobalt oxide now sells at $1.50 per pound and metallic cobalt at $2.50 per pound. The oxide is converted into metal in the electric furnace. Stocks of cobalt on hand at the refineries are not necessarily at the option of the refiners, since they cannot purchase silver ore or concentrates without taking also the cobalt which these contain. The new uses of which mention has been made have acted as an outlet for much cobalt which in some form or other would otherwise have accumulated at the works. Nevertheless, when peace returns, if trade resumes its wonted channels, there will be cobalt oxide of Ontario origin for all necessary uses so long as the silver mines remain in production, and perhaps longer.

The production of cobalt in metal, compounds and alloys for 1917 was as follows:—

	Produced, lbs.	Shipped, lbs.
Cobalt Oxide	802,448	418,703
Cobalt Metal	393,773	315,327
Cobalt in Stellite	.....	81,068
Cobalt Sulphate and Carbonate	52,485	52,485
Cobalt and Nickel Oxides, not separated	.....	4,757

There is published as Part III of this report, "Cobalt: Its Uses, Alloys, and Metallurgy," by C. W. Drury, Associate Professor of Metallurgy at Queen's University, Kingston, to which reference should be made for full information on the subject. Mr. Drury has obtained a variety of interesting and useful results by experimenting with a number of new alloys of the metal.

Copper

There is a good deal of non-nickeliferous copper ore in Ontario, on the north shore of Lake Huron, at various points west of Lake Superior, and also in the northern and eastern portions of the Province, but, so far, attempts at mining it have not met with large success. Bruce Mines has shown that these sulphide bodies occur in workable dimensions, and it is probable that if better conditions existed with regard to realizing the value of the ores, there would be a considerable production of copper from this source. As it is, copper mining is much hampered by the lack of local reduction works. All ores or concentrates must be shipped to Trail, B.C., or to points in the Eastern States, and the charges for freight and smelter treatment leave little margin, even at the present high price of copper, except in

the case of very rich ore. The Kenyon Copper Company, at Massey, is in a position to treat by flotation 100 tons of ore daily, producing therefrom concentrates containing from 20 to 25 per cent. copper, but operations are not remunerative at the price of copper fixed by the U.S. Government in September, 1917, namely, 23½ cents per pound. The recent revision of this price to 26 cents per pound will afford a somewhat better opportunity.

From the recently opened deposits near Mine Centre shipments were made by H. H. Wood. The Port Arthur Copper Company, which operated and shipped in 1916 under the name of the Mine Centre Copper Company, did considerable development work. The total shipments of ore and concentrates amounted to 4,173 tons, containing 431,402 pounds of copper. In addition, there was a recovery by U.S. refineries of 106,106 pounds of copper from silver ore and concentrates received from Cobalt silver mines, and 2,032 pounds from Porcupine gold slags. The whole production was, therefore, 539,540 pounds, or, say, 270 tons of copper. The Ontario refineries treating the ores and concentrates from Cobalt recognize the presence of a small percentage of copper varying from .4 to 1.24 per cent., but no effort is made to recover it except in one plant, where the by-product is being stocked in an unfinished condition.

Following is a list of the producers of purely copper ores in 1917:—

COPPER ORE PRODUCERS, 1917.

Name of Operator.	Name of Mine.	Location.	P.O. Address of Manager, etc.
Errington, Jos.	.....	Gogama, C.N.Ry...	San Francisco.
Hudson Copper Co., Ltd.	.....	Havilah	Havilah.
*Kenyon Copper Mines, Ltd.	Massey	Sault Branch, C.P. Ry.	Massey.
Ray, S. W.	Tip-Top	Kashabowie	Port Arthur.
Sudbury Copper Co.	.....	Iron Bridge	Toronto.
Wood, H. H.	.....	Mine Centre	Toronto.

*Formerly known as the Sable River Copper Company.

The chief source of the copper production of the province is the nickel-copper ore of the Sudbury area, where the smelters last year turned out 78,897 tons of matte, the copper contents of which were 21,197 tons. This was a decrease of 1,233 tons as compared with 1916, when the smelter product was 80,010 tons of matte containing 22,430 tons of copper. The average copper contents of the matte in 1916 were 28 per cent., and in 1917, 26.8 per cent. Further details regarding the Sudbury nickel-copper industry will be found under the heading of Nickel.

Nickel

The business of mining and smelting the nickel-copper ore of the Sudbury region has grown to large dimensions, as a few statistics will show. Last year 3,356 employees were employed in the mines and works, 1,854 underground, and 1,502 on the surface, to whom were paid wages amounting to $5,570,587. The mines were worked uninterruptedly. For roasting in heaps in the open air, to which process most of the ore is still subjected, some 28,846 cords of wood were required, having a value

of $115,250. To smelt the ore in the blast furnaces and converters 182,091 tons of coke were used, worth $2,187,353. In all, 1,506,828 tons of ore were raised from the mines, and 1,453,661 tons were smelted. The Bessemer matte product was 78,897 tons, the estimated contents of which were 41,887 tons of nickel and 21,197 tons of copper. The average composition of the whole of the matte product was thus 53.09 per cent. of nickel and 26.86 per cent. of copper, being a little higher in nickel and lower in copper than the matte of 1916, when the figures were 51.6 per cent. of nickel and 28 per cent. of copper.

The matte produced by the two smelting companies is quite dissimilar in the proportions of these metals. In 1917 the average contents of the Canadian Copper Company's matte were nickel 56.27 per cent., and copper 23.04 per cent., while the product of the Mond Nickel Company carried 39.57 per cent. of nickel and 43.10 per cent. of copper. This variation of composition reflects the difference in the nature of the ores smelted by the respective companies.

Ore production by the Canadian Copper Company was as follows:—

	Tons.
Creighton mine	1,003,814
Crean Hill mine	113,908
No. 2 mine	1,907
Total	1,139,629

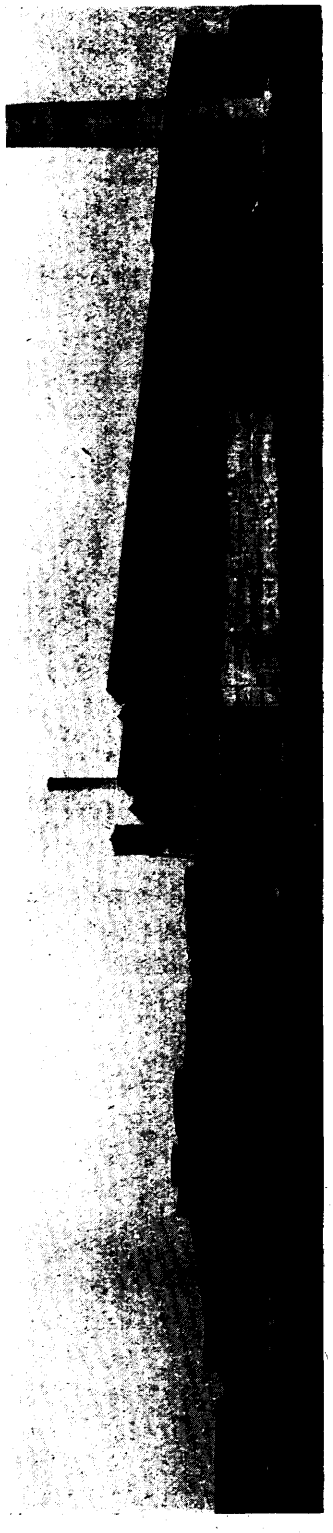
By the Mond Nickel Company:—

	Tons.
Garson mine	116,968
Victoria No. 1 mine	45 972
Worthington mine	75,012
Levack mine	88,587
Bruce mine	34,796
Total	361,335

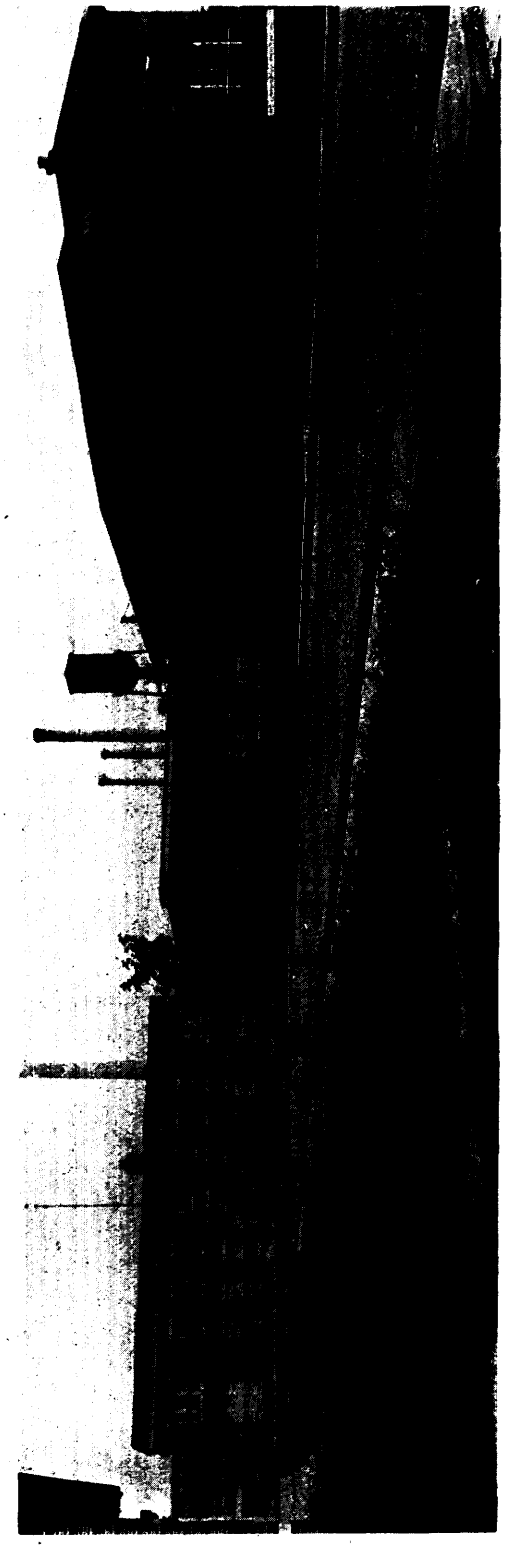
The Alexo Mining Company raised 5,864 tons of nickel-copper ore from the mine of that name in the township of Dundonald, on the Porcupine branch of the Timiskaming and Northern Ontario railway, all of which was shipped to the Mond Company's works, at Coniston, to be smelted.

One of the most important of recent developments in the nickel industry is the establishment by the International Nickel Company of Canada, Limited, of a large refining plant at Port Colborne, Ont. It had for years been matter for regret that while Ontario was the greatest source of this important metal, it was entirely exported after having been smelted into matte, and the final separation of the nickel and copper was carried on elsewhere. It was shown beyond doubt by the Report of the Royal Ontario Nickel Commission[1] that nickel could be refined in Ontario, and that, so far from the long-maintained contention to the contrary being true, any one of the processes in existence was quite capable of being successfully operated here. Neither climatic conditions, want of skilled labour or chemicals, nor the cost of assembling the fuel, acids and other necessaries for the process, when put to the test proved to be an insuperable difficulty, and the Port Colborne refinery is now in operation. The process employed is the Orford one with variations, and the capacity of the works is 10.000 tons of nickel per annum, with a relative quantity of copper. A description of the plant is given elsewhere in this Report.

[1] A. T. Wilgress, Printer to the King's Most Excellent Majesty, Toronto, 1917.



Blast Furnace, Roasting Buildings and Cottrell Plant.



Administration Group of Buildings.

The two illustrations show the new Port Colborne plant of the International Nickel Company of Canada, Limited July, 1918.

It was expected that the British America Nickel Corporation, Limited, which is developing the large nickel-copper ore body known as the Murray mine, near Sudbury, would have followed suit by the erection of a refinery near the mine. The difficulty of procuring the necessary quantity of electrical power in the locality, however, proved too great to be overcome, and after considerable search the company decided to erect the refining works on the Quebec side of the Ottawa river near Hull, where sufficient energy could be obtained from that river, and ground has now been broken for the necessary buildings. The smelting plant is being constructed at the mine.

Table VIII. summarizes the course of the nickel-copper mining industry during the five years ending 1917. It will be seen that the tonnage of ore raised in 1917 was twice as great as that in 1913, the quantity smelted 76 per cent. more, the matte produced was 70 per cent. more, and the nickel and copper contents greater respectively by 68 and 63 per cent. The value of the nickel increased by 15¾ millions of dollars, and of the copper by upwards of 6 millions of dollars; these increases, however, are in part due to the higher prices adopted for computation. It is noteworthy that while the actual number of workmen was 156 smaller in 1917 than in 1913, the wages paid were 2¼ millions of dollars more. That is to say, the average earnings of the employees rose from $937 each in 1913 to $1,659 each in 1917, an increase of 77 per cent.

TABLE VIII.—NICKEL-COPPER MINING AND SMELTING, 1913-1917.

Schedule.	1913	1914	1915	1916	1917
Ore raised.....tons.	784,697	1,000,364	1,339,322	1,572,804	1,536,828
Ore smelted..... "	823,403	947,053	1,272,283	1,546,215	1,453,661
Bessemer matte produced.. "	47,150	46,396	67,703	80,010	78,897
Nickel contents of matte .. "	24,838	22,759	34,039	41,299	41,887
Copper contents of matte... "	12,938	14,448	19,608	22,430	21,197
Value of Nickel in matte.... $	5,237,477	5,108,997	17,019,500	20,649,279	20,943,500
Value of Copper in matte... $	1,839,438	2,080,034	3,921,600	8,299,051	7,842,890
Wages paid..... $	3,291,956	3,131,520	3,581,639	4,920,720	5,570,587
Men employed	3,512	3,464	4,178	4,730	3,356

The companies engaged in nickel-copper mining in 1917 were as follows:—

NICKEL-COPPER PRODUCERS, 1917.

Name of Company.	Name of Mine.	P.O. Address.
Canadian Copper Company	Creighton, Crean Hill, etc.	Copper Cliff.
Mond Nickel Company, Limited	Garson, Levack, etc...	Coniston.
The Alexo Mining Co., Ltd.	Alexo	Porquis Junction.

From the silver ores of the Cobalt mines there were produced in the Ontario refineries 225,480 pounds of metallic nickel, mostly in the form of shot, of about 98 per cent. purity. This is sold to manufacturers of platers' supplies and made into anodes. A market for metallic nickel has also been found in Italy, where it

is used in the structure of airplanes. The present capacity of the silver ore refineries for the production of metallic nickel is about 400 tons per annum. There are considerable stocks of nickel-bearing residues and nickel oxide at present on hand. Nickel sulphate is also being produced, a large use for which is in the hardening of oils and fats. A considerable quantity of nickel oxide was made during the year, as this form is the one in which the nickel is recovered from the ore, but only a small portion was marketed as oxide, most of it being converted into metallic nickel or nickel sulphate and sold as such. Some 4,757 pounds of unseparated oxides of nickel and cobalt were also sold, the value being $2,378.

Iron Ore and Pig Iron

Of the 176,833 tons of iron ore marketed in 1917, there were 136,343 tons exported to the United States. The balance went to Ontario blast furnaces. There were three producers: Moose Mountain, Ltd., also the Magpie and Helen mines of the Algoma Steel Corporation, Ltd. The last-mentioned shipped to the Magpie, where the ores from the two mines were mixed and treated in the roasting furnaces to produce a Bessemer grade of ore. Shipments from Moose Mountain were in the form of concentrates and briquettes. The number of men employed in the mines was 475, and the wages paid them amounted to $493,078.

Blast furnaces at Sault Ste. Marie (3), Hamilton (2), Port Colborne (1), and Deseronto (1) smelted 94,318 tons of Ontario ore and 1,221,881 tons of imported ore, producing therefrom 691,233 tons of pig iron valued at $14,201,695. It may be noted that only 7.16 per cent. of the value of the pig iron output can be credited to domestic ore.

Business was exceedingly brisk in the making of pig iron last year. The insistent demands of the war called for more and more iron, more and more steel, and the ordinary industrial requirements were for the time being obliged to accept scant consideration. This was also the condition in the United States, and in both countries the industry was strictly controlled. The two leading companies produced 862,504 tons of steel, consuming for the purpose a much larger quantity of pig iron than they made themselves. The total product of pig iron was 7,969 tons less than in 1916. The price of pig iron rose nearly 50 per cent., the average valuation for 1916 being 13.94 per ton, while in 1917 it was $20.54. Steel was returned in 1916 at an average valuation of $18.70 per ton; last year the figures were $25.13 per ton.

Electro-Metals, Limited, Welland, produced a large tonnage of ferro-silicon, using quartzite, ganister rock, and pyrites cinder.

The undermentioned companies operated blast furnaces in 1917:

IRON BLAST FURNACES IN OPERATION, 1917.

Name of Company.	No. of Furnaces operated	Fuel used.	Location.
Algoma Steel Corporation, Limited.....	3	Coke	Sault Ste. Marie.
Canadian Furnace Company, Limited...	1	Coke	Port Colborne.
Standard Iron Company, Limited	1	Charcoal and Coke	Deseronto.
Steel Company of Canada, Limited.....	2	Coke	Hamilton.

Table IX gives particulars of the iron and steel-making industry of the Province for the last five years.

TABLE IX.—PRODUCTION IRON AND STEEL, 1913 TO 1917.

Schedule.	1913	1914	1915	1916	1917
Ontario ore smelted .....tons	132,708	163,779	293,305	215,366	94,318
Foreign ore smelted ..... "	1,095,561	752,560	623,094	1,056,810	1,221,881
Limestone for flux ..... "	351,741	252,258	215,686	296,988	319,535
Coke ..... "	706,852	590,902	486,022	708,273	723,657
Charcoal .....bush.	2,206,191	920,045	1,314,957	1,843,209	1,288,390
Pig iron produced .....tons	648,899	556,112	493,400	699,202	691,233
Value of pig iron produced ..... $	8,719,892	7,041,079	5,910,625	9,739,704	14,201,695
Steel made .....tons	648,948	479,320	471,059	686,959	862,504
Value of steel made ..... $	11,230,109	7,786,303	7,618,272	12,847,309	22,179,982

Molybdenite

The production of molybdenite concentrates in Ontario in 1917 was 77,517 pounds, an increase over 1916 of 52,955 pounds. The use of molybdenite in the manufacture of special tool steels, owing in part to the scarcity of tungsten, has led to a good deal of prospecting for deposits, and to the opening up and working of some of the most promising. Occurrences of molybdenite are apt to be pocketty and irregular, but are occasionally on a large scale, such as the mine now being worked at Quyon, Que. The alloy ferro-molybdenum, in which form the mineral is used by steelmakers, was made last year at Orillia and Belleville, the production being about 150,000 pounds.

Following is a list of the owners, with their addresses, from whose properties shipments of molybdenite were made:—

MOLYBDENITE SHIPPERS IN 1917.

Name.	Location of Deposit.	P.O. Address.
Armstrong, R. M.	Ashdod	Toronto, 13 Adelaide St.
Bourgault, M. A.	Calabogie	Ottawa, Marine Dept.
Canadian Molybdenite, Ltd.	Bagot township	Toronto, 801 Kent Bldg.
Foley, M. L.	Ross township	Toronto, 12 Maynard Ave.
Grey & Grey	Wilberforce	Toronto, 43 Imperial Life Bldg.
International Molybdenum Co., Ltd.	Mount St. Patrick	Renfrew.
Kelly, Mrs. W. R.	Tamworth	Tamworth.
McCoy, W. C.	Lyndoch township	Schutt.
Ontario Molybdenum Co., Ltd.	Tory Hill	Toronto, 305 Mail Bldg.
Opeongo Mining Syndicate	Opeongo	Renfrew.
Padwell, George	Monmouth township	Wilberforce.
Renfrew Molybdenum Mines, Ltd.	Brougham township	Montreal, Que, 402 Southam Bldg.
Spain, William J.	Dacre	New York, 417 Fifth Avenue.
Taylor, A. W.	Bagot township	Toronto, 123 Bay Street.

W. E. Joiner, of Moline, Ill., is engaged in developing molybdenite showings in the township of Cardiff, district of Haliburton, near Wilberforce station, on the Irondale, Ottawa, and Bancroft railway. One of these, owned by the Paudash Lake Molybdenite Mines, Limited, is on lot 18 in the ninth concession, where

the mineral occurs in large crystals. The other, known as the Joiner property, is on the north half of lot 3 in the twentieth concession. Frank C. Loring, M.E., states that the mineralized area on the latter has a northerly and southerly extent of about 1,500 feet and an easterly and westerly width of 150 to 400 feet, the ridge on which it occurs rising 100 to 150 feet above the low ground adjoining. A number of pits and trenches opened on the ridge and westerly slope have exposed molybdenite. In Mr. Loring's opinion the indications are promising for the presence of a large quantity of the mineral. Mr. Joiner proposes to further test the property by a number of open cuts across the ridge easterly and westerly from rim to rim, by blasting off the face of the bluff, and by diamond drilling.

Concentrating plants in operation were as follows:—

MOLYBDENITE CONCENTRATORS, 1917.

Concentrator.	Tons ore treated.	Lbs. concentrates produced.
International Molybdenum Company, Limited, Renfrew.	419.5	11,578
Mines Branch, Mines Department, Ottawa	250.8	6,521
Renfrew Molybdenum Mines, Limited, Mt. St. Patrick..	3,656.5	57,254
Total	4,326.8	75,353

In electric furnaces at Orillia and Belleville, ferro-molybdenum was produced as follows:—

FERRO-MOLYBDENUM PRODUCERS, 1917.

Refinery.	Location	Ferro-Molybdenum lbs.
International Molybdenum Co., Limited	Orillia	81,000
Tivani Electric Steel Co	Belleville	69,000
Total		150,000

The value of the ferro-molybdenum product was $349,355.

A comprehensive account of molybdenite in Ontario was contained in a report by Arthur L. Parsons, published in the twenty-sixth annual volume of the Bureau, 1917.

Lead

The production of ore last year amounted to 16,602 tons, compared with 6,481 tons in 1916. The output was almost wholly from the mine at Galetta, in Carleton County, owned by the James Robertson Estate, Montreal. A few tons were raised by the North Victoria Mines, Limited, from a property near Kinmount, in the district of Haliburton, and a small quantity of concentrates from the old Frontenac lead mine were smelted by the Kingston Smelting Company, Limited, although the mine itself was not worked. The Galetta smelter and that of the Kingston Smelting Company turned out a total of 4,228,512 pounds of pig lead,

valued at $316,534, of which 1,772,512 pounds, worth $172,601, were from Ontario ore, and 2,456,000 pounds, worth $243,933, from ore imported from outside points.

The number of mine employees was 74 and of smelter hands 47, total 121. Wages paid, mines $54,029, smelters $31,499, total $85,528.

LEAD ORE PRODUCERS, 1917.

Name of Company.	Location of Mine.	P.O. Address.
Estate of James Robertson	Galetta	Montreal.
North Victoria Lead Mines, Limited	Kinmount	Toronto.

LEAD ORE SMELTERS, 1917.

Name of Company.	Location of Smelter.	Address.
Estate of James Robertson	Galetta	Montreal.
Kingston Smelting Company, Limited	Kingston	Kingston.

Materials of Construction

Clay Products

The clay industry in war time may be regarded as more or less non-essential. In the United States the Fuel Administration has taken this view, hence orders have been issued curtailing the output of clay products for 1918 from 15 to 50 per cent., and placing the entire manufacturing programme on a war basis. In Ontario many brick and tile plants were idle throughout the year 1917.

Though the value of clay products has risen considerably during 1917 owing to high operating costs, the output also shows a small increase as compared with 1916. This does not appear to be the case with tile and hollow ware as far as quantity is concerned, but it may be pointed out that such products should be reported on a tonnage rather than a numerical basis, because of the wide range both in size and shape of drain and building tile. Building permits in Toronto in 1917 exceeded in number those of 1916 by 12 per cent., but the total value of the buildings was 28 per cent. less.

Pressed and Fancy Brick.—The output of pressed and fancy brick in 1917 was 36,233 M, worth $474,614, as compared with 31,742 M, worth $318,942, in 1916. Of this production the Milton Pressed Brick Company contributed over one half. Wages amounting to $206,844 were paid to 407 employees.

Common Brick, Drain and Building Tile.—Apart from two large makers of building tile, hollow clay blocks are produced only to a limited extent, and chiefly in localities where gravel is scarce. They are used for barn foundations and for other buildings such as chicken and pig pens, milk houses, garages, etc., since they

afford a dry, warm wall that can be cheaply erected. Sizes vary: 4 by 4 by 12; 4 by 8 by 12 and 6 by 10 by 12 inches being common. Smaller sizes are used for interior walls in houses. The large makers in Ontario are the National Fireproofing Company of Canada, Limited, and the Sun Brick Company.

The average period of operation for the brick and tile plants was 131 days in the year 1917. Many of the smaller plants operate in the summer months only. Employees numbered 909, and $473,375 was paid in wages.

As fuel and labcur costs continue to advance, the cost of manufacturing clay products increases. In 1917 for common brick, also drain and building tile, the following figures show the output, value, fuel consumption, and cost:—

OUTPUT AND VALUE OF BRICK AND TILE, 1917.

Product	M.	Value $	Value per M.
Common Brick	68,214	713,824	$10 46
Drai n Tile	15,940	546,040	.....
Holl w Building Tile	3,933	301,688	.....

FUEL CONSUMPTION.

Wood			Coal or Coke			Natural Gas		
Cords	Value $		Tons	Value $		M. cu. ft.	Value $	
	Total	per cord		Total	per ton		Total	per M.
17,289	74,258	4 29	19,856	150,802	7 59	157,180	24,712	0 16

Following is a list of the brick and tile operators who reported an output in 1917:—

BRICK AND TILE PLANTS.

Name.	Address.	Product.
Alvinston Brick & Tile Co., Ltd.	Alvinston	Brick, Tile and Hollow Blocks.
Armstrong Bros	Fletcher	Tile.
Attercliffe Standard Brick, Block & Tile Co.	Attercliffe	Tile.
Arnott, Thos. H.	Bracebridge	Brick.
Baird & Son, H. C.	Parkhill	Brick and Tile.
Baker, Geo. E.	Arnprior	Hollow Blocks.
Baker Bros.	Casselman	Brick.
Bell Bros.	Paisley	Brick.
Bogart Bros.	Southwold	Tile.
Bond & Bird	Woodstock, R.R. No. 5.	Brick.
Brampton Pressed Brick Co., Ltd.	Brampton	Pressed Brick.
Broadwell & Son, B.	Kingsville	Tile.
Brown, J. W.	Vienna	Tile.
Brownscombe, H.	Cargill	Brick and Tile.
Brownscombe Bros.	Paisley, R.R. No. 2	Brick and Tile.
Buck, J. L.	Port Rowan	Brick and Tile.
Butwell, Henry	Toronto	Brick.

BRICK AND TILE PLANTS.—*Continued.*

Name.	Address.	Product.
Cabana, Jr., Oliver	Zurich	Brick and Tile
Cairo Brick and Tile Works	Cairo	Brick and Tile
Campbell, Neil F.	West Lorne	Tile.
Canada Sand-Lime Pressed Brick Co., Ltd.	West Toronto	Sand-Lime Brick.
Canadian Pressed Brick Co., Ltd.	Hamilton	Pressed Brick.
Clark, Walter	Corunna	Brick and Tile.
Cooper, W. H.	Hamilton	Brick.
Curtin, Frank	Lindsay	Brick.
Curtis Bros.	Peterboro', R.R. No. 9	Brick and Tile.
Deller & Sons, Geo.	Norwich	Brick, Tile and Hollow Blocks.
Deller, Wm. H.	Thorndale, R.R. No. 4	Tile.
Dochart Brick & Tile Works	Arnprior	Brick, Tile and Blocks.
Dolan, John	Watford, R.R. No. 2	Tile.
Dominion Sewer Pipe Co., Ltd.	Aldershot	Brick and Tile.
Don Valley Brick Works	Todmorden	Common, Pressed and Fancy Brick.
Elliott, Chas.	Bluevale	Brick and Tile.
Elliott & Sons, Jas.	Steelton	Brick.
Fox, G. J.	Dresden	Brick.
Frank, E. D.	Strathroy, R.R. No. 6	Brick and Tile.
Frid Bros.	Hamilton	Brick.
Frost, Geo. H.	Toronto	Brick.
Gardiner, William	Blenheim	Brick and Tile.
Govenlock, J. M.	Seaforth, R.R. No. 1	Tile.
Hallatt, H.	Comber	Brick and Tile.
Halton Brick Co., Ltd.	Terra Cotta	Pressed Brick.
Hamilton Pressed Brick Co., Limited	Hamilton	Pressed Brick.
Hepworth Silica Pressed Brick Co., Ltd.	Hepworth	Pressed Brick.
Hill Brick Co.	Madoc	Brick.
Hill, A. W.	Coatsworth, R.R. No. 1	Brick and Tile.
Hinde Bros.	West Toronto	Brick.
Hiscock & Sons	Cobourg	Brick.
Hitch, Mrs. Susan	Ridgetown	Brick, Tile and Hollow Blocks.
Hitch, Thos.	St. Thomas	Brick and Tile.
Hohl, John	Wellesley, R.R. No. 1	Brick and Tile.
Holland & Son, William	Ruscomb	Tile.
Holton, R. J.	Clifford, R.R. No. 3	Tile.
Howlett, Fred.	Petrolia	Tile.
Interprovincial Brick Co. of Canada, Ltd.	Cheltenham	Pressed Brick.
Janes, D. A.	Delaware	Brick and Tile.
Jasperson, B.	Kingsville	Brick, Tile and Hollow Blocks.
Jervis & Son, John	Dorchester Station	Brick and Tile.
Jordan, D.	Chatham	Brick and Tile.
Kaar, John	Brownsville	Brick and Tile.
Koebel, Joseph Z.	St. Clements	Brick and Tile.
Kruse Bros.	Egmondville	Brick and Tile.
Kuhn, Henry J.	Crediton	Tile.
Labey & Son, Geo. A.	Foxboro'	Tile.
Leamington Brick & Tile Co., Ltd.	Leamington	Brick and Tile.
Lindsay, Stephen	Wallaceburg, R.R. No. 2	Tile.
Logan Brick Works	Toronto	Brick.
Lowe, Jos.	Meaford, R.R. No. 1	Tile.
Lowes, Gordon	Kent Centre	Brick and Tile.

BRICK AND TILE PLANTS.—*Continued.*

Name.	Address.	Product.
MacKay Bros.	Dutton	Brick and Tile.
McCredie & Reid	Belmont, R.R. No. 3	Brick and Tile.
McGibbon, Dugald	Shedden	Tile.
McLoughlin, John	London	Brick.
Marshall, W. W.	Woodstock	Brick and Tile.
Martin, David	Thamesville	Brick and Tile.
Middleton, Chas.	Wyoming	Tile.
Milton Pressed Brick Co., Ltd.	Milton	Pressed and Fancy Brick.
Miner, J. T.	Kingsville, R.R. No. 2	Brick and Tile.
Napanee Brick & Tile Co., Limited	Napanee	Brick and Tile.
National Fire Proofing Co. of Canada, Ltd	Aldershot	Hollow Blocks.
Naylor & Sons, J. W.	Trenton	Brick.
New, Edward	Hamilton	Brick.
Norton, Alsey	Bolton	Tile.
Odell & Sons, Wm.	Ingersoll	Brick, Tile and Blocks.
Ollman Bros.	Hamilton	Brick,
Ontario Paving Brick Co., Limited	West Toronto	Brick.
Ott Brick & Tile Mfg. Co., Limited	Kitchener	Brick.
Ottawa Brick Mfg. Co., Limited, The	Ottawa	Brick.
Owen Sound Brick Co., Limited	Owen Sound	Brick.
Parks, H. W.	Dresden	Tile and Hollow Blocks.
Paxton & Bray	St. Catharines	Brick.
Pears & Son, James	Toronto	Brick.
Pembroke Brick Co., The	Pembroke	Brick.
Petty, Chas.	Cherrywood	Tile.
Phillips & Son, Thos.	Lucknow, R.R. No. 1	Tile.
Phinn, Geo. E.	Lucan	Brick, Tile and Hollow Blocks.
Port Credit Brick Co., Limited, The	Port Credit	Common and Pressed Brick.
Price Estate, John	Toronto	Brick.
Provincial Secretary's Department	Mimico	Drain, Floor and Building Tile; Brick.
Richardson & Son, James	Kerwood	Brick and Tile.
Ries, John	Carlsruhe	Brick and Tile.
Russell, Joseph	Toronto	Brick.
Sadler, F. L.	Dublin	Brick and Tile.
Silicate Brick Co. of Ottawa, Ltd.	Ottawa	Sand-Lime Brick.
Sipprell, J. H.	Wilkesport	Tile.
Smith & Son, Alex.	Dutton, R.R. No. 2	Brick and Tile.
Snelgrove & Teer	Beaverton	Brick and Tile.
Stickwood, Chas.	Newmarket	Brick.
Sudbury Brick Co., Limited	Sudbury	Brick.
Sun Brick Co., Limited	Toronto	Fancy Brick and Hollow Blocks.
Thompson Bros.	Essex	Brick and Tile.
Thornton, John	Perth	Brick.
Toronto Brick Co., Limited	Toronto	Sand-Lime Brick.
Wagstaff, Chas.	Lindsay	Brick and Tile.
Waite, J. E.	Forrester's Falls	Brick and Tile.
Wallace & Son, R.	North Bay	Brick.
Wallaceburg Brick Co.	Wallaceburg	Brick.
Warwick Brick Works	London	Brick.
Watson Brick Co.	Bracebridge	Brick and Tile.
Wood, W. H.	Brockville	Brick.
Wright, J. C.	Proton	Brick and Tile.
Yaeck, Louis	Walkerton	Brick and Tile.
York Sandstone Brick Co., Limited	East Toronto	Sand-Lime Brick.

Pottery.—No high-grade pottery is manufactured in Ontario, the glacial clays not being suited for the purpose. The value of pottery made in 1917, as reported by the producers mentioned below, was $94,501. Wages paid 41 employees amounted to $35,318.

The following is a list of operators in 1917:—

POTTERY PRODUCERS, 1917.

Name.	Address.
R. Campbell's Sons	Lock St. South, Hamilton.
J. Cranston Estate	216 Dundurn St. South, Hamilton.
Davis, Joseph S.	1967 Yonge St., Toronto.
Foster Pottery Company	Main St. West, Hamilton.
Taylor, Geo. M.	Port Hope.

Sewer Pipe.—There are three companies making sewer pipe in Ontario. Raw material suitable for sewer pipe purposes is not widely distributed. It is a plastic Medina shale free from lime, and the entire quantity comes from the vicinity of Waterdown, near Hamilton. Sewer pipe manufacture involves careful manipulation in order to secure a high percentage of perfectly vitrified, salt-glazed and unwarped pipe.

Sewer pipe marketed in 1917 was worth $378,923. The wages paid 202 men employed in the industry amounted to $168,421.

Following is a list of the companies:—

SEWER PIPE WORKS, 1917.

Name of Company.	Location of Plant.	P.O. Address of Manager, etc.
Dominion Sewer Pipe Co., Ltd.	Swansea	Swansea.
Hamilton & Toronto Sewer Pipe Co., Ltd.	Hamilton	Hamilton.
Ontario Sewer Pipe Co., Ltd.	Mimico	Mimico.

Brick, Tile, Sewer Pipe and Pottery

The following table shows the comparative value of the output of clay products since the outbreak of war:—

Year.	Brick.		Pottery.	Drain Tile.	Sewer Pipe.	Total.
	Common.	Pressed, Fancy, Terra Cotta, etc.				
	$	$	$	$	$	$
1914	2,336,207	894,384	25,720	277,530	571,756	4,105,597
1915	763,591	375,865	49,387	321,253	361,283	1,871,379
1916	509,559	495,895	87,025	275,471	216,749	1,584,699
1917	713,824	776,302	94,501	546,040	379,923	2,509,590

Refractory Clay from Mattagami River

Hitherto clays have not been found in Ontario suitable for making chinaware or porcelain, and in consequence the pottery trade of the Province has not been able to advance beyond the coarsest kinds of ware, such as flower pots, jardinieres, etc., except by the use of imported clays.

A dissovery made by Capt. C. M. McCarthy, of Elk Lake, on the east bank of the Mattagami river, opposite an island at the foot of the Long Portage, has shown the existence there of a deposit of excellent white fire clay of highly refractory character, believed to be capable also of taking the place of English "ball" clay in the manufacture of porcelain. An examination of the clay was made by Prof. Geo. A. Guess, of the University of Toronto, in November, 1917, who reported that it was a good grade of ball clay, the following being a partial analysis:—

	Per cent.
Silica	52.7
Alumina	32.1
Iron	Trace
Lime	Trace

It had a very high plasticity, and an air shrinkage of 6.7 per cent. Burned to cone 5 (1,230° C.) it showed a shrinkage of 14.8 per cent. The colour on burning was almost white—a slight cream colour. The test pieces on burning cracked after the manner of undiluted ball clay.

A fuller analysis by W. K. McNeill, Provincial Assayer, gave the following composition:—

	Per cent.
Silica	53.10
Alumina	31.98
Ferric Oxide	1.52
Ferrous Oxide	Nil
Lime	0.51
Magnesia	Trace
Soda	0.54
Potash	0.28
Loss on ignition	12.35
Total	100.28

Samples were sent to the Canadian Porcelain Company, Limited, Hamilton, who undertook to give them a practical test. After doing so, the company reported as follows on 10th January, 1918:—

> We fired samples of the ball clay of Capt. C. M. McCarthy in our kilns and find that the same is practically as plastic as the English ball clay, but has a slightly greater shrinkage. We believe that the clay would be satisfactory for use in porcelain bodies after proper allowance had been made for the variation in the shrinkage.

The clay was also tested at the Mines Department, Ottawa, J. Keele, chief ceramic engineer, reporting it to be a light grey to white clay when dry, and requiring 23 per cent. of water to bring it to the best working consistency. It had good plasticity and working qualities. Its drying qualities were good, and the shrink-

age of dried test pieces was 6 per cent. It burned to a porous but strong body of nearly white colour at the lower temperatures or up to 2,100° Fahr. When burned to temperatures higher than this the body became slightly denser and cream-coloured. When raised to temperature of cone 33 (3,254° Fahr.) the clay softened. Mr. Keele pronounced it a No. 1 fire clay, and one of the most refractory clays yet found in Canada. Its working, drying, and burning qualities were very satisfactory, so that it could be moulded into special shapes for refractory purposes.

In making pottery trials, the clay was thoroughly mixed with an excess of water and washed through a 200-mesh screen. The residue remaining on the screen was 20 per cent. of the original weight and consisted almost wholly of small quartz grains. The washed clay was dried, and a mixture was made consisting of 50 per cent. of the clay, 20 per cent. ground feldspar, and 30 per cent. ground quartz. This mixture was made into a slip and cast in the form of small cups. These were burned at a low temperature and four of them sent to the Mayer China Company, of Beaver Falls, Pa., where they were burned in the china biscuit kiln to cone 10, and glazed and re-fired in the china glost kiln at cone 4. The pieces turned out had a beautiful ivory tone, but were not suitable for china or semi-porcelain wares, for which a white colour is strictly required.

Mr. Keele adds that the clay could be used to advantage in making sanitary porcelain, vitrified floor tiles and wall tiles, or probably for electric porcelain. Much of the china clay imported for these purposes is not as good a colour as the Mattagami clay, and a little cobalt stain added to this clay would materially improve the colour.

A sample of red clay, found on the same property, proved on testing to be very plastic and smooth, being rather more plastic than the white clay. It burned to a red colour and hard, dense body at about 2,200° Fahr. It fused at cone 20 (2,786° Fahr.), so that it is not a fire clay, but only semi-refractory. A good fire brick could probably be made from a mixture of one part red clay with two parts of white clay, and a similar mixture could also be used for the manufacture of stoneware pottery.

In June, 1918, Capt. McCarthy reported he had pretty thoroughly investigated this deposit of clay by sinking pits, digging trenches, and putting down auger holes. He is convinced the clay occurs over the whole width of his claim of 40 chains, and that it is about 100 feet or over in depth. The red clay lies to the south of the white.

Lime

The output of lime last year as shown in Table II was 2,820,507 bushels, valued at $1,111,264, while that for 1916 was given as 1,453,254 bushels, worth $657,364. The large increase in production is explained by the fact that heretofore the lime made by large manufacturing concerns such as the American Cyanamid Company and the Dominion Sugar Company for use in their processes was not included in the statistics, since it did not come upon the market for sale as lime. It would seem, however, that for whatever purpose the lime is used, whether in manufacturing or treating other products, or for building, the figures ought properly to be

reckoned in the general total. The two companies mentioned produced in 1917 nearly 1,000,000 bushels. It will be noted that while the price in 1916 averaged 18.6 cents per bushel, in 1917 it rose to 23.3 cents. The making of lime tends more and more to fall into the hands of the large operators. The day of the small kiln worked by the farmer or his boys, spasmodically and to supply the needs of a very local and restricted market, has virtually passed. In this, as in every other manufacturing industry, proper organization, technical skill and sufficient capital are necessary. For fuel in burning, wood is still largely used, but more lime is now burned with coal than any other fuel. Coke is also employed, and a few makers use natural gas. The number of men employed was 325, and the wages paid $262,132.

Below are given the names of producers and the location of plants in Ontario which operated in 1917:—

LIME PRODUCERS, 1917.

Name of Owner or Company.	Location.
American Cyanamid Co.	Niagara Falls.
Beachville White Lime Co., Limited	Beachville.
Bergin, Patrick	Napanee.
Cameron, W. M.	Carleton Place.
Canada Lime Company, Limited	Coboconk.
Chalmers & Campbell	Owen Sound.
Chestnut, W. D.	Duntroon.
Christie, Henderson & Co., Limited	Puslinch, Kelso and Hespeler.
Contractors' Supply Co., Limited	Melville Junction and Teeswater.
Delta Lime Co., Limited	Delta.
Dominion Sugar Co., Limited	Wallaceburg, Chatham and Kitchener.
Elora White Lime Co., Limited	Elora.
Gallagher Lime & Stone Co., Limited	Hamilton.
Guest, Mrs. E. J.	Ancaster.
Harvey, E., Limited	Rockwood.
Higginson & Stevens	Hawkesbury.
Jamieson, J. M.	Forrester's Falls.
Jamieson Lime Co.	Renfrew.
McGilvray, James	Priceville, R.R. No. 2.
McTernan, John	Torbolton.
Marshall Lime & Cement Works, Jas.	Hamilton.
Parks Bros.	Troy.
Robertson Co., D., Limited	Milton.
Smith, John S.	Inverhuron.
Standard Chemical Iron & Lumber Co., Limited	Eganville.
Standard White Lime Co., Limited	Beachville, Guelph, and St. Marys.
Toronto Brick Company, Limited	Coboconk.
Toronto Lime Co., Limited	Limehouse and Dolly Varden.
Weppler, Henry	Priceville, R.R. No. 1.

Portland Cement

The quantity of cement made in Ontario factories and sold in 1917 shows a small decline as compared with 1916. Building construction was hampered through scarcity of labour, and hence the demand was less. Barrels of cement marketed in 1916 were 2,143,949, valued at $2,242,433, while the 1917 figures were 2,063,231

and $2,934,271, respectively. The average price per barrel, however, rose from $1.05 to $1.42. Cement on hand at the end of the year totalled 567,261 barrels.

The industry employed 589 men in 1917, and wages paid amounted to $538,355.

The following cement plants were operated:

PORTLAND CEMENT PLANTS, 1917.

Name of Company.	Location of Plant.	P.O. Address of Manager, etc.
Canada Cement Company, Limited, Plant No. 5 ..	Thurlow tp., near Belleville	Herald Bldg., Montreal, Que.
do do do No. 8 ..	near Port Colborne...	do do
The Hanover Portland Cement Co., Limited	Hanover	Hanover.
National Portland Cement Co., Limited	Durham	Durham.
The Ontario Portland Cement Co., Limited	Blue Lake	Brantford.
St. Marys Portland Cement Co., Limited	St. Marys	St. Marys.

The following works were not operated during the year: Canada Cement Company, Limited, Plant No. 4, Thurlow; No. 5, Hungerford; No. 7, Lakefield; No. 9, Shallow Lake; Union Cement Company and Imperial Cement Company, Owen Sound. The last-named company is defunct. The Maple Leaf Cement Company, Atwood, and the Kirkfield Portland Cement Company, Raven Lake, were also idle.

Cement Products

From the Portland cement made from clay and limestone or marl, cement brick, blocks, tile and sewer pipe are manufactured. The demand for tile is increasing, and in many localities cement tile are competing successfully with the clay product, particularly for large sizes. As sand, gravel and cement are recorded in the table of production it has not been thought advisable to include cement products in the total valuation of the mineral output of the Province.

Returns received show an output as follows for the year 1917:—

Product.	Number.	Value
Cement Brick	130,000	$1,420
Cement Blocks	48,661	8,312
Cement Tile and Sewer Pipe.....	2,412,787	90,586
Total	.....	$100,318

The industry employed 105 men and $28,641 was paid in wages. The average time the producers operated was 105 days.

The following list gives the names and addresses of manufacturers of cement products reporting to the Bureau of Mines:—

MANUFACTURERS OF CEMENT PRODUCTS, 1917.

Name.	Address.	Product.
Andrews, S. J.	Clinton	Blocks and Tile.
Beuglas, Jas.	Bright, R.R. No. 3	Tile.
Brennan & Hollingworth	Hamilton	Tile.
Clark, W. H.	Gananoque, R.R. No. 3	Blocks.
Corlett, A. S.	Leamington	Brick.
Deline, L.	Enterprise	Blocks and Tile.
de Jersey, O. W.	Forest	Blocks.
Deveney & Campbell	St. Marys	Blocks and Tile.
Dillon, Jno.	Seeley's Bay	Tile
Fletcher & Sons, J. H.	Fonthill	Blocks.
Grece, G. C.	Wallaceburg	Blocks and Tile.
Hagerman, A. V.	Odessa	Tile.
Hay & Son, J. C.	Listowel	Tile.
Hoy, William J.	Prescott	Brick, Blocks and Tile.
Hyndman, Jno.	Gorrie	Tile.
Iler Concrete Tile Co.	Arner	Tile.
Karr & Rose	Petrolia	Tile.
Kilgour, D. G.	Eganville	Tile.
Kinzel & Son, Jos.	Preston	Blocks and Tile.
McLenaghan, W. A.	Essex	Blocks and Tile.
McQueen, Alex.	Arthur	Tile.
Malcolm, Jno.	Fergus.	Tile.
Markus, Wm., Ltd.	Pembroke	Blocks.
Mitchell, Frank	Pickering	Tile.
Moore, D. G.	Ailsa Craig	Blocks and Tile.
National Concrete Co.	Lindsay	Blocks and Tile.
Oil Springs Tile & Cement Co.	Oil Springs	Tile.
Ord, John A.	Guelph, R.R. No. 3	Tile.
Pfaff, W. E.	Hensall	Blocks and Tile.
Philp, Wm.	Port Perry, R.R. No. 4.	Tile.
Schmidt, J. T.	St. Jacobs	Brick, Blocks and Tile.
Schram, A. J.	Camlachie	Tile.
Smith, A. G. C.	Acton	Blocks and Tile.
Taylor & Hall	Peterboro	Blocks and Tile.
Webster Construction Co., Limited	London	Tile.
Williams, E. J.	Wheatley	Blocks and Tile.
Wyatt, W. J.	Cottam	Blocks and Tile.

Sand and Gravel

For making and repairing roads, for concrete work and building purposes generally, sand and gravel are annually raised in large quantities. Special varieties of sand, such as those used for moulding in foundries or for glass-making, are also in demand. The glacial action which in past ages determined the form and nature of the present surface of the Province resulted in the deposition of innumerable accumulations of detrital material, which is now found so useful in the economy of everyday life. In certain parts, such as counties in the extreme southwest part of the peninsula, sand and gravel are less abundant and dearer. With regard to the Province as a whole, the cost of sand and gravel largely depends upon the cost of labour and transportation. A considerable quantity of these materials is taken

from the beds of the great lakes and boundary rivers, much of which is exported to lake ports south of the line. Licenses authorizing such removal are issued by the Department of Lands, Forests and Mines on a royalty basis, the charges varying from three to twelve cents per cubic yard. From this source the receipts for the fiscal year ending October 31, 1917, were $28,372.93.

In view of the importance of sand and gravel, an investigation into these resources has been begun by the Bureau. Auguste Ledoux, Professor of Mineralogy in the University of Brussels, Belgium, is now carrying on this work, and the first instalment of the results of his labours is printed as Part II of this report under the title "Sands and Gravels Deposits of Southern Ontario." It is intended to continue the investigation next year and to include in it the deposits of the newer parts of the Province in so far as they are accessible to examination.

Returns have been received by the Bureau from 129 firms or individuals who operated sand or gravel pits or who dredged for these materials in 1917. Many operations of this kind were on a small scale and carried on only at intervals. Owing doubtless to the curtailment of operations on public works, the output of sand and gravel was somewhat less in 1917 than in 1916, the quantity raised being 1,187,973 cubic yards and the value $431,597, as against 1,265,973 cubic yards worth $470,963 in 1916. Following is a list of sand and gravel operators who removed 1,000 cubic yards or more during the year:—

SAND AND GRAVEL OPERATORS, 1917.

Name of Owner or Company.	Material.	Address.
Armstrong Supply Co., The, Limited	Gravel	Hamilton, 106, Dunsmere Ave.
Ashton, Thos.	Sand	Toronto, 1354 Queen St. E.
*Barnes, William	Sand	Hamilton, 132 Blake St.
†Barton Sand & Gravel Co., The, Limited	Sand and Gravel	Bartonville.
Cadwell Dredging Co., Limited	Sand and Gravel	Windsor.
Cameron Steamship Co.	Gravel	Detroit, Mich.
Canadian Steel Corporation, Limited	Gravel	Ojibway.
Canadian Towing & Wrecking Co., Limited	Sand and Gravel	Port Arthur.
Chapman, Walter	Gravel	Uxbridge.
Chatham, Wallaceburg & Lake Erie Railway Co.	Gravel	Chatham.
Chippawa River Sand & Gravel Co.	Gravel	Chippawa.
Cleary & Annable	Gravel	Mille Roches.
Constructing & Paving Co. of Ontario, Limited	Sand and Gravel	Toronto, 708 Confed. Life Bldg.
Creeper, John	Sand and Gravel	Belleville, R.R. 5.
Crow, H. E.	Sand and Gravel	Chatham, 30 Emma St.
Empire Limestone Co.	Sand	Buffalo, N.Y., 19 Hudson St.
Empire Sand & Gravel Co., Limited	Sand	Weston.
Fonthill Gravel Co.	Sand	Thorold, P.O. Box 655.
*Gillespie, Thos. M.	Sand	Perth, P.O. Box 16.

* Moulding sand producers.
† Washing and screening plants.

SAND AND GRAVEL OPERATORS, 1917.—*Continued.*

Name of Owner or Company.	Material	Address.
Godson Contracting Co., Limited	Sand and Gravel..	Toronto, 72 Queen St. E.
Goodale, Emerson	Sand and Gravel..	Hamilton, 98 Aikman Ave.
Hamilton, J. C.	Sand	Pembroke.
†Hamilton Sand & Gravel, Limited	Sand and Gravel..	Hamilton, 37½ McNab St.
Hansen, H. C.	Sand and Gravel..	Cleveland, O., 7325 Clinton Ave.
Hope Township, Municipality of	Sand and Gravel..	Port Hope, R.R. 1.
Karr & Rose	Gravel	Petrolia.
Kelley Island Lime & Transport Co., Ltd.	Sand	Sandusky, Ohio.
Kerr, John, Estate of	Sand and Gravel..	Petrolia.
Kingston Sand & Gravel Co.	Sand	Kingston, R.R. 5.
Lindsay, Corporation of	Sand	Lindsay.
Lyons Fuel & Supply Co., Limited	Gravel	Steelton.
McMurray, Geo.	Sand and Gravel..	London.
McPhail & Wright Construction Co., Limited	Sand	Sault Ste. Marie.
Mallory, Wm. B.	Sand and Gravel..	Sebringville, R.R. 1.
**Maple Sand, Gravel and Brick Co., Limited	Sand and Gravel..	Toronto, 178 Spadina Ave.
Morrison, J. H. I.	Sand and Gravel..	Brockville.
Ollman Bros.	Sand	Hamilton, Macklin St.
Oneida Lime Co., Limited	Glass Sand	Buffalo, N.Y., 406 Erie Co. Bldg.
Ontario Malleable Iron Co., Limited	Sand	Oshawa.
Ontario Sand Company	Sand and Gravel..	Niagara Falls.
Ponsford, A. E.	Sand and Gravel..	St. Thomas, 605 Talbot St.
Porter, Thompson	Sand and Gravel..	Mount Dennis, 866 Weston Rd.
*Quigley, O. E.	Moulding and Core Sand	Hamilton.
Rideau Canal Supply Co.	Sand	Ottawa.
Robinson, A.	Sand and Gravel..	Lindsay.
Roesand Company, Limited	Sand and Gravel..	Erin.
Sand and Supplies, Limited	Sand and Gravel..	Toronto, 103 Bay St.
Sleemon, Philip	Gravel	Port Hope, R.R. 1.
Smith, J. W.	Gravel	Leamington.
Soo Dredging and Construction Co., Limited	Gravel	Sault Ste. Marie.
Soo Dredging and Towing Co.	Gravel	Sault Ste. Marie.
Stamford Sand Co.	Sand	Niagara Falls, 268 Victoria Ave.
Standard Gravel Co., Limited	Gravel	Niagara Falls, 52 Erie Ave.
Stothart, J.	Sand and Gravel..	Peterboro, R.R. 6.
Thomas, W. H.	Gravel	Oshawa.
Tombling, W. J.	Sand and Gravel..	Ottawa.
Twin City Tug Line	Sand	Port Arthur, P.O. Box 42.
Union Stock Yards, Limited	Sand and Gravel..	Toronto.
United Fuel and Supply Co.	Gravel	Detroit, Mich.
Windsor, Essex & Lake Shore Rapid Railway Co....	Sand and Gravel..	Kingsville.
Windsor Sand & Gravel Co., The, Limited	Sand and Gravel..	Walkerville.
Wood, J. T.	Sand and Gravel..	Exeter.
York Sand and Gravel Co., Limited	Sand and Gravel..	Toronto, 445 Gladstone Ave.

* Moulding sand producers.
† Washing and screening plants.
** Screening plant.

Stone

There is no lack of stone in Ontario, and there are many kinds. Granite, gneiss, trap, sandstone, limestone, dolomite, quartz, marble, all may be had in abundance, according to locality. In southwestern Ontario the sedimentary formations furnish first-class building material both in sandstone and limestone, and a plentiful supply of the latter for the multifarious uses to which it is put—lime-making, as a fertilizer, in the chemical industry, etc., while granite and trap for street and road-making can be quarried in eastern and northern Ontario. Quartz and quartzite occur, especially on the north shore of Lake Huron and the islands adjoining, and beds of variegated and beautiful marble ranging in colour from white to mauve and red exist in some of the eastern counties.

The total production of stone, excluding quartz, which is given separately, had a value of $939,052, as against $755,312 in 1916.

Stone Production

Classified according to variety rather than uses, the quarry products of the Province for 1917, together with comparative values for the two preceding years, were as follows:—

——	Limestone.	Sandstone.	Trap.	Granite.	Marble.	Quartz
	$	$	$	$	$	$
1915.....	587,000	5,500	32,100	15,500	10,600	142,354
1916.....	625,628	14,268	91,762	23,655	.....	223,514
1917.....	728,975	115,932	70,570	25,575	.....	358,674

Below are given the names of quarry operators reporting a production for 1917, classified according to product:—

LIMESTONE AND SANDSTONE QUARRIES, 1917.

Name of Owner, Firm or Company.	Location.	Kind of Stone.
Beachville White Lime Co, Limited.....	Beachville	Limestone.
Bergin, Patrick	Napanee	do
Britnell & Co., Limited	Burnt River	do
Canada Crushed Stone Corporation, Limited..	Dundas	Limestone and Sandstone.
Canadian Towing and Wrecking Co., Limited..	Port Arthur	Rubble.
Contractors' Supply Co., Limited	Orangeville	Crushed Limestone.
Cook, J. S.	Wiarton	Limestone.
Crushed Stone, Limited	Kirkfield	Crushed Limestone.
Farr, Mrs. C. C.	Haileybury	Limestone.
Hagersville Crushed Stone Co., Limited	Hagersville	do
Hamilton, Corporation of	Hamilton	do, crushed.
Henderson Farmers' Lime Co.	Woodstock	do, ground.
Kingston, Corporation of	Kingston	do, crushed.

LIMESTONE AND SANDSTONE QUARRIES, 1917.—*Continued.*

Name of Owner, Firm or Company.	Location.	Kind of Stone.
Longford Quarry Co., Limited	Longford Mills	Limestone.
MacDonald, Jos. H.	Point Anne	do
Markus, Wm., Ltd.	Pembroke	do
Michigan Central Railway	Hagersville	do
Oliver-Rogers Stone Co., Limited, The	Owen Sound	do
Ontario Rock Co., Limited	Rossmore	do
Ontario Stone Corporation, Limited	Uhthoff	do
Perkins, Geo. A.	Owen Sound	do
Point Anne Quarries, Limited	Point Anne	do
Queenston Quarry Co., Limited	St. Davids	do
Reid, C. F.	Odessa	do
Robertson, D., & Company, Limited	Milton	Sandstone.
Robillard, H., & Son	Ottawa	Limestone.
Roddy & Monk	Kingston	do
Solvay Process Co., The	Amherstburg	do
St. Marys Horse Shoe Quarry, Limited	St. Marys	do
Standard Crushed Stone Company, Limited	St. Davids and Windmill Point	do
Standard White Lime Co., Limited	Beachville, Guelph and St. Marys	do
Thibault, Adelard	Billings Bridge	do
Walker Bros.	Thorold	do
Welland County Lime Works Co., Limited	Port Colborne	do
Wentworth Quarry Co., Limited	Vinemount	do

GRANITE AND TRAP QUARRIES, 1917.

Name of Owner, Firm or Company.	Location.	Kind of Stone.
Brown, Robert	Lyndhurst	Granite.
Bruce Mines Trap Rock Co., Limited	Bruce Mines	Trap.
Gordon Granite Co., D. J.	Gananoque	Granite Blocks and Monuments.
Horne, Wm.	Ignace and Butler	Granite Blocks and Monuments.
National Potash Corporation, Limited	Gravenhurst	Crushed Granite.
Ontario Rock Co., Limited	Preneveau	Trap.

Actinolite

Some 120 tons of actinolite from stocks on hand were shipped by the Actinolite Mining Company, Limited, whose mine is situated at Actinolite, in the county of Hastings. The product was valued at $1,320, and was intended for use in the manufacture of roofing material.

Asbestos

From a deposit in the township of Deloro, near Porcupine, the Slade-Forbes Asbestos Company shipped 10 tons of asbestos valued at $2,150. A total of 800 tons of asbestos rock was mined during the season.

Barite

In the township of Langmuir, Porcupine Mining Division, the Premier Langmuir Mines, Limited, has been developing a barite property about 30 miles from the Timiskaming and Northern Ontario Railway. The vein is a large one and carries a little silver. A mill for grinding the barite and preparing it for market is being erected and will shortly be in operation. Mr. J. A. McIntosh, of Toronto, is president of the company.

Barite occurrences have long been known to exist in eastern Ontario, principally in the counties of Frontenac, Lanark, and Hastings, also on McKellar Island, Lake Superior, and on the north shore of that lake. Some of these have been worked, but there has been little or no production of late years. More recently, deposits have been found in the Fort Matachewan gold area, some of which are described by A. G. Burrows.[1] These comprise the Biederman claim, in Cairo



Premier Langmuir Mines, Ltd., Plant, fall of 1917. Narrow gauge track from 2nd vein and also to dock ½ mile distant on Night Hawk river.

township, and a deposit near Yarrow lake, in Yarrow township. Another deposit has recently been reported from the township of Lawson.

Barite (or barytes) is a heavy white mineral, sometimes coloured by impurities, having the composition $BaSO_4$. It may be granular, or in masses of wedge-edged crystals, and occurs in veins in limestones and sandstones, also associated with lead or other ores. White bleached and floated ground barite is used in ready-mixed paints, in making rubber goods, and in stiff, heavy cardboards and papers. In the intermediate form of "lithopone," a growing use is found for barite in the preparation of "flat" wall paints, in rubber manufactures, and also in enamel and calcimine. A variety of barium chemicals, such as the chlorate, chloride, nitrate, etc., serve a number of uses; the chlorate and nitrate in pyrotechnics, the chloride as a water softener, in the purification of table salt, etc. Barium monoxide, and

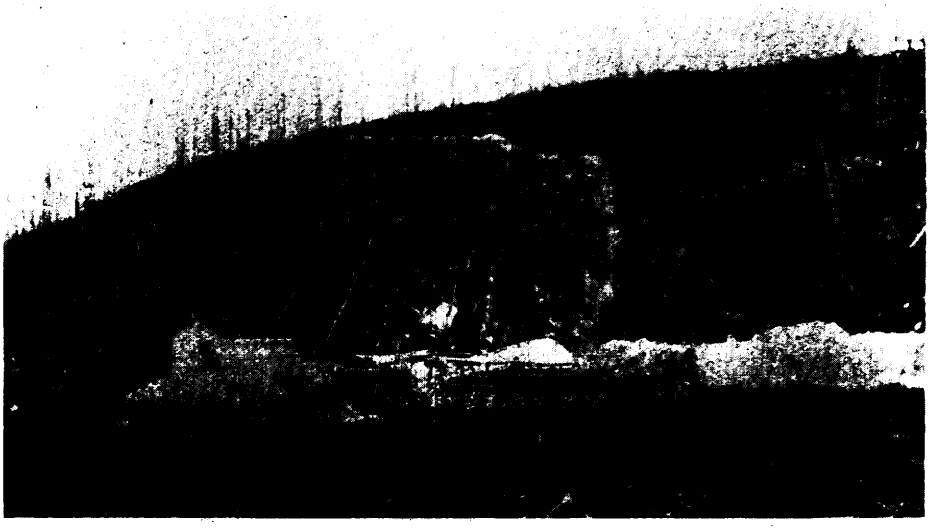
[1] Bulletin No. 34, Ont. Bur. Min., 1918, pp. 27-8, The Matachewan Gold Area, republished in this Report.

dioxide have also their uses. As "blanc-fixe" or permanent white, barite is extensively used as an adulterant of white lead, also in making putty.

A barium industry is rapidly developing in the United States, the principal deposits there being in the States of Georgia, Missouri, and Tennessee. The native article has already taken the place of imports from Germany, which before the war largely supplied the wants of eastern manufacturers, coming in as crude by cheap ocean transportation. Crude barite in 1916 was produced in the United States to the extent of 222,000 short tons, valued at $1,011,000, or about $5 per ton. The value of the domestic barium products was upwards of $8,500,000.

Corundum

Mining was continuous throughout the year at the property of the Manufacturers' Corundum Company, Limited, Jewellville, but as the ore can only be hauled



Premier Langmuir Mines, Ltd., showing 6-foot barite vein, summer of 1917.

out over the winter roads, the concentrating mill ran only from January 24 to July 25. The quantity of corundum ore mined was 6,799 tons, and of grain corundum produced 188 tons, valued at $31,213. The employees were 46 in number, and the wages paid them amounted to $33,817.

Feldspar

The production last year was 18,334 tons, an increase of 5,369 tons over that of 1916. The value was $81,802, or $4.45 per ton, compared with $3.25. The principal site of the feldspar industry is on the line of the Kingston and Pembroke railway, in the county of Frontenac. Feldspars, Limited, and Feldspar Quarries, Limited, the former at Hartington, and the latter in the township of Portland, were the leading producers. Eureka Flint and Spar Company also quarried considerable spar at Verona and exported it to Trenton, N.J. The output has hitherto found a market as crude rock in the pottery manufacturing trade in New Jersey

and Ohio, but the product of the largest mine is at the present time being entirely used in making insulating material for use in the U.S. army. There is now a grinding mill at Parham, which supplies the Canadian trade with ground spar. The Canada Feldspar Corporation, Limited, near Fermoy, and Stephen Fitzpatrick and Company, in the township of Herschel, quarried and shipped small quantities of feldspar. The last-named company did mostly development work, and claims to have exposed three varieties of spar, namely, the red or pink potash variety, white spar, and greenish soda spar. The National Potash Corporation, Limited, Gravenhurst, has a stone-crushing plant at Muskoka Wharf, and is installing a plant with the view of extracting potash from the feldspar which occurs on the property. The works are not yet in operation.

The companies producing feldspar in 1917 were as follows:—

FELDSPAR PRODUCERS, 1917.

Name.	Location of Deposit	P.O. Address.
Canada Feldspar Corporation, Limited....	near Verona	Toronto, 168 Madison Ave.
Eureka Flint & Spar Co., The	Verona	Trenton, N.J.
Feldspars, Limited	Bedford tp.	Hartington, R.R. No. 1.
Feldspar Quarries, Limited	Portland tp.	Toronto, 33 Richmond St. W.
Fitzpatrick & Co., Stephen	Herschel tp.	Toronto, 79 Adelaide St. E.
Kingston Feldspar & Mining Co.	Verona and Godfrey	Kingston.
National Potash Corporation, Limited ...	Gravenhurst	Toronto, 178 Spadina Ave.

Fluorspar

A little fluorspar has in the past from time to time been extracted from the deposits known to exist near Madoc, in the county of Hastings, but the demand was never great, and this branch of the mining industry could scarcely be said to have an existence. The war has changed this, and the call for fluorspar, which began to be heard in 1916, continued into 1917 even more loudly. Previous to 1916 there had been no production since 1911, when 30 tons were reported as extracted, valued at $200. In 1916 shipments were 1,283 tons, and in 1917, 4,327 tons. The selling price rose concurrently. In 1911 shipments were valued at $6.66 per ton, in 1916 at $7.90 per ton, and last year at $15.13. The demand came from steel manufacturers for use as a flux.

The veins of fluorspar worked last year were near Moira lake, in the townships of Madoc and Huntingdon, and a fuller account of the deposits, together with a map showing their exact locality, will be found on a later page in the report of the Chief Inspector of Mines. The number of employees was 56, and the wages paid for labour $29,582.

Fluorspar has recently been found in quartz veins in the townships of Alma and Cairo, near Fort Matachewan, Northern Ontario. The deposits are small. They are described by A. G. Burrows in his report on the Fort Matachewan gold

area.[1] Here the mineral is of a purple colour, while in the Madoc deposits the tint is a sea-green or white.

Following were the operating individuals and firms:—

FLUORSPAR SHIPPERS, 1917.

Name.	Location.	Address.
Cross & Wellington	Lot 11, Con. XIII, Huntingdon	Madoc.
Gillen & Henderson	Lot 7, Con. XIII, Huntingdon.	Madoc.
Herrington, Herbert S.	Lot 2, Con. XII, Huntingdon..	Madoc.
Mineral Products, Limited	Lot 2, Con. III, Madoc	Madoc.
O'Reilly Company	Lot 6, Con. I, Madoc	Madoc.
Wallbridge, Mrs. Jane	Lot 4, Con. I, Madoc	Madoc.
Wellington & Munro	Lot 13, Con. XII, Huntingdon .	Madoc.
	Lot 1, Con. I, Madoc	Madoc.

Graphite

The output of refined graphite in 1917 was somewhat less than in 1916, being 3,173 tons, as against 3,416. The valuation, $210,018, was also slightly less, the average per ton being $66.18, as compared with $73.06. Black Donald Graphite Company, Limited, and Globe Graphite Mining and Refining Company, Limited, were the two operating companies. The mine and mill of the former are at Whitefish lake, Brougham township, and of the latter at Port Elmsley, on the Rideau canal. Employees in the mines and works numbered 156, to whom wages amounting to $120,083 were paid.

The uses of graphite are numerous. They include the manufacture of lubricants, lead pencils, foundry facings, stove polish, paint, etc. Crucibles and high grade lubricants are made from the flake variety, which commands the highest price; for other uses the amorphous variety is employed. Hitherto there has been a considerable demand for crystalline flake for the manufacture of crucibles to be used in making special grades of steel, and the demand was chiefly for the Ceylon product, importation of which has been cut off. However, the tremendous requirements of the war for steel have brought about changes in the steel trade. The crucible method of manufacture, with its small units and limited capacity has been side-tracked, and this has lessened the demand for the higher grades of graphite. Moreover, the necessity for war material is imperious, and ordinary industrial needs are forced to take second place. In consequence, foundry operations other than munitions have been much curtailed, and a smaller quantity of the lower grades for facing purposes suffices. These conditions have had their natural effect upon the graphite industry, especially since the beginning of 1918, and the present outlook is for a diminishing production.

[1] Bulletin No. 34, Ont. Bur. Min., 1918, The Matachewan Gold Area, p. 25.

Following is a list of graphite operators:—

GRAPHITE OPERATORS, 1917.

Company.	Location of Mine.	P.O. Address.
*Allan, J. G.	near Denbigh	Hamilton, 27 Hillcrest Avenue.
*Beidelman, J. C.	Lyndoch tp.	Montreal, P.Q., 29 Cote des Neiges Road.
Black Donald Graphite Co., Limited	Brougham tp.	Calabogie.
*National Graphite, Limited	Monteagle tp.	Toronto, 402 Lumsden Building.
The Globe Graphite Mining and Refining Co., Limited	Port Elmsley	Syracuse, N.Y., U.S.A., 410 Dillaye Building.
*Tonkin-du Pont Graphite Co., Limited	Maynooth†	Phoenixville, Pa., U.S.A., 309 Church St.

* Idle in 1917. † Refinery at Wilberforce.

Gypsum

The production of gypsum is confined to the deposits in the valley of the Grand river, where the Caledonia mine, in Seneca township, and the Martindale mine, in Oneida township, are now owned and worked by the Ontario Gypsum Company, Limited, an amalgamation of the Alabastine Company and Crown Gypsum Company, which became effective January 1, 1917. Crushed and calcined gypsum to the extent of 48,943 tons were shipped during the year, the value of the same being $130,138. This compares with 36,668 tons, worth $116,206, in 1916. The number of employees was 70, who received as wages $59,966.

Gypsum, ground but not calcined, is employed as a retarder in Portland cement, as land plaster, as paint material, and for other minor uses. After being calcined, it is made into wall plasters of various kinds, into dental plaster, and is also sold to glass factories. It is used in this form in Portland cement. Other uses are the manufacture of statuettes and similar objects. Combined with fibrous material it is made into building blocks, for whose fire-resisting qualities much is claimed, because of the non-conducting and non-expanding properties of gypsum.

Very large beds of gypsum are found on the banks of several of the rivers running into James bay, but these are as yet too remote for utilization.

Iron Pyrites

In few departments of the mineral industry have the demands of war had so noticeable an effect as in the mining of iron pyrites. Sulphuric acid is a prime requisite in the manufacture of explosives. Prior to the war much of the sulphur required for making the acid was supplied by the sulphur deposits of Sicily, remains of the ancient volcanic forces once active in that island. The entrance of Italy into the war and the diversion and destruction of ships stopped the transatlantic exports, and the output of sulphur from the mines on the Mexican Gulf was insufficient for the requirements of the ammunition factories of the United States and Canada. This condition was doubly emphasized when in April, 1917, the United States joined the Allies. The pyrite deposits of Ontario being close at

hand and conveniently situated for water transportation, were called upon to make good a large part of the deficiency. Shipments of pyrite from this Province rose from 107,258 tons in 1914 to 145,315 tons in 1915, 175,593 tons in 1916 and 286,049 tons in 1917. The probability is that in 1918 the rate of increase will be maintained. Like practically all products, mineral and other, the price has risen materially. In 1915 the producers returned their output at a valuation of $2.43 per ton, in 1916 at $2.68 per ton, and in 1917 at $3.88. The following figures show how greatly the war has stimulated the mining of pyrite in Ontario:—

IRON PYRITES PRODUCTION, 1913 TO 1917.

Year.	Production.	Value.	Valuation per ton.
	tons	$	$
1913	71,620	171,687	2.39
1914	107,258	264,722	2.46
1915	145,315	353,498	2.43
1916	175,593	471,807	2.68
1917	286,049	1,111,264	3.88

It will thus be seen that in five years the output of iron pyrites has increased in quantity four times and in value more than six times.

The list given below enumerates the operators for 1917. The Nichols Chemical Company, Limited, was much the largest producer, from its mines at Northpines and Goudreau, the former near the junction of the Grand Trunk Pacific railway and the Fort William branch, and the latter on the line of the Algoma Central, in the Michipicoten area. The Nichols Company is the Canadian arm of the General Chemical Company of the United States. It also operates a mine and acid plant at Sulphide, Hastings county. The Rand Consolidated Syndicate is working a deposit at Goudreau. At Flower station, on the Kingston and Pembroke railway, the mine opened by T. B. Caldwell has passed under a working lease to the Grasselli Chemical Company, Limited. A quantity of ore was mined in 1917, but no shipments made.

The proportion of sulphur in the pyrite shipped from the mines varies from 31.76 to 45 per cent. The average in the shipments for last year was in the neighbourhood of 35 per cent., hence the sulphur contents would amount to upwards of 100,000 tons. This would be the equivalent of 300,000 tons of ordinary strong sulphuric acid. It is expected that about one-third of the total pyrite requirements of the United States for 1918 will be obtained in Ontario.

Notwithstanding the comparative abundance of pyrite in Ontario, considerable quantities of elemental sulphur are yearly imported into this Province, partly for use in manufacturing sulphuric acid, but mainly to be converted into sulphurous acid needed in making wood pulp. It would seem that in northern Ontario, where the mining of pyrite and the manufacture of pulp and paper are both carried on, it should be possible to substitute the native for the imported article, and to effect economy in doing so.

The number of workmen employed in the pyrite industry was 580, of whom 209 were engaged in underground work, and 371 above ground. They were paid wages totalling $583,819.

IRON PYRITE SHIPPERS, 1917.

Name of Owner, Firm or Company.	Location or Name of Mine.	P.O. Address of Manager, etc.
Algoma Steel Corporation, Limited	Helen	Sault Ste. Marie.
Canadian Sulphur Ore Company, Limited.	Queensboro	Toronto, Crown Office Building.
Nichols Chemical Company, Limited (*a*)	Goudreau	Goudreau.
Nichols Chemical Company, Limited	Sulphide	Sulphide.
Nichols Chemical Company, Limited (*b*)	Vermilion Lake	Northpines.
Rand Consolidated Syndicate	Goudreau	Buffalo, N.Y., 853 Ellicott Square.

(*a*) Formerly known as The Madoc Mining Company.
(*b*) Formerly known as The Northern Pyrites Company, Limited.

Mica

During 1917 shipments of mica were made by producers of both rough-cobbed and thumb-trimmed grades. Of the former 40 tons, worth $7,100, were marketed, and of the latter 790,905 lbs., worth $85,353, or a total of 435 tons valued at $92,453.

Owing to labour scarcity, mining operations have been curtailed, but a great deal of dump material has been sorted and marketed. A shortage of mica is in prospect owing to the large demand for this material for war purposes, and also to the limited production. The Loughborough Mining Company, Limited, Kent Bros., and estate of J. M. Stoness, S. H. Orser, and A. G. Martin were among the larger producers.

There were 88 employees at work during the year, who were paid $48,490 in wages.

Shipments were made by the following during 1917:—

MICA PRODUCERS, 1917.

Name of Owner or Producer.	Location or Name of Mine.	P.O. Address of Manager, etc.
Anglin Mica Co.		Kingston.
Buck Lake Mining Co.	Loughborough tp.	Perth Road.
Fahey & Sullivan	South Crosby tp.	Elgin.
Grierson & Gallagher	North Burgess tp.	Perth, R.R. No. 5.
Kent Bros. and Estate J. M. Stoness	Bedford tp.	Kingston.
Loughborough Mining Co., Ltd.	Lacey mine	Sydenham.
McConnell, Rinaldo	North Burgess tp.	Toronto, 1002 Kent Bldg.
McLaren, W. L.	North Burgess tp.	Perth.
Martin, A. G.	Connors Mine, Portland.	Ottawa, 234 Besserer St.
Orser, S. H.	North Burgess tp.	Perth.
Sydenham Mica and Phosphate Mining Co., Limited	Loughborough tp.	Perth.
Tett & Bro., J. P.	Bedford tp.	Bedford Mills.
Waffle, W.		Westport.
Webster & Co.	North Burgess tp.	Ottawa, 274 Stewart St.

Natural Gas

The total amount of natural gas produced in Ontario during the year was 20,026 million cubic feet.

In the following table of distribution by fields, compiled by the Mine Assessor, the yield from a number of very small operators is not included.

	Million cubic ft.	
1. Welland, Haldimand, etc., field	3,760.2	or 19.2 per cent.
2. Kent field (old field)	15,229.7	77.9
3. Kent, new field (Dover Tp.)	220.7	1.1
4. Elgin	290.8	1.6
5. Lambton	44.6	0.2

The old field situated in Welland, Haldimand, Norfolk, Wentworth and Brant counties has now produced 61,432 million cubic feet. Small new pools are discovered from time to time but are not sufficient to compensate for the decline in output of the old wells, and the outlook for an increase of gas from this section is not bright. The most promising area of substantial size left for exploration is at Long Point, where drilling is now going on.

The Kent field in Romney, Tilbury and Raleigh townships has again been the mainstay of the production, and the yield from this field to the end of 1917 amounts to 81,030 million cubic feet. This is equivalent in heating value to 4,000,000 tons of coal approximately. The course of events in this field is dealt with at length below.

The new field in Dover township came into operation for the first time last year. The gas is found in the Trenton at a depth of about 3,300 feet and is associated with oil.

The Elgin field has been described at length in previous Reports, and there is nothing new to record. The production from Elgin county now amounts to 2,556.2 million cubic feet.

The Lambton field at Oil Springs has unfortunately had a short life; the production has fallen to 670.6 million cubic feet, and is rapidly declining each year.

Noteworthy events have taken place since the beginning of 1918 in the Kent county natural gas field, affecting the social and industrial life of the community. Failure of gas supply, concurring with an unusually severe winter, led to much hardship and even suffering among the many thousands of people in southwestern Ontario who have come to depend upon gas for that primal necessity of human life, fuel. The use of gas for heating and cooking purposes has become well nigh universal in the cities, towns, villages and even farms which have access to a supply. It makes no ashes and little dirt, is easy to turn on and off, and it is cheap. But an increasingly large proportion of the gas has been going to manufacturers, many of them using large quantities in the coarser and heavier industries, and getting their gas at a much lower rate than domestic consumers. The feeling has for some time been growing that natural gas should be treated as a fuel for household consumption only, and the crisis last winter led to an outcry against the manufacturing and industrial use of gas. Strong representations were made to the Government, and the Legislative Assembly with practical unanimity passed

an Act handing over the control of the natural gas supply to the Ontario Railway and Municipal Board.

The Natural Gas Act, 1918

G. R. Mickle, Mine Assessor, who supervises the inspection of gas and oil wells in the Province on behalf of the Department, and whose duties have made him familiar with the gas situation deals with it as follows:—

The most important event in the year affecting the natural gas industry was the failure of the Kent gas field to respond to the ever increasing and exorbitant demands made on it, and the consequent break-down of the whole system, causing a shortage of gas in many homes, with the inevitable suffering this entails. The government was petitioned to bring the matter before the Ontario Railway and Municipal Board. This was done, and a sitting of the Board was held in Chatham about the middle of January. In consequence of the Board's report the Natural Gas Act of 1918 was passed. This Act places the regulation of the natural gas output in the hands of the Ontario Railway and Municipal Board. Under the powers conferred by the Act the Board ordered natural gas to be cut off from a number of industries till the 1st of April. This Order was made about the middle of February. From 1st April to 1st July industrial consumers with a few exceptions were allowed to use the same amount of gas as they had consumed during the same months last year. On 1st July a general order was issued by the Board largely confining the use of gas to domestic purposes, and greatly restricting its industrial use. The only use of natural gas for power permitted by this order is for the highly economical gas engine, and in methods and appliances which ordinarily are served with artificial gas, which is nowhere cheap. The amount that may be so used by any company is limited to 5,000,000 feet per year. At the same time, pending changes during the transition period, permits were issued by the Board for a supply of gas to carry on operations while plants are being reconstructed to use other fuel.

Assuming the policy outlined to be continued, the result must be a prolongation of the life of the field for the benefit of the domestic consumers now using gas. With the high prices now prevailing for the most convenient solid domestic fuel, and the difficulty of securing hard coal even at $11.00 per ton, this is certainly a great boon to all the communities now served with natural gas.

Difficulties in Regulation and Public Control

The history of the Kent gas field does not differ essentially from that of any other field yielding gas. The difficulty is in the nature of the product, which is unlike anything else with which we are accustomed to deal. The essential difference, and the root of all the trouble, lies in the fact that there is no physical means by which the holder of one piece of land can be prevented from drawing gas from adjoining territory. If the holder of a lease could be assured of his ability to draw off the gas underlying his leases, which rightfully belongs to him, and to utilize it in the most economical manner, there would be no excuse for entering into a crazy competition to exhaust the field as quickly as possible, and sell the gas at any price rather than let a competitor have it. This condition inevitably leads to some public control of production and distribution as the only possible solution of the difficulty. There does not seem to be any insurmountable obstacle in the way of determining what proportion of the total amount of gas in reserve underlies any particular set of leases, and consequently what percentage of the total production permissible should be allotted to any one company.

Boyle's Law and Natural Gas

This law, if properly understood and followed, is a certain guide in planning the rate of production that should be permitted in any gas field. The rate of production should, of course, be governed by the amount of gas which exists in any field, of which Boyle's law is a sure means of measure. The expression so often used of the "uncertainty" of the gas supply is absurd when the rock pressures and production are studied in the light of this law. So far from being uncertain, the amount of gas existing in a field can be calculated within reasonably close limits years before the point of exhaustion is reached. As this law is the most important thing in connection with natural gas and has been disregarded, it seems worth while to explain it at some length, and show its application in planning a rational scale of production from any field. Considering that Boyle's discovery of the law that bears his name was announced in 1660—over 250 years ago—and has appeared in every text-book on physics for generations, it is surprising that it is so generally ignored. Boyle called his discovery the "Doctrine of the Spring and Weight of the Air," the spring, or pressure as we would now say, being due to the weight. In his work called "The Defence of the Doctrine of the Spring and Weight of the Air," the following passage, which seems

to forecast the general attitude towards the natural gas question, occurs: "I see no cause to despair that, whether or no my writings be protected, the truths they hold forth will in time, in spite of opposition, establish themselves in the minds of men, as the circulation of the blood, and other formerly much contested truths, have already done."

It has been a long wait.

Let us imagine that a tank or container is constructed of glass as illustrated in fig. 1 with dimensions of 10 ft. by 10 ft. by 10 ft., so that it contains exactly 1,000 cubic feet. Suppose this to be first filled with water, and provided with a pipe to form an inlet for gas and another pipe as an outlet for the water. Now allow natural gas or air or any other gas to enter slowly and displace the water. In fig. 1 the point of time is shown when the water is about half gone. Allow the gas to flow in slowly till the water is all gone, then instantly close both inlet and outlet. The tank will of course contain exactly 1,000 cubic feet of natural gas, and the pressure gauge will read zero, although there is a pressure in the tank exactly equal to the atmospheric pressure which the gauge does not record. This is shown in fig. 2. This atmospheric pressure is known to be approximately 15 lbs. to the square inch, and in considering the relation between volume and pressure we should start from the absolute zero, or add 15 lbs. approximately to the gauge reading. Thus if we wish to calculate the difference in volume between gas at atmospheric pressure or zero on the gauge, and 6 oz. on

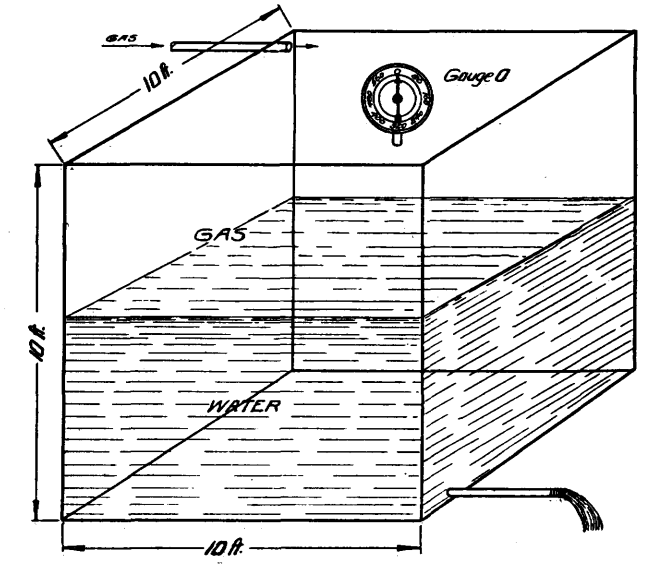


Fig. 1.—Diagram showing method of replacement of water by gas.

the gauge, add 15 lbs to each, then, reducing both to ounces, we have respectively pressures of 240 oz. and 246 oz., and there will be 2.5 per cent. more gas at the 6 oz. gauge reading than there was at the zero reading, as will be seen later on.

Coming to fig. 3, the gas has been passed into the tank till the gauge reads 15 lbs. or 30 lbs. above the absolute zero; that is, there is a pressure of two atmospheres above zero, and there will be exactly 2,000 cubic feet of gas in the tank. Therefore the pressure counting from the zero point has been doubled, and the volume occupied by the first 1,000 cubic feet in the tank has been reduced to one-half. Boyle's law is often expressed in this way: $pv =$ constant, that is, where $p =$ pressure and $v =$ volume, the product of the two is always the same. The original 1,000 cubic feet is compressed into one-half the space it occupied at zero gauge or atmospheric pressure, and so on. Each increase in pressure of an atmosphere means that an amount of gas equal to the volume of the container or tank, in this case 1,000 cubic feet, has been added. Fig. 4 shows the tank with a gauge reading of 590 lbs., or approximately 40 atmospheres, and consequently the tank will contain 40,000 cubic feet of gas. This was the rock pressure that originally existed in the Kent field. And it would make no difference if, instead of having one clear space of exactly 1,000 cubic feet, the tank had been made larger and then gravel and sand thrown in till the aggregate pore space equalled 1,000 cubic feet.

The tank, having been filled, can be emptied in exactly the same way; every atmosphere drop in pressure means that 1,000 feet have been drawn off. Fig. 5 illustrates the state

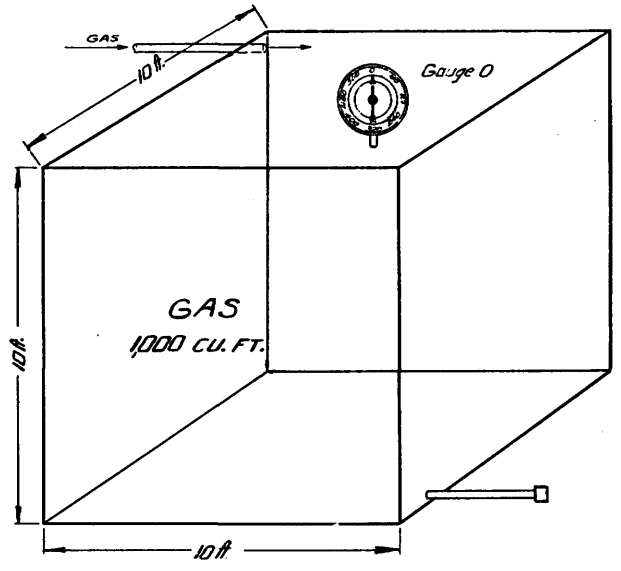


Fig. 2.—Diagram shows condition at instant all water is replaced.

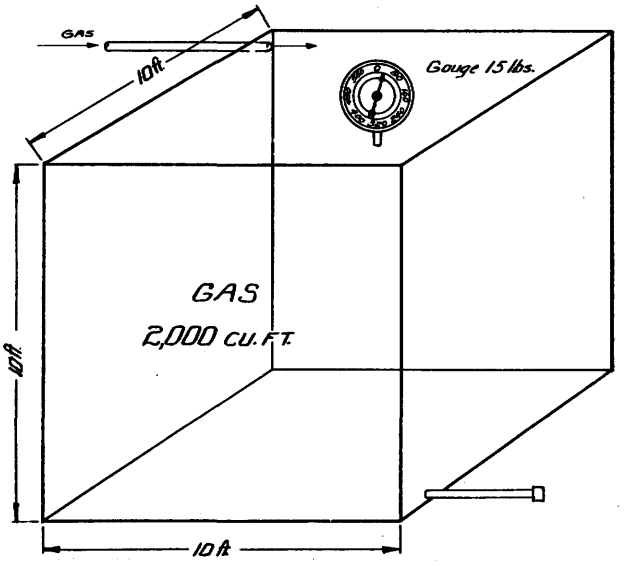


Fig. 3.—Pressure in tank now two atmospheres above absolute zero, or 15 lbs. on gauge.

of affairs existing at the present time (1st June, 1918) in the Kent field when, as explained below, the average gauge pressure was found to be 320 lbs, or 22 atmospheres approximately.

Turning now to the gas field, let us regard it, as it should be regarded, as a container or tank, and not as some mysterious geological anticlinal structure. We have not one solid chamber full of gas, but a condition resembling the case imagined above, namely, a tank of dimensions of several thousand cubic feet filled with sand and gravel to such an extent that finally the aggregate volume of the spaces between the sand and gravel is equal to 1,000 cubic feet. And in this field tank, instead of one pressure gauge we have a gauge on each well, of which there are about 300 distributed all over the field, so that the average pressure is capable of close estimation. According to Boyle's law, for each increase or decrease of pressure of one atmosphere in the imaginary tank, and counting from the absolute zero, 1,000 cubic feet have been added to or drawn from the tank. In an exactly similar way, a loss of one atmosphere in pressure means a loss in our field tank of a certain number of cubic feet which is exactly the volume or cubical space contained in the tank that might be occupied by gas. It will be seen that as the gas is drawn from the field there is a certain production of gas for each atmosphere drop in pressure, which of course gives us the aggregate volume of all the pore space in the rock constituting the tank or gas field. It is evident that the proper rate of production to ensure an economical use of the supply of gas could have been estimated at least six years ago, and that the loss occasioned by increasing the production according to the demand beyond the capacity of the field was quite unnecessary.

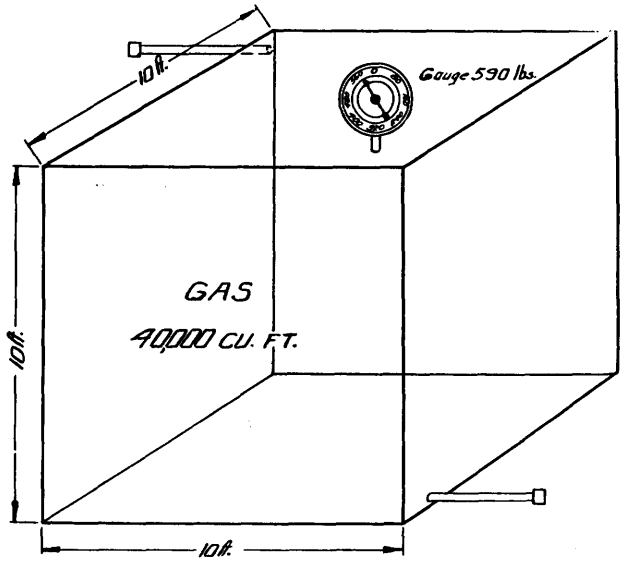


Fig. 4.—Pressure increased to 40 atmospheres.

Relation Between Drop in Pressure and Output of the Field

Up to 1st June, 1918, the production of the Kent gas field was 86,450 million cubic feet approximately, this being made up of the production to the end of 1917 of 81,030 million cubic feet, and an estimated production of 5,420 million feet from 1st January to 1st June, 1918. During this production the rock pressure dropped from 590 lbs. to 320 lbs. on 1st June, or a loss of 270 lbs. This determination of the average rock pressure was made by the writer with great care, the field being subdivided into a number of areas in which the rock pressures were fairly uniform, and a weight being given to each area proportionate to its size, and also to the average open flow capacity of the wells in each area.

This 270 lbs. drop in pressure is equivalent to 18.75 atmospheres at 14.4 lbs. per atmosphere, that being the atmospheric pressure at the altitude of the gas field. The output for each decline of one atmosphere in pressure is accordingly 4,610 million cubic feet, which is the aggregate volume of the pore space in the rock. It is naturally more easy to closely calculate the relation between the loss of pressure and the output, the more nearly the field approaches the point of exhaustion. When the pressure is down to nearly zero, and the field is abandoned, we will know exactly the relation between the two, but the knowledge will then be of little value.

For all practical purposes, however, it can be seen that the relation between decline in pressure and output, and consequently the rate of production which should be allowed, was known and published with sufficient accuracy years ago. Thus from information given in various Reports of the Bureau of Mines, it can be seen that at the end of 1912 the production from the Kent field was 23,132 million cubic feet, with a loss in pressure of about 90 lbs., or 6.2 atmospheres, or 3,730 million feet per atmosphere, or a difference of 20 per cent. from the amount finally calculated. At the end of 1913 the output was 31,108 million feet, with a loss in pressure of 8 atmospheres, or 3,888 million feet per atmosphere, a difference of 16 per cent. from the standard. Taking the year 1913 alone, which of course would give an independent check, the production was 7,976 million feet and a decline of 1.8 atmospheres, or 4,431 million feet per atmosphere, a difference of 5 per cent. from the final estimate. The output from 1913 to June, 1918, was 55,342 million feet and drop in pressure 10.75 atmospheres, or 5,148 per atmosphere, or 12 per cent. variation from the final figures.

In the case of all these estimates, previous to 1918, no special effort was made to accurately determine the rock pressure and the output at any given date, which of course would be necessary in order to establish the relation between the two. The records of production are kept according to the calendar year, whereas the most convenient time to take the rock pressures is in midsummer, when the wells are not working at the fullest capacity, consequently any of the figures given previous to 1918 are only approximations.

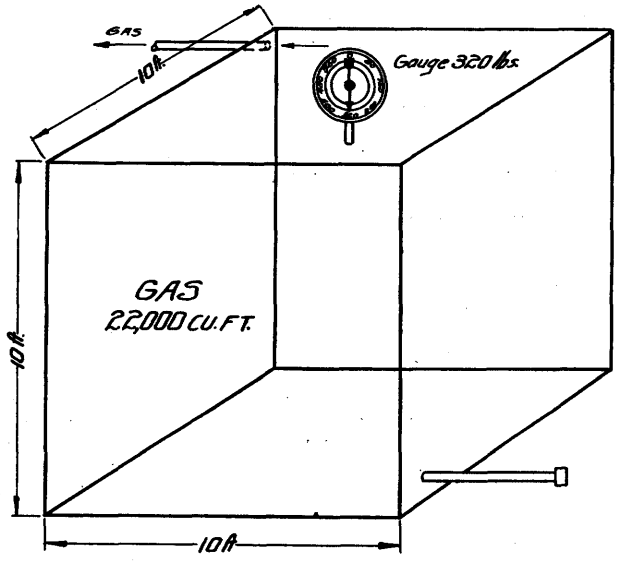


Fig. 5.—Shows condition of Kent field at present with about 22 atmospheres pressure.

At the end of 1917 pressure was assumed to be 320 lbs., which was evidently too low. As it is more convenient to have the end of the year as the accounting period, and 5,420 million cubic feet was the estimated production from January to 1st June, this corresponds to 1.17 atmospheres or 16.8 lbs. At the end of 1917, therefore, the pressure must have been 337 lbs., and not 320 as assumed in Sessional Paper No. 78 (1918) by the writer.

The Natural Limit to the Rate of Production for a Gas Field

In determining the annual output which should be allowed from any field, apart altogether from a consideration of the quantity which it is rational to permit, there is a maximum limit imposed by nature due to the physical conditions of the field, there being salt water in the rock underlying the gas, and this salt water being only kept back by the pressure of the gas and thus prevented entering the wells and ultimately cutting off the supply of the gas. Experience in the past has shown that where the production from a field has been accelerated too much, thereby reducing the pressure at each producing well, salt water comes in and finally shuts off the output of the well entirely. There is no way of calculating exactly what this rate should be, but it can be approximated from experience, and it would appear that a reduction of the pressure by one atmosphere per year is a natural limit. A loss of one atmosphere of pressure means that the production is exactly equal to the total volume of all the

incalculable number of pores which constitute the field tank, and consequently involves great motion. When it is considered that the gas is stored in countless millions of minute pores, and must find its way slowly owing to the great friction through vast numbers of the smallest openings, it can be seen that time is required to equalize the pressures throughout the field and not allow a very low pressure at the well which would permit the entrance of water. With a purely domestic consumption it would be possible to give the wells a rest in the summer months when the consumption is for cooking only and the output consequently very small—only from 4 to 5 per cent. altogether of the total annual domestic consumption being used in the months of July and August.

The history of the Essex gas field, which is only 20 miles from the Kent field, the gas being exactly the same in composition and therefore almost certainly having come from the same source, is instructive in this respect and should furnish sufficient warning. The Essex field was discovered in 1889, the depth of the gas being about 1,000 feet and the rock pressure 500 lbs. In the Kent field the depth of the wells is about 1,300 feet and original pressure 590 lbs. In 1900 the pressure was reduced to between 325 and 350 lbs.[1], or a maximum drop of about 12 atmospheres in 11 years. In 1901 about three-quarters of the wells were full of salt water.[2] The production in 1902 was much smaller than in 1901.[3] The export was shut off towards the end of 1901 and the field was practically abandoned in 1903.[4] The records of production are unfortunately very incomplete, but about 22,500 million cubic feet from this field appear to have been utilized,[5] and as there was an enormous waste in the early days of the field, probably not less than 30,000 million cubic feet came from this area. Of this all but about 3,000 million feet were produced before 1901, or a production of not less than 27,000 million was accompanied by a drop of 12 atmospheres pressure or 2,250 million feet per atmosphere. Assuming this field could have been operated down to 50 lbs. pressure, or a further deduction of 287 lbs. or 20 atmospheres, it should have produced 45 000 million feet after 1900, instead of about 3,000 million. It has been shown already that in the Kent field a production of 4,610 million feet corresponded to a loss of 1 atmosphere in pressure. This will be as nearly as can be determined the purely domestic consumption assuming the order of the Ontario Railway and Municipal Board is carried out. It was shown above that the total output up to June, 1918, was about 86,000 million, and if the field can be operated down to 50 lbs. pressure (the Welland field is being operated below 50 lbs.) the same amount must be left as has been produced up to that time.

It would be a great calamity if the same thing happened in the Kent as in the Essex field, and in the public interest measures should be taken to avert the threatened destruction of the supply. The estimated consumption for the first half only of 1918 is 5,880 million cubic feet, the restriction as to industrial use not coming generally into force till 1st of July. The distribution of the consumption for 1917 was 9,400 million cubic feet for industrial users and 5,829 million for all other consumers. Under the order[6] of the Board referred to above there should ultimately be an estimated saving among the non-industrial consumers of 1,457 million cubic feet per year, making the actual domestic consumption 4,372 million feet, to which must be added an estimated industrial consumption for the special purposes mentioned in the order of about 300 million feet, or a total in all of 4,672 million cubic feet. In tabular form the consumption based on the results for 1917 is as shown below:—

	Million cubic feet.
Estimated total industrial consumption, 1917	9,400
All other consumers (non-industrial)	5,829
Total	15,229
Estimated industrial consumption, January-July, 1918	2,260
Estimated non-industrial consumption, January-July, 1918	3,620
Total consumption, 6 months	5,880

[1] Ont. Bur. of Mines Rep., Vol. X, p. 19.
[2] Ont. Bur. of Mines Rep., Vol. XI, p. 43.
[3] Ont. Bur. of Mines Rep., Vol. XII, p. 38.
[4] Ont. Bur. of Mines Rep., Vol. XIII, p. 22.
[5] Ont. Bur. of Mines Rep., Vol. XXV, p. 39.
[6] A later order of the Board (August 30, 1918) permits the use of natural gas until June 1, 1919, in hospitals, sanitariums, hotels, restaurants, offices, stores, schools, churches, halls and other public buildings, also libraries, clubs, and theatres, where the same was in use during the winter of 1917-18, subject to the condition that the consumption shall not exceed that for the corresponding period of last winter. Much of the estimated saving shown above will therefore for the coming season be eliminated.

This represents a saving over the same period last year of 2,440 million cubic feet. The estimated consumption when the Board's order is completely in operation is as follows:—

	Million cubic feet.
Estimated saving by abolition of flat rate	100
Estimated saving by limitation of free users, etc.	47
Estimated saving by cutting off public buildings, offices, etc	1,310
Total	1,457
Non-industrial consumption, 1917	5,829
Deduct estimated saving	1,457
Estimated domestic consumption	4,372
Add estimated industrial consumption for special purposes	300
Total	4,672

Natural Gas Statistics

The following table summarizes the statistical information collected for 1917, and for purposes of comparison figures for 1916 are given also. The mileage of pipe lines for the non-producing companies which distribute natural gas is included in the total mileage of pipe line. In 1916 this item was not so included:—

	1916.	1917.
Gas wells drilled in year:		
Productive	135	121
Non-productive	38	52
Producing wells at end of year	1,802	1,905
Miles of pipe line	2,233	2,925
Workmen employed	653	780
Wages for labour	$404,039	$537,946
Gas production:		
Quantity (M. cu. ft.)	17,953,396	20,025,699
Value	$2,404,499	$3,220,123

The following producers of natural gas reported an output for 1917:—

NATURAL GAS PRODUCERS, 1917.

Name of Person or Company.	Producing Wells, Dec. 31, 1917.	Township.	P.O. Address of Manager, etc.
Aikins, W. J.	1	Onondaga	Dunnville.
Aldrich Gas & Oil Co., Limited	10	Rainham	Hamilton.
Azoff Natural Gas Co., Limited	1	N. Cayuga	Canfield.
Barnard-Argue-Roth-Stearns Oil & Gas Co., Limited	1	E. Tilbury	401 Iroquois Building, Buffalo, N.Y.
*Beaver Oil & Gas Co., Limited	23	Romney & E. Tilbury.	Buffalo, N.Y.
Bertie Natural Gas Co., Limited	8	Bertie	Ridgeway.
Canadian Gas Co., Limited	43	Romney, Tilbury E...	1426 Dime Bank Bldg., Detroit, Mich.

NATURAL GAS PRODUCERS, 1917.—*Continued.*

Name of Person or Company.	Producing Wells, Dec. 31, 1917.	Township.	P.O. Address of Manager, etc.
Canadian Steel Foundries, Limited	8	Crowland	Thorold.
Canfield Natural Gas Co., Limited.	3	N. Cayuga	Canfield.
Chippawa Development Co., Ltd...	7	Willoughby	Chippawa.
Chippawa Oil and Gas Co., Limited	42	Caistor, Canboro and Cayuga	Tavistock.
Coleman, J. A.	4	Wainfleet	Wellandport.
Commonwealth Oil & Gas Co., Ltd.	2	Onondaga	240 King St. E., Hamilton.
Crystal Oil & Gas Co., Ltd.	1	Onondaga	Paris.
Danskin, D.	1	Brantford	Cainsville.
Darling Road Co-operative Gas Co.	6	Canboro, N. Cayuga	Canfield.
Deagle, John	1	Onondaga	Middleport.
Diener Gas & Mfg. Co., Ltd.	1	Canboro	Dunnville, R.R. No. 5.
Dominion Natural Gas Co., Ltd....	742	Lincoln, Wentworth, Elgin, Norfolk and Haldimand (counties)	842 Marine Bank Bldg., Buffalo, N.Y.
Douglas, W. A.	1	Onondaga	Caledonia.
Dunn Natural Gas Co., Limited ..	27	Dunn	Dunnville.
Duxbury, Wellington	1	Walpole	Hagersville.
Eastside Gas Co., Limited	7	Sherbrooke	Lowbanks.
Emerson, Troughton & Laidlaw ..	4	Canboro	Attercliffe Station.
Empire Limestone Co.	4	Humberstone	19 Hudson Street, Buffalo, N.Y.
Fairbank, Estate of, J. H.	1	Enniskillen	Petrolia.
Fletcher, J. I.	1	Binbrook	Hannon, R.R. No. 1.
Fisherville Gas Co., Nos. 1 & 3 ...	2	Rainham	Fisherville.
Gas & Oil Co. of Springvale, Ltd..	2	Walpole	Hagersville, R.R. No. 4.
Grand River Oil & Gas Co.	2	N. Cayuga	Cayuga.
*Glenwood Natural Gas Co., Ltd....	80	Raleigh, Romney and Tilbury E.	Buffalo, N.Y.
Hager, Ham	1	Onondaga	Middleport.
Hamilton Gas & Oil Co., Limited..	3	Seneca	Hamilton.
Hendee Natural Gas Co.	6	S. Cayuga	Cayuga.
Home Natural Gas Co.	4	Oneida	Hamilton.
Hoover, D. E.	1	Rainham	Selkirk.
Industrial Natural Gas Co., Ltd...	38	Bertie, Crowland and Humberstone	Thorold.
Jones, James S.	3	Dunn	Port Maitland.
Jones, Nelson	2	Canboro, Moulton	Attercliffe Station.
Kindy Gas Co., Limited	7	Rainham	South Cayuga.
Kindy & Sons, D.	7	Rainham	Selkirk.
Kittinger Gas Co., Limited	5	Moulton	118 E. Eagle St., Buffalo, N.Y.
Kohler, May & Hoover	12	Canboro	Selkirk.
Lake Erie Developing Syndicate ..	1	Raleigh	Chatham.
Lalor, F. R.	5	Moulton	Dunnville.
Lalor & Vokes	10	Walpole	Dunnville.
Lamb, Alfred	9	Walpole	Selkirk.
Liesinger-Lembke Co.	1	Humberstone	Buffalo, N.Y.

NATURAL GAS PRODUCERS, 1917.—*Continued.*

Name of Person or Company.	Producing Wells, Dec. 31, 1917.	Township.	P.O. Address of Manager, etc.
McKillop Sons, Ltd., Kohler, May & Hoover	4	Canboro	Selkirk.
Marshall Lime & Cement Works, Jas.	15	Glanford and Seneca.	Hamilton.
Martin, Edward	3	Dunn	Dunnville.
Medina Natural Gas Co., Limited	22	Bayham	Chatham.
Mickle, Geo. T., & McKechnie, S.	5	Canboro	Ridgetown.
Midfield Natural Gas Co., Limited.	7	N. Cayuga	32 Stinson St., Hamilton.
National Gas Co., Limited	72	Rainham, Seneca	119 Carrick Ave, Hamilton.
Niagara National Gas & Fuel Co., Ltd.	4	Humberstone	Fenwick.
North Shore Gas Co., Limited	14	Rainham	Merchants Bank Bldg., Hamilton.
Northwestern Gas Co., Limited	4	Brant (county)	13 Scott Block, Erie, Pa.
Oil Springs Oil & Gas Co., Ltd.	6	Enniskillen	Oil Springs.
Onondaga Oil & Gas Co., Ltd., The	6	Onondaga	Brantford.
Ontario Gypsum Co., Ltd., The	4	Seneca	Paris.
Pilkington Bros., Ltd.	5	Crowland	St. Catharines.
Port Colborne - Welland Natural Gas & Oil Co., Limited	25	Seneca, Oneida, Onondaga	Port Colborne.
Provincial Natural Gas & Fuel Co. of Ontario, Limited, The	13	Welland (county)	Niagara Falls.
Relief Gas Co., Limited	14	Gainsboro, Wainfleet.	117 Queenston Street, St. Catharines.
Richmond Gas & Oil Co., Ltd.	4	Bayham	Chatham.
Robinson Road Gas Co.	4	Canboro and Moulton	Dunnville, R.R. No. 4.
Sparham, A. F.	6	Glanford	Caledonia.
*Standard Natural Gas Co., Ltd.	45	Onondaga	Buffalo, N.Y.
Sterling Gas Co., Limited	66	Humberstone, Wainfleet, Moulton and Sherbrooke	Port Colborne.
Stevensville Gas & Fuel Co.	3	Bertie	Stevensville.
Sundy Gas Well Co.	3	Canboro	Dunnville.
Telephone City Oil & Gas Co., Ltd.	3	Onondaga	Brantford.
Union Natural Gas Co., of Ontario, Limited	124	Dover, Raleigh and Tilbury	Niagara Falls.
*United Gas Companies, Limited	53	Wainfleet, Moulton and Gainsboro	Buffalo, N.Y.
Vacuum Gas & Oil Co., Limited	2	Middleton	608 Lumsden Building, Toronto.
Vansickle, A. W.	2	Onondaga	Onondaga.
Wainfleet & Moulton Gas Co.	3	Middleton	Lowbanks, R.R. No. 1.
Welland County Lime Works Co., Limited	29	Wainfleet	Port Colborne.
Wedrick, M.	3	Walpole	Nanticoke.
Weylie & Benjamin	4	Glanford	Glanford Station, R.R. No. 2.

* Subsidiary company controlled by the Dominion Natural Gas Company, Limited, 842 Marine Bank Building, Buffalo, N.Y.

Following is a list of non-producing companies which pipe natural gas from the wells to points of consumption or who distribute it there:—

PIPE LINE COMPANIES OR DISTRIBUTORS ONLY OF NATURAL GAS.

Name of Company.	Miles of Pipe Line, Dec. 31, 1917.	Head Office.
*Brantford Gas Co., Limited	58.9	Buffalo, N.Y.
Central Pipe Line Co., Limited	60.0	Chatham.
Chatham Gas Co., Limited	30.0	Chatham.
Independent Natural Gas Co.	....	Dunnville.
*Ingersoll Gas Light Co., Limited	24.4	Buffalo, N.Y.
Lake Shore Natural Gas Co., Limited	7.1	294 Baynes St., Buffalo, N.Y.
*Manufacturers Natural Gas Co., Limited	5.6	Buffalo, N.Y.
Nelles Corners Gas Co.	....	Nelles Corners.
Northern Pipe Line Co., Limited	35.8	P.O. Box 66, Niagara Falls.
Petrolia Utilities Co., Ltd.	12.0	Petrolia.
Rosehill Natural Gas Co., Limited	2.5	15 City Hall, Buffalo, N.Y.
Sarnia Gas Co., Limited	29.0	Sarnia.
*Southern Ontario Gas Co., Limited	210.6	Buffalo, N.Y.
Tilbury Town Gas Co., Limited	12.5	P.O. Box 66, Niagara Falls.
United Gas & Fuel Co. of Hamilton, Limited	325.0	72 James St. N., Hamilton.
Wallaceburg Gas Company	....	Wallaceburg.
Wellandport Natural Gas Company	....	Wellandport.
Windsor Gas Co., Limited	71.5	33 Chatham St. W., Windsor.
*Woodstock Gas Light Co., Limited	44.1	Buffalo, N.Y.
Total	929.0	

* Company controlled by the Dominion Natural Gas Company, 842 Marine Bank Building, Buffalo, N.Y.

Gas and Oil Well Inspection

There are three oil and gas well inspectors appointed by the Provincial government to see that the regulations provided by the Legislature are observed in preventing the waste of natural gas and the proper plugging of abandoned wells. John Scott, of Petrolia, is inspector for the Lambton oil field; A. E. Near, Gas Line, for the Welland-Haldimand field, and J. W. Beno, Chatham, for Tilbury and surrounding territory. The effect of this inspection, and especially the operation of the tax on natural tax which is levied in full at two cents per thousand cubic feet when wasted, and only at one-tenth of this rate when consumed, has been to almost entirely eliminate the waste of this valuable fuel which was previously so common.

Extracts from the reports of the Inspectors follow.

A. E. Near states:—

Considerable drilling has been done during the year, especially by the two largest companies operating in this district, the Dominion Natural Gas Company, Limited, of Hamilton, and the Provincial Natural Gas and Fuel Company of Niagara Falls, Ont.

The Dominion Natural Gas Company drilled 67 wells, of which 47 were producing and 20 non-producing. They also purchased 7 wells and abandoned 44 exhausted ones, leaving them at the end of the year with 742 producing wells, from which they supplied gas to 38,812 customers.

The Provincial Natural Gas and Fuel Company drilled 13 wells in the Welland County field, of which only 4 were producing. They abandoned 13 exhausted wells, leaving them at the close of the year a total of 213 producing wells, from which they supplied their many customers in Niagara Falls, Welland, Bridgeburg, Fort Erie, Stevensville and Crystal Beach. On account of a general decline of gas this company on November 1 last ordered their customers to discontinue using gas for all furnaces and large heaters, in order to ensure an adequate supply for cooking purposes and light heating only.

In the Onondaga gas field, the Dominion Gas Company are operating 15 wells which produce oil as well as gas, and during the past year 450 barrels of oil were secured from these wells by means of pumps.

The Provincial Natural Gas and Fuel Company recently completed a gas well on the farm of A. E. O. Page in the township of Bertie at Point Albino, and secured an open flow of 500,000 cubic feet. This gas was obtained at a depth of about 3,300 feet, in the Trenton limestone.

The Sterling Gas Company of Port Colborne in November last completed two gas wells with an open flow of one million cubic feet. These wells are located in the township of Sherbrooke, in the county of Haldimand, at Lapp's Point on the Lake Erie shore a short distance east of Gull Island. This additional supply of gas is greatly appreciated by the citizens of Port Colborne and Humberstone, where the shortage of gas was experienced in the winter of 1916.

From information secured I can readily say there is without doubt a general decline of gas in pressure as well as in volume throughout this whole district.

Mr. Beno reports the following developments in the gas fields in the counties of Essex and Kent:—

In the Tilbury East, Romney and Raleigh area, the Glenwood Natural Gas Company, Limited, St. Thomas, drilled in 9 wells and 5 dry holes; the Union Natural Gas Company, Chatham, drilled 7 wells and 2 dry holes; the Canadian Natural Gas Company, Limited, Detroit, drilled 5 wells and laid 7 miles of 3-inch gas mains; the Beaver Oil and Gas Company, Limited, St. Thomas, drilled 2 wells, and the Dunegan Gas Company, Chatham, drilled 1 gas well.

In Dover West, the Union Natural Gas Company, Limited, drilled in gas well No. 1 on lot 3 in the third concession to a depth of 3,183 feet. This well came in with a rock pressure of 1,235 lbs., and a flow of 3,000,000 cubic feet of gas per day. It has since developed into a gas and oil well combined. The same company drilled four dry holes in the neighbourhood on the following lots and to the depths given: Dover township, lot 1, concession three, 3,765 feet; lot 4, concession three, 3,304 feet; lot 4, concession five, 3,265 feet; and lot 5, concession one, Tilbury East, 3,735 feet.

The Central Development Company struck a light gas flow at 1,421 feet on lot 16, concession fifteen, Raleigh township, and dry holes on lot 136 T.R.W., Raleigh, and lot 6, concession two Tilbury East, at a depth of 2,100 and 3,504 feet respectively. The Beaver Oil and Gas Company put down a dry hole 2,975 feet deep on lot 36 in the front concession of Gosfield South.

Altogether, in this field the following changes from the position in 1916 are reported: 2 oil wells, 24 gas wells and 13 dry holes drilled, also 15 miles of gas line laid down. The dry holes, in addition to 7 sunk in the Dover area, were on the following lots: Raleigh township, lot 1, concession thirteen; lot 19, M.R.N.; lot 5, concession thirteen; Tilbury East, lot 185, concession two, R.W.; Raleigh, lot 186, concession two, R.W.; lot 136, concession two, R.W.; Mersea, lot 2, concession six. Eight oil wells, 8 gas wells and 14 dry holes were abandoned, all of which were properly plugged according to the law.

The total number of gas wells being operated in this field is 280; oil wells, 34. The united length of all the gas mains, of size varying from 3 to 12 inches in diameter, is estimated at 517 miles.

Mr. Beno states that the gas supply has diminished from 50 to 60 per cent. during the last two years, by reason of the heavy draught on the wells, and opines that if this draught continues the field will soon be exhausted.

In the Lambton oil field there is a little gas, mainly at Oil Springs. There is also one well in the township of Euphemia. These have been in operation for some three years. There are no wells producing both oil and gas commercially, though a few oil wells yield gas enough to pump them.

Petroleum

Crude petroleum in 1917 exceeded the 1916 output by 214,019 Imperial gallons, the production being 7,104,700 gallons, as against 6,890,681 gallons. In price there was a series of advances which brought the value per barrel from $1.98 on January 1 to $2.48 on December 31, the average for the year being $2.34 per barrel. A small decline in the older fields was more than offset by the output of the new field in the Township of Mosa, Middlesex county, which produced 20,998 barrels during the year. This new pool is the most promising one located in recent years, and in the month of October yielded 6,889 barrels, or nearly as much as the best month's output from the Petrolea and Enniskillen field, at present the largest source of oil in Ontario. The oil in Mosa is found at a depth of 390 to 450 feet in the Corniferous limestone, which is also the oil-bearing formation of the older fields. The first strike was made by F. J. Carman on or about February 1, 1917. Up to the end of February, 1918, about 40 producing wells had been drilled, and 13 dry holes. A number of other wells were in process of being drilled. The pool as then located was on lots 5 to 8 in the fifth, sixth, and seventh concessions of the township. In quality the oil is good, the gravity being 33°. Facilities for handling and marketing the oil are satisfactory, tank cars conveying it from the field to the pipe line at Glencoe.

Drilling operations at Rockwood, in the county of Wellington, were not successful in obtaining oil. At Flesherton, Grey county, shows of oil have been found, but no reservoir has been located.

Oil was reported to have been found on the west bank of the Wanapitei river on lots 9 and 10, in the sixth concession of the township of Street, near the crossing of the Canadian Northern railway, and considerable local interest was aroused in the spring and early summer of 1918. An examination was made on behalf of the Bureau by E. S. Estlin, who found the presence of oil to be shown by a fine brilliant film which floated on the water when a shovelful of gravel taken from the bank was thrown into the river. Nearby were the remains of an old lumbering camp abandoned about 20 years ago, and upon clearing away the growth immediately above the gravel bank on the river side traces of a small building were found, the floor area being covered with chips and shavings saturated with what appeared to be ordinary coal oil. This was no doubt the site of the oil-house once connected with the lumber camp and also the source of the oil which showed in the gravel below. A little of the oil was with some pains procured from the floating films, and proved on examination to be coal oil or kerosene.

A comparison of the deliveries of oil from the several producing areas, for the years 1916 and 1917 is as follows, the figures being given in barrels of 35 Imp. gals.:—

PETROLEUM PRODUCTION BY FIELDS.

Field.	1916	1917	Gain	Loss
Lambton	142,208	132,524	.....	9,684
Bothwell	33,856	29,682	.....	4,174
Dutton	2,851	2,941	90	.....
Tilbury	16,296	10,041	.....	6,255
Onondaga	1,617	383	.....	1,234
Belle River	46	.....	.....	46
Mosa	.....	20,998	20,998	.....
Thamesville	.....	6,420	6,420	.....
Total	196,874	202,989	27,508	21,393

Inspector Scott furnishes the following list showing particulars of the oil wells of Lambton county and vicinity.

OIL WELLS, 1917

Municipality.	Pumped.	Baled.	Not operated.	Abandoned.	Total.
Sarnia township	174	.....	42	60	276
Plympton "	30	.....	42	21	93
Moore "	155	.....	61	55	271
Enniskillen "	2,477	437	896	121	3,931
Oil Springs	1,012	.....	63	27	1,002
Bothwell	278	.....	.....	7	285
Thamesville	15	.....	29	6	50
Dawn township	.....	.....	63	28	91
Euphemia township	56	.....	.....	22	78
Brooke township	10	.....	.....	2	12
Dutton	192	.....	15	.....	207
Mosa township	35	.....	.....	12	47
Indian Reservation	.....	.....	11	.....	11
Total	4,434	437	1,222	361	6,454

In Essex and Kent counties Inspector Beno reports that two new oil wells were sunk and eight wells abandoned during the year, the total number in operation being 34. This is a reduction of 17 from 1916, when 51 were being worked. The finding of oil in considerable quantity in the well bored for gas on lot 3, in the third concession of Dover West, is significant because of the fact that the oil was obtained in the Trenton limestone and at the great depth of 3,183 feet. The Corniferous formation has heretofore been the source of all Ontario petroleum, but the well in Dover West, notwithstanding the failure of other holes in the vicinity to reproduce its record, affords ground for the hope that deep exploitation of the Trenton, in the southwestern part of the Province, may prove that formation here to be an important reservoir of oil, such as it has proved to be in the northwestern part of the State of Ohio.

Salt

There was again an increase both in the quantity and value of the salt production, the output for 1917 being 138,909 tons, as compared with 128,935 tons in 1916, and the value $1,047,707 as compared with $700,515. The value of the packages is not included. The product was classified as follows:—Coarse, 46,537 tons; fine, 56,028 tons; table and dairy, 34,251 tons; land, 2,093 tons. Included in coarse salt is 14,301 tons, being the equivalent of the brine used by the Canadian Salt Company, Limited, in its chemical plant at Sandwich in the manufacture of caustic soda and bleaching powder. The number of workmen employed in the salt industry was 312, and the wages paid them were $234,925.

There is no salt mined in Ontario, the practice being to pump up the brine, which is then evaporated. Hence all the rock salt sold here for the use of cattle, etc., is imported.

Brunner, Mond Canada, Limited, are erecting a plant at Amherstburg for the manufacture of alkalies. The limestone required will be obtained from the company's quarries about three-quarters of a mile east of the plant, and the brine from its wells on lot 29, in the first concession of Anderdon township, three miles away. It is the company's intention to begin the production of soda ash at the rate of about 100 tons daily, and also at a later date to consider the manufacture of bicarbonates, caustics and chlorides. The works will not be turning out any product until the autumn of 1918.

The list of companies producing salt in 1917 is as follows:—

SALT COMPANIES, 1917.

Name of Owner, Firm or Company.	Location of Wells or Works.	P.O. Address of Manager, etc.
Canadian Salt Company, Limited	Windsor, Sandwich	Windsor.
Dominion Salt Company, Limited	Sarnia	Sarnia.
Elarton Salt Works Company, Limited	South of Egremont Road, Warwick tp.	Hyde Park.
Exeter Salt Works Company, Limited	Exeter	Exeter.
North American Chemical Co., Ltd.	Goderich, Clinton	Clinton.
Ontario People's Salt and Soda Co., Limited	Kincardine	Kincardine.
Western Canada Flour Mills Company, Limited	Goderich	Goderich.
Western Salt Company, Limited	Mooretown and Courtright	Courtright,
Wingham Salt Works (Alex. Young Estate)	Wingham	Wingham.

Talc

The production of talc continues to increase. In 1915 the shipments were 1,720 tons of crude and 9,285 tons of ground talc; in 1916, 3,665 tons crude and 8,145 tons ground; in 1917, 2,398 tons crude and 13,678 tons ground. The valuation of shipments, including both kinds, in 1915 was $85,325, in 1916 $111,489, and in 1917 $179,554. The talc deposits are situated near Madoc, in the county of Hastings, and the two mills for the grinding and preparation of the mineral are in that town. The latter are operated by Geo. H. Gillespie and Company,

Limited, and Anglo-American Talc Corporation respectively. Both the crude and ground product are for the greater part exported to the United States.

There were 56 employees engaged in the mining and milling of talc, who received in wages $49,734.

The uses of talc are numerous and important. The properties which are availed of in manufacturing processes are its foliated or fibrous structure, its softness, light colour, lustre, flexibility, unctuous feel, low conductivity and high absorption of heat and electricity. The most important employment of talc is in the manufacture of paper, especially in those varieties used for book and writing purposes. As a filler it not only adds to the weight of the paper, but it imparts whiteness to the colour and renders it opaque, absorptive and capable of taking on a high polish, thus fitting it for lithographing and illustrations. For paper-making, talc is to some extent displacing china clay. It is also used in the manufacture of rubber goods, in sizing and bleaching cotton cloth, in insulator coverings, in soap-making, as a dusting lubricant for shoes and gloves, in cosmetics and toilet preparations, paints, foundry facings, for dressing skins and leather, as a binder in gypsum wall plasters, and in the compact varieties for pencils, "tailors' chalk," and gas tips.

The firms engaged in the talc business were as follows:—

TALC OPERATORS, 1917.

Firm or Company.	Location of Mine or Works.	Address of Manager, etc.
Anglo-American Talc Corporation, Ltd..	Madoc	Madoc.
Cross and Wellington	Huntingdon tp.	Madoc.
*Eldorite, Limited	Eldorado	Eldorado.
Geo. H. Gillespie and Company, Ltd. .	Madoc (grinding mill)	Madoc.

* Idle in 1917.

Mining Divisions

The administration of the mining lands of the Province is primarily in the hands of the Recorders for the Mining Divisions in which are comprised the various mineral areas. When a prospector stakes out a claim, he must file his application with the Recorder for the Mining Division in which the land is situated. The Recorder is clothed by the Mining Act with power to settle disputes between the holders of mining claims, and there is a right of appeal from his decision to the Mining Commissioner, and in cases of importance from the latter to the courts of law. There are fifteen mining divisions in the Province, three of which, namely, Timagami Forest Reserve (part), Fort Frances and Eastern Ontario are administered by the Deputy Minister of Mines at the Department in Toronto. Of the others, Coleman Special Mining Division is in charge of the Mining Recorder for the Timiskaming Division at Haileybury, Gowganda under that of the Recorder for Montreal River Division at Elk Lake, and Kowkash under that of the Recorder for Port Arthur Division at Port Arthur.

Following is a statement which shows the collections on account of mining revenue by the several Mining Recorders during the fiscal year ending October 31, 1917:—

RECEIPTS OF MINING DIVISIONS, 1917.

Mining Division.	Name and Address of Recorder	Receipts, 1916–17.				
		Purchase Price.	Permits.	Miner's Licenses.	Recording Fees.	Total.
		$ c.	$ c.	$ c.	$ c.	$ c.
Kenora	W. L. Spry, Kenora	606 40	.....	456 00	539 75	1,602 15
Port Arthur	J. W. Morgan, Port Arthur.	3,899 07	.....	2,464 00	2,899 60	9,262 67
Sault Ste. Marie	W. N. Miller, S.S. Marie...	8,306 10	.....	837 00	1,194 50	10,337 60
Sudbury	C. A. Campbell, Sudbury...	8,937 71	130 00	2,132 00	4,670 45	15,870 16
Timiskaming ... Coleman Special.	N. J McAulay, Haileybury } " " }	4,137 84	50 00	5,314 00	3,651 75	13,153 59
Larder Lake	J. A. Hough, Matheson.....	23,664 90	.....	2,120 00	8,420 75	34,205 65
Gowganda ..... Montreal River...	A. J. Browning, Elk Lake } " " }	4,967 80	410 00	922 00	4,554 00	10,853 80
Porcupine	G. H. Gauthier, S. Porcupine	5,205 12	60 00	2,040 15	4,137 10	11,442 37
Parry Sound	H. F. McQuire, Parry Sound	.....	.....	225 00	303 00	528 00
Kowkash	M. R. Morgan, Tashota	.....	120 00	842 00	2,322 50	3,284 50
	Total	59,724 94	770 00	17,352 15	32,693 40	110,540 49

Mr. A. J. Browning died of pneumonia after a week's illness, April 30, 1918, and was succeeded by Mr. H. E. Sheppard, formerly Mining Recorder for Gowganda and Montreal River Divisions, who had returned from overseas service in France and received his discharge. The head office of the Kowkash Division was removed to Port Arthur by Order-in-Council, dated January 28, 1918, and was placed under the charge of Mr. J. W. Morgan, the Recorder for Port Arthur Division. The almost entire cessation of business in Kowkash Division made this step expedient.

Reports from Mining Recorders

In reporting to the Bureau upon the business of the year, the Mining Recorders occasionally remark upon matters of current interest in their several Divisions. Extracts from these reports are appended herewith:—

Kenora.—Claims recorded, 32; cancelled, 16. Mining activity has been less than usual. At the Rognon mines new camps have been built to accommodate more men, and it is the intention to move 600 tons of ore to the mill at the Redeemer mine in Van Horne township for treatment. Southwest of English and near Keewatin lake, the Nicuso syndicate of Ottawa have spent a large amount of money in development work, a diamond drill being in use most of the summer on a deposit of iron pyrites. Just east of Quibell, on the National Transcontinental railway, in the unsurveyed township of Buller, another large deposit of pyrite has been found and several claims recorded. At Northpines the Nichols Chemical Company are doing a big business and employ a large number of men.

Port Arthur.—Claims recorded, 180; cancelled, 59. No new discoveries of much importance have been made in this Division during the year 1917. So many prospectors have joined the army for service in France that little prospecting can be expected until the end of the war.

Sault Ste. Marie.—Claims recorded, 135; cancelled 9. The whole mining division from Michipicoten to Bruce Mines, and as far north as the township of Hayward, has been unusually active. The gold claims near Wawa lake, Michipicoten, which have been lying dormant for many years, are likely to be re-opened and worked by a strong Pittsburg company. In township 49, on the Algoma Central railway, Dan McCarthy, while prospecting for iron pyrites in October, 1917, found a vein of quartz with a spectacular showing of free gold. He and his party staked eight claims, having found free gold on five of them. Other discoveries of free gold have since been made, and claims staked. J. P. Cline, of South Porcupine, made a good discovery of free gold at Pine lake, on the eastern boundary of township 49. The gold occurs in schist between large bodies of pyrite, claims for which have also been staked on the boundary line between townships 49 and 27. Mr. Harry Dreany has had a diamond drill operating on his iron claims, and has located a large body of ore. Gold was discovered in the township of Hayward.

Sudbury.—Claims recorded, 262; cancelled 62.

Timiskaming: Coleman Special.—Claims recorded, 269; cancelled, 75. There was little prospecting in these divisions, except in Rickard township, where a discovery of gold was made by one John Raty, and three claims taken up which were optioned to the Mining Corporation of Canada and are now being developed. Several discoveries were reported from the township of Eby and a number of claims recorded. Very little development work was done, except where necessary to hold new claims, largely because of the general extension of time given on old claims by the Order-in-Council of May 26, 1917. This extension, however, was of material benefit to a number of prospectors. Fewer miner's licenses were issued owing to the number of prospectors who have enlisted and are serving their country overseas.

Larder Lake.—Claims recorded 160. Receipts show an increase over 1916 of nearly $3,000. This division is steadily growing in importance, and during the year 1918 should add to the list several new producing gold mines. Much development work was done, principally at Kirkland Lake, Boston Creek, Skead, Larder Lake and Munro. Several discoveries were made; one of which, near Bourke's, in the township of Benoit, appears to be of exceptional merit. Another, assaying well in gold content, was made in August in the unsurveyed territory south of Lake Abitibi, on the Lightning river. Many of the best prospectors of this division lie buried in France and Flanders.

Gowganda.—Claims recorded, 113; cancelled, 80. The chief staking was around the O'Brien mine, in Nicol and Haultain, and around Reeve-Dobie, in Milner. The following properties have been worked: O'Brien mine, Castle, Welsh claims, T.C. 177, Collins on Leroy lake, Mining Corporation of Canada on Hylands claims, all in Nicol Township; Crews-McFarlan, Reeve-Dobie, Silverado, in Milner.

Montreal River.—Claims recorded, 294; cancelled, 147. A considerable amount of prospecting was done, and the receipts were two and a half times as much as in 1916. This was due chiefly to the staking in Powell, Cairo, and Yarrow townships, owing to the discovery of gold on the McKay-Davidson and

Otisse claims. A road has been cut from a point on the Montreal river above Indian Chutes so as to enable machinery to be placed on the properties. Mining was done in Auld township on Kenabeek mines, in Cane on Quesnell claims, in Mickle at the Brant mines (old Mapes-Johnston), and at White Reserve in Maple Mountain area, also some work at McKenzie lake in Speight. Lieut. Skill, long Recorder of this division, was killed in action somewhere in France in 1917.

Porcupine.—Claims recorded, 236; cancelled, 160. There was a considerable falling off in receipts, directly attributable to the extensions granted for assessment work to men serving overseas, and to other claim-holders on account of war conditions. There have been no new finds afield. Prospecting and staking were confined to claims as they became open in the older portions of the camp. The numerous extensions of time have kept most of the claims in good standing and put an end to activity for the time being. The showing maintained by the producing mines in 1917, in spite of the shortage of labour and largely increased cost of production due to war conditions, was most gratifying.

Parry Sound.—Claims recorded, 25. Some mica claims in McConkey township were sold to Detroit parties who are preparing to work them during the summer of 1918. Some feldspar claims have changed hands, also the Parry Sound Copper Mining Company's holdings near Parry Sound, where the new owner did some diamond drilling.

Kowkash.—Claims recorded, 135; cancelled, 69. During the first nine months business was good, but winter set in about October 1 and all mining and prospecting came to an end, the Wells property having been closed down.

Mining Companies

Mining companies incorporated under the laws of Ontario numbered 100 in 1917, with an authorized capitalization of $117,183,000, as against 83, with a nominal capital of $109,075,500, in 1916. There were seven companies of foreign incorporation licensed to do business in the Province, and to employ capital amounting in the aggregate to $7,202,000.

The lists follow:—

MINING COMPANIES INCORPORATED IN 1917.

Name of Company.	Head Office.	Date of Incorporation.	Capital.
Algoma Exploration & Development Co., Ltd...	Sault Ste. Marie	Aug. 29.....	$40,000
Alloy Steel Works, Limited	Toronto	Oct. 15.....	2,000,000
Anglo-Kirkland Gold Mines, Limited	Haileybury	Mar. 17.....	500,000
Asquith Gold Mining Company, Limited	Toronto	Oct. 9.....	2,000,000
Atlas Gas & Oil Company, Limited	Toronto	April 3.....	300,000
Baldwin Gold Mining Company, Limited	Toronto	Feb. 13.....	2,500,000
Bellinger-Porcupine Mines, Limited	Toronto	Mar. 2.....	2,000,000
Big Duck Lake Mining Company, Limited	Ottawa	July 14.....	30,000
Bolton Mining Company, Limited	Windsor	Jan. 4.....	500,000
Bourkes Mines, Limited	Toronto	July 21.....	2,500,000
Brant Mines, Limited	Brantford	Sept. 1.....	1,500,000
Buffalo Kirkland Mines, Limited	Toronto	Mar. 21.....	1,500,000

MINING COMPANIES INCORPORATED IN 1917.—*Continued.*

Name of Company.	Head Office.	Date of Incorporation	Capital.
Bungalow Brick Company, Limited	Toronto	April 3	40,000
Canadian Oil Fields, Limited	Brantford	Jan. 9	500,000
Cane Silver Mines, Limited	Toronto	Oct. 12	1,500,000
Castle Mining Company, Limited	Toronto	Sept. 7	1,500,000
Chaput-Hughes Gold Mines, Limited	Toronto	April 11	2,000,000
Colossus Gold Mines, Limited	Toronto	Jan. 19	2,000,000
Continental Development Company, Limited	Toronto	Feb. 12	250,000
Consolidated Metals Corporation, Limited	Toronto	Oct. 17	3,000,000
Crœsus Lake Gold Mines, Limited	Toronto	Aug. 1	1,000,000
Crystal Products, Limited	Toronto	Sept. 26	300,000
Delta Chemical Company, Limited	Toronto	Aug. 15	40,000
Dominion Kirkland Gold Mines, Limited	Toronto	Oct. 6	2,000,000
Dominion Mica Mining Company, Limited	Toronto	April 2	50,000
Dominion Molybdenites, Limited	Toronto	May 2	1,000,000
Eastern Mining and Milling Company, Limited	Toronto	Sept. 1	500,000
East Kirk Mining Company, Limited	Toronto	Jan. 20	2,500,000
Feldspar Milling Company, Limited	Toronto	May 3	50,000
Feldspar Quarries, Limited	Toronto	Feb. 15	40,000
Fidelity Mining & Development Co., Limited	Haileybury	May 14	2,000,000
Fisher Gold Mining and Milling Co., Limited	Toronto	June 5	2,500,000
Flesherton Oil Fields, Limited	Windsor	Aug. 27	500,000
Galt Building Products, Limited	Galt	May 7	40,000
Gold Banner Mines, Limited	Toronto	Sept. 21	2,000,000
Graham Development & Contracting Co., Ltd.	Fort William	July 23	100,000
Howrey Creek Mining Corporation, Limited	Toronto	Dec. 7	1,000,000
Kent County Oil, Gas and Coal Co., Limited	Windsor	Dec. 19	40,000
Kerr Lake Mines, Limited	Cobalt	Oct. 13	3,000,000
Kirkland Combined Mines, Limited	Toronto	May 28	2,000,000
Kirkland-Porphyry Gold Mines, Limited	Haileybury	Aug. 3	3,000,000
Kirkland-Townsite Gold Mines, Limited	Haileybury	Mar. 15	2,000,000
Lucky Cross Bondholders, Limited	Toronto	Sept. 14	100,000
McConnell Consolidated Mines, Limited	Toronto	April 16	1,000,000
McEnaney Gold Mines, Limited	Toronto	June 30	3,000,000
McGinley-Teck Gold Mines, Limited	Haileybury	April 27	2,000,000
Macassa Gold Mines, Limited	Toronto	Feb. 10	2,000,000
Mineral Products, Limited	Madoc	Feb. 2	100,000
Nickel Lake Mining Company, Limited	Fort Frances	Dec. 10	1,000,000
Nipissing Mines Company, Limited	Toronto	June 28	6,000,000
North Davidson Mines, Limited	Toronto	Mar. 30	2,000,000
Ontario-Kirkland Gold Mines, Limited	Haileybury	Sept. 18	1,500,000
Ontario Molybdenum Company, Limited	Toronto	April 17	40,000
Oxford Lime Products, Limited	Woodstock	April 13	40,000
Paragon-Hitchcock Mines, Limited	Collingwood	May 22	2,000,000
Paudash Lake Molybdenite Mines, Limited	Wilberforce	Nov. 13	150,000
Penn Porcupine Mining Co., Limited	Toronto	Feb. 2	3,000,000
Pontiac Molybdenite Company, Limited	Toronto	May 12	500,000
Porcupine Whelpdale Mines, Limited	Toronto	Sept. 13	2,500,000
Rand Consolidated Mines, Limited	Toronto	July 12	5,000,000
R.A.P. Gold Mining Co., of Boston Creek, Ltd.	Toronto	Jan. 29	2,500,000
Reeve-Dobie Mines, Limited	Toronto	May 4	2,000,000
Rockwood Oil and Gas Company, Limited	Toronto	Oct. 9	1,000,000
Rominco Mines Company, Limited	Toronto	Mar. 12	10,000
Rypan Porcupine Mines, Limited	Toronto	Jan. 23	2,000,000
St. Luke's Oil and Gas Company, Limited	Toronto	July 24	2,000,000
Sarvice, Limited	Chatham	July 9	48,000
Sesekinika Lake Gold Mines, Limited	Toronto	Jan. 18	2,000,000
Standard Gravel Company, Limited	Niagara Falls	Feb. 24	40,000
T.C. 177 Mining Company, Limited	Gowganda	Mar. 10	40,000
Thackeray Mines, Limited	Toronto	April 19	2,000,000
The Battle Natural Gas Company, Limited	Hamilton	Oct. 11	100,000
The Cascade Lead-Silver Mines, Limited	Toronto	May 9	1,000,000
The Duck Lake Mining Company, Limited	Fort William	Dec. 26	250,000

MINING COMPANIES INCORPORATED IN 1917.—*Continued.*

Name of Company.	Head Office.	Date of Incorporation	Capital.
The Glenn-Clayton Mining Company, Limited..	Toronto	Mar. 2.....	1,000,000
The Goldore Mining Corporation Limited	Toronto	Feb. 17.....	40,000
The Great West Chemical Corporation, Limited	Port Arthur	Oct. 31.....	1,500,000
The Hennepin Mining Company, Limited	Port Arthur	Feb. 20.....	40,000
The Hope Exploration Co. of Canada, Limited	Niagara Falls ..	Feb. 6.....	100,000
The Indian Trail Mines, Limited	Toronto	Nov. 15.....	1,000,000
The London Smelting and Refining Co., Ltd...	London	Mar. 14.....	45,000
The Maple Leaf Exploration Company, Limited	Toronto	Sept. 22.....	40,000
The Merlin Oil and Gas Company, Limited	Merlin	April 26.....	40,000
The Mining Investors' Corporation, Limited ..	Toronto	Sept. 19.....	40,000
The National Potash Corporation, Limited	Toronto	April 30.....	1,500,000
The Progressive Gas and Oil Co., Limited	Hamilton	Aug. 18.....	1,000,000
The St. Clair Oil and Gas Corporation, Limited	Toronto	Jan. 30.....	3,000,000
The Shining Tree Mining and Milling Co., Ltd.	Sudbury	April 13.....	500,000
The Tilbury Brick and Tile Company, Limited	Tilbury	Feb. 15.....	40,000
The Tory Hill Marble and Mica Co., Limited..	Toronto	Mar. 21.....	100,000
The Velvet Mining Company, Limited	Windsor	Mar. 12.....	40,000
The Walkerville Brick and Tile Co., Ltd.	Walkerville	Oct. 31.....	40,000
Trenton Gas & Oil Company, Limited	Toronto	Aug. 9.....	40,000
Union Cement, Limited	Owen Sound ...	May 4.....	1,000,000
United Kirkland Gold Mines, Limited	Haileybury	May 10.....	2,000,000
Vandorf Brick Works, Limited	Toronto	Oct. 5.....	40,000
Warco Oil and Gas Company, Limited	Brantford	Sept. 6.....	300,000
Wasapika Gold Mines, Limited	Toronto	June 7.....	1,000,000
Wisconsin-Skead Mines, Limited	Haileybury	Aug. 27.....	2,000,000
Wright-Porcupine Mines, Limited	Haileybury	Jan. 30.....	2,000,000
		Total.....	$117,183,000

MINING COMPANIES LICENSED IN 1917.

Name of Company.	Head Office for Ontario.	Date of License.	Capital for use in Ontario.
Electric Steel & Engineering, Limited	Welland	July 18.....	$2,000,000
McLaurin Mining Company	Port Arthur	Feb. 8.....	50,000
National Abrasive Company	Toronto	May 18.....	60,000
Ontario Petroleum Co.	Bothwell	Nov. 20.....	40,000
Ontario Western Mining Company, Limited ...	Cobalt	June 7.....	12,000
The International Nickel Co. of Canada, Ltd..	Toronto	Jan. 6.....	5,000,000
The Solvay Process Company	Toronto	Mar. 31.....	40,000
		Total	$7,202,000

Mining Revenue

Sources of Government revenue are the following: Sales and leases of mining lands, miners' licenses, recording and other fees under the Mining Act, royalties on sand and gravel, and taxes levied under the Mining Tax Act, namely, on mining profits, mining lands, and natural gas. Of these the tax on profits is the most considerable. The Act puts a tax of 3 per cent. on the net profits of mining companies up to $1,000,000, and a graded rate beginning at 5 per cent. on profits in excess of this amount, the first $10,000 of profits being exempt. An exception is made of nickel-copper mining concerns, whose rate is graded from 5 per cent. upward, and is computed on the selling price of the refined products less the cost of production.

The revenue for the fiscal year ending October 31, 1917, was as follows:—

Sales of mining land	$57,054 50
Mining leases	16,845 01
Miner's licenses, recording fees, etc.	62 256 41
Sand and gravel royalties	28,372 93
Mining Tax Act	1,557,543 37
Provincial Assay Office	726 52
Miscellaneous	31 50
Total	$1,722,830 24

Sales and Rentals.—Mining lands are sold at $2.50 per acre in the unsurveyed territory, where the purchaser is obliged to procure a survey at his own expense, or $3.00 per acre in the surveyed lands which have been laid out by the Government. In Forest Reserves, mining lands are disposed of only by lease for a period of ten years, renewable at option of the lessee. The following table of mining lands sold and leased gives the particulars for the fiscal year. The receipts do not quite agree with those given in the above summary, since the latter comprises all sums received, while in the table is included only sales and leases actually completed within the year.

MINING LANDS SOLD AND LEASED, 1917.

District.	Sales.			Leases.			Total.		
	No.	Acres.	Amount.	No.	Acres.	Amount.	No.	Acres.	Amount.
			$ c.			$ c.			$ c.
Timiskaming	359	12,496.52	33,382 39	93	3,292.75	3,052 90	452	15,789.27	36,435 29
Thunder Bay	37	1,398.97	3,258 69	3	120.00	120 00	40	1,518.97	3,378 69
Algoma	47	2,796.44	7,031 16	....	.....	.....	47	2,796.44	7,031 16
Sudbury	57	2,251.62	6,732 28	43	1,549.54	1,549 54	100	3,801.16	8,281 82
Nipissing	5	263.42	602 75	....	.....	.....	5	263.42	602 75
Kenora	7	260.30	590 75	....	.....	.....	7	260.30	590 75
Elsewhere	14	687.04	1,387 62	....	.....	.....	14	687.04	1,387 62
Total	526	20,154.31	52,985 64	139	4,962.29	4,722 44	665	25,116.60	57,708 08

Miner's Licenses, Recording Fees, etc.—For a miner's license entitling the holder to stake out mining claims on Crown lands a fee of $5 is fixed by the Mining Act. A license is good until March 31 next after the date of issue, and may be renewed on or before April 1 at a like cost. A license issued after October 1 costs $3 only. A permit to prospect for minerals in a Forest Reserve costs $10, and is good for twelve months. The fee for recording a mining claim is $10.

Sand and Gravel Royalties.—As already stated, licenses may be issued for the removal of sand and gravel from Crown lands on payment of a royalty charge varying from three to twelve cents per cubic yard. These lands are for the most part those covered by the waters of the great lakes or boundary rivers.

Mining Tax Act.—Revenue is derived from three sources, the receipts for the fiscal year being as follows:—

Acreage tax	$14,347 99
Profit tax	1,503,967 62
Natural gas tax	39,227 76
Total	$1,557,543 37

In 1916 the receipts were $186,827.12.

By amendment to the Mining Tax Act passed at the session of 1917, the tax on mining lands was increased from two to five cents per acre, and it was made applicable to mining land wherever situated, instead of to areas only without county organization, as formerly. The higher rate may be expected to produce a somewhat larger revenue.

An explanation has already been given of the changes made in the Mining Tax Act, so far as the profit tax is concerned. Following is a statement, classified according to products, of the mining companies who paid the profit tax and the respective amounts paid during the last fiscal year:—

Gold:		
Porcupine Crown Mines, Limited	$3,771 50	
The Dome Mines Company, Limited	7,597 46	
McIntyre-Porcupine Mines, Limited	4,195 54	
		$15,564 50
Silver:		
The Mining Corporation of Canada, Limited	$10,494 55	
Seneca-Superior Silver Mines, Limited	6,640 20	
Nipissing Mining Company, Limited	40,358 44	
Cobalt Comet Mines, Limited	288 45	
Kerr Lake Mining Company, Limited	14,393 25	
Crown Reserve Mining Company, Limited	184 74	
McKinley-Darragh-Savage Mines of Cobalt, Limited	3,883 95	
Penn-Canadian Mines, Limited	207 50	
La Rose Mines, Limited	3,328 56	
Timiskaming Mining Company, Limited	2,766 46	
The Coniagas Mines, Limited	9,811 27	
M. J. O'Brien	5,682 09	
Casey Cobalt Silver Mining Company, Limited	1,134 28	
		99,173 74
Pyrite:		
Northern Pyrites Company	$715 60	
The Nichols Chemical Company, Limited	498 57	
		1,214 17
Nickel-Copper:		
Alexo Mining Company, Limited	$468 87	
The Mond Nickel Company, Limited	20,000 00	
The Canadian Copper Company, 1916	530,110 00	
The Canadian Copper Company, 1917	836,782 00	
		1,387,360 87
Miscellaneous:		
Algoma Steel Corporation (Iron)	$135 48	
Cross and Wellington (Talc)	5 72	
Black Donald Graphite Company, Limited (Graphite)	513 14	
		654 34
Total		$1,503,967 62

It should be added that the taxes under the Mining Tax Act are payable on or before October 1. Occasionally there is some delay in adjusting or remitting the amount, and payment may not be actually made until after the close of the financial year, which ends with October. This will account for the absence of one or two mining companies from the above list, which includes only those who paid within the fiscal year.

Operation of the Mining Tax Act in 1917

Mr. G. R. Mickle, Mine Assessor, makes the following comments:—

Under this Act three taxes are levied, viz.: (1) the Profit Tax, being on the profits made by the different mining companies computed as outlined in the Act with certain deductions for taxes paid municipalities; (2) the Natural Gas Tax, being a fixed amount of two-tenths of a cent per thousand cubic feet; and (3) the Acreage Tax of five cents per acre on all mining lands. The total amount paid in respect of these taxes for 1917 amounted to $1,643,847.39, and the distribution is as follows:—

Profit Tax	$1,583,864 07
Natural Gas Tax	36,057 90
Acreage Tax (15th April, 1917, to 15th April, 1918)	23,925 42
Total	$1,643,847 39

These amounts given above are the taxes belonging to 1917 which are not due till Oct. 1st, and consequently some of them are not paid before the end of the fiscal year for the Province, Oct. 31st. This statement, therefore, will not agree with the Public Accounts.

Of this amount $555,879.12 was tax for 1916 on nickel mines which was not collected or determined in 1916, as the Act was entirely altered with respect to nickel and nickel-copper mines. Any comparison with past years is of no value under these circumstances. Of the total amount collected as profit tax, nickel mines contributed $1,413,129.99; silver mines, $94,606.29; gold mines, $75,215.51; and miscellaneous mines, $902.28.

The natural gas tax was about 20 per cent. more than was collected last year. Unless important new fields are found there must be a decline of revenue from this source, since the output is being restricted as explained elsewhere in this Report.

The acreage tax is the largest collected in any year, due to the increase of the tax from two to five cents per acre. It is too soon to judge yet what the effect of this change will be. According to the average rate of collection per year of the two cent tax, about 15 per cent. of the lands are in arrears for the 1917 tax; whether this means that the owners of these lands intend to let the title lapse or are merely taking breath, will be known in a year or so.

Provincial Assay Office

W. K. McNeill, Provincial Assayer, reports as follows for the year 1917:—

To an increased demand for minerals occasioned by war conditions, probably, was due to a great extent the increase in the work of this Office for the year. The Assay Office was utilized more than ever by those interested in the mining industry, and apart from actual assaying of ores and mineral products, a great deal of general information and advice was given, for which no fee was charged.

During the year the equipment was augmented by a Brown crusher and pulverizer and a Case gas assay furnace.

The work, as in former years, may be classified as follows:

1. Examination and assaying of samples for prospectors, mining engineers, geologists, and the public generally. For this work the Department charges the regular fee.
2. Analyses of samples of rocks, etc., for the geologists of the Bureau of Mines.
3. The sampling of car lots of Cobalt silver ores shipped from the mines, upon which the government collects a royalty. This work is in charge of Mr. T. E. Rothwell, Assistant Assayer.
4. The assaying and valuation of these car lots.
5. Assaying of the products of the Cobalt silver ores, for which the government gives a bounty.
6. Special research work.

The work may be further classified as follows:

Gold and Silver Assays.—803 samples were submitted for gold and silver, including car lots, each car being represented by one sample.

Platinum minerals.—15 samples were submitted for platinum minerals. These were also tested for palladium, iridium and other allied metals.

Copper ore.—57 samples were analysed for copper. These were mostly from Ontario, although a few were sent from the province of Quebec.

Nickel and Cobalt ores.—51 samples were tested for nickel and cobalt.

Iron ores.—15 samples were analysed for iron, sulphur and phosphorus.

Molybdenum ores.—39 samples, mainly concentrates, were received and reported upon.

Zinc and Lead ores.—23 samples were analysed for the zinc and lead content.

Rock analyses.—14 rock samples were submitted by the Provincial Geologist for complete analysis.

Limestones.—79 samples were submitted; of these 14 were for complete analysis, the others for magnesia content.

Identification.—96 samples were submitted by mail and reports issued. In addition, some hundreds of samples were brought directly to the office and identified. No charge is made for this work.

Miscellaneous.—60 samples were submitted. Under this heading are included barite, fluorspar, manganese, chromium, etc.

The work of the Department is carried on with the assistance of T. E. Rothwell, Assistant Assayer, and A. T. Leat, who is employed as a sampler and general assistant.

Samples sent in by the public will be dealt with in the order of their arrival. In every instance specimens and samples should be accompanied by statement specifying the precise locality from which they were taken.

Crushed samples representing large quantities or samples less than five pounds weight may be sent by mail as third class matter. Write name and address plainly on each parcel. Send instructions, with money in payment of fees in a separate letter. Samples may be sent by express, charges prepaid.

Sample bags addressed to the Laboratory for sending ore pulp by mail may be obtained free on application; also canvas bags for shipping.

Money in payment of fees, sent in by registered letter, post-office order, postal note, or express order, and made payable to the Provincial Assayer, must invariably accompany sample to insure prompt return of certificate, as no examination is commenced until the regulation fee is paid.

Samples addressed as follows: "To Provincial Assay Office, 5 Queen's Park, Toronto, Ont."

The following schedule of fees is as revised, and took effect June 1st, 1918:

TARIFF OF FEES FOR ANALYSES AND ASSAYS

1. Assays:

Gold	$1 50
Silver	1 50
Gold and Silver in one sample	2 50
Platinum Minerals	5 00
Gold and Platinum Minerals in one sample	7 00
Separation of Platinum Minerals	Prices on application.

2. Iron Ores:

Iron (metallic)	$1 50
Silica	1 50
Iron and Insoluble residue	2 50
Ferrous Oxide	2 00
Phosphorus	3 00
Sulphur	2 50
Iron, Sulphur, Phosphorus and insoluble	8 00
Manganese	3 00
Titanium	4 00
Complete analysis	Price on application.

3. Limestones, Dolomites, Marls, Clays, Shales:

Determination of:

Insolubles	$1 50
Silica	1 50
Ferric Iron	3 00
Ferrous Iron	2 00
Alumina	3 00
Lime	2 00
Magnesia	2 50
Potash	5 00
Soda	5 00
Alkalies (on one sample)	6 00
Water (combined)	2 00
Moisture	1 00
Carbon Dioxide	2 00
Sulphur	2 50
Phosphorus Anhydride	3 00

4. Examination of Clay, Shale, or Cement Rock for Cement Manufacture:
Determination of:
Silica, Iron Oxide, Alumina, Lime, Magnesia, Sulphur, and Volatile matter. Prices on application.

5. Coal, Coke, Peat, Etc.:
Determination of:

Moisture	$1 00
Volatile Combustible	1 50
Fixed Carbon	1 50
Ash	1 50
Sulphur	2 50
Phosphorus	3 00
Calorific value (B.T.U.)	5 00
Ultimate analysis	Price on application.

6. Mineral Waters ..... Price on application.

7. Ores and Minerals:

Determination of:

Alumina	$3 00
Antimony	4 00
Arsenic	4 00
Bismuth	4 00
Cadmium	4 00
Chromium	5 00
Cobalt	5 00
Nickel	5 00
Cobalt and Nickel on same sample	6 00
Copper	2 00
Fluorite	4 00
Lead	3 00
Molybdenum	4 00
Manganese	3 00
Tin	4 00
Zinc	3 00

8. Rocks, Complete Analysis ..... Price on application.

9. Slags, Sand, Etc. ..... Price on application.

10. Identification of Minerals and Rocks not requiring Chemical Analysis... Free.

11. Test for Radio-Activity ..... Free.

Any analytical work not specified in this circular will be undertaken on application to the Provincial Assayer.

The pulp of each sample is retained for future reference.

MINING ACCIDENTS IN 1917

Chief Inspector of Mines, T. F. Sutherland, Toronto; Inspectors, E. A. Collins, Cobalt; J. H. Stovel, Sudbury

During the year 1917 at the mines, metallurgical works, quarries, clay and gravel pits regulated by the Mining Act of Ontario there were 34 fatal accidents causing the death of 36 men, as compared with 51 deaths in 1916. Of these, 18 accidents resulting in 19 deaths occurred underground. Seven men were killed above ground at the mines, six at the metallurgical works, and four at the quarries.

Seventeen companies had fatal accidents during the year.

Table of Fatalities

	1916	1917
Mines, underground	30	19
Mines, surface	7	7
Metallurgical works	8	6
Quarries	6	4
Total	51	36

The fatalities at the mines were divided amongst the several districts as follows:

	1916	1917
Gold mines of Porcupine and Kirkland Lake	14	8
Silver mines of Cobalt and adjacent districts	8	9
Nickel-copper mines of Sudbury	13	9
Iron mines of Michipicoten	2	0
Total	37	26

By months the fatalities occurred as follows:

	1916	1917
January	7	8
February	4	3
March	1	2
April	2	3
May	7	2
June	5	0
July	1	5
August	2	6
September	3	1
October	1	3
November	10	0
December	8	3
Total	51	36

Analysis of Fatalities at Mines

Cause:—	1916 Per cent.	1917 Per cent.
Falls of ground	24.3	15.4
Shaft accidents	27.0	15.4
Explosives	21.6	15.4
Miscellaneous underground	8.1	26.9
Surface	18.9	26.9

Table of Fatal Accidents in Mines, Metallurgical Works and Quarries, 1901 to 1917

—	Persons killed at metallurgical works and mines.	Persons employed at metallurgical works and producing mines.	Persons employed at non-producing mines (estimated).	Total persons employed.	Fatal accidents per 1,000 employed.
1901.....	13	4,135	550	4,685	2.77
1902.....	10	4,426	450	4,876	2.05
1903.....	7	3,499	400	3,899	1.79
1904.....	7	3,475	400	3,875	1.80
1905.....	9	4,415	500	4,915	1.83
1906.....	11	5,017	750	5,767	1.90
1907.....	22	6,305	1,140	7,445	2.93
1908.....	47	7,435	1,750	9,185	5.11
1909.....	49	8,505	2,000	10,505	4.66
1910.....	48	10,862	2,000	12,862	3.73
1911.....	49	12,543	2,000	14,543	3.37
1912.....	43	13,108	2,000	15,108	2.84
1913.....	64	14,293	2,000	16,293	3.93
1914.....	58	14,361	1,500	15,861	3.60
1915.....	22	13,114	1,500	14,614	1.51
1916.....	51	14,624	2,000	16,624	3.07
1917.....	36	16,791	1,000	17,791	2.02
Total.....	546	156,908	21,940	178,848	3.05

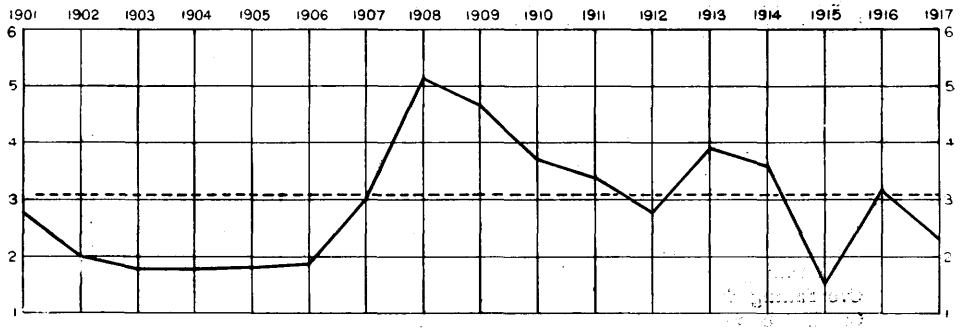


Diagram showing Mining Fatalities per thousand men employed between the years 1901-1917. The dotted line represents the average for the period.

The occupation and nationality of the men killed are set out in the following table:

Occupation.	English-speaking.	Austrian.	Finn.	Bulgarian.	Russian.	German.	Italian.	Total.
Machine runner	3	2	1	.....	1	.....	.....	7
Trammer	1	3	.....	.....	1	.....	1	6
Machine helper	3	.....	2	.....	.....	.....	.....	5
Labourer	2	1	.....	.....	.....	.....	.....	3
Foreman	2	.....	.....	.....	.....	.....	.....	2
Blockholer	.....	.....	.....	1	.....	1	.....	2
Hoistman	2	.....	.....	.....	.....	.....	.....	2
Chute blaster	.....	.....	.....	1	.....	.....	.....	1
Timberman	1	.....	.....	.....	.....	.....	.....	1
Millman	1	.....	.....	.....	.....	.....	.....	1
Mechanic	1	.....	.....	.....	.....	.....	.....	1
Teamster	1	.....	.....	.....	.....	.....	.....	1
Engineer	1	.....	.....	.....	.....	.....	.....	1
Stovetender	1	.....	.....	.....	.....	.....	.....	1
Coal dryer	1	.....	.....	.....	.....	.....	.....	1
Ladleman	.....	1	.....	.....	.....	.....	.....	1
Total,	20	7	3	2	2	1	1	36

The ages of the men killed were as follows:

17-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	Total.
2	7	10	4	5	4	1	1	2	36

Cause and Place of Fatalities in Mines

Below Ground:—
- Falls of ground 4

Shaft Accidents:—
- Falling from skip 1
- Struck by objects falling down shaft 1
- Falling down shaft 2

Explosive Accidents:—
- Walked into blast 2
- Premature explosion while lighting holes 1
- Remaining in vicinity of blast and struck by rock 1

Miscellaneous Accidents:—
- Falling down raise 1
- Falling down ore pass 1
- Rock rolling down stope 1
- Ore falling from chute 1
- Crushed between car and chute 1
- Timber falling down raise 1
- Stull breaking 1

Above Ground:—
- Struck by loaded skip (ore transportation) 1
- Slipped under moving locomotive (ore transportation) 1
- Slide of lumber from loaded car 1
- Caught by counterweight cable 1
- Wound around pulley in mill 1
- Kicked by horse 1
- Falling down rock dump 1

Metallurgical Plants:—	
Asphyxiation	1
Burned by hot gases	1
Ran over by railroad car in yard	1
Struck by ladle	1
Fall from oiling platform	1
Crushed between passenger coach and platform	1
Quarries:—	
Explosion in magazine	2
Caught in conveyor belt	1
Fall of rock from face	1

Falls of Ground

This was formerly a prolific cause of fatal accidents, particularly in the larger mines of the Province. Due to more efficient scaling methods, fatalities from this cause have been greatly reduced. During the year 1917 four men were killed by falling ground, three in Cobalt and one in Sudbury. At the Trethewey mine, April 17th, two shovellers were warned away from dangerous ground by the shift boss. While attempting to leave the stope one man fell into the open top of the chute into which they were shovelling, and was struck by the rock rolling down the stope. He died from his injuries April 22nd.

At the Nipissing Fourth of July shaft on January 12th two men were struck by falling ground while scaling in a winze. The shift boss had ordered two machine crews to scale the walls of the winze carefully. The corner of the winze where the fall occurred had been scaled with picks, but a scaling bar or gad was not used. One of the helpers, David, was instantly killed and his partner, Lauzon, received serious injuries, and died from pneumonia a few days later. This was evidently a case of bad judgment on the part of the machine men who did the scaling. The ground was bad, but there was no reason why it could not have been properly scaled and made safe.

At the Creighton mine, on March 12th, a blockholer, Joseph Durat, was struck by a small piece of rock which fell from the back of stope 15, tenth level. Scaling was in progress at the time, and Durat, without any apparent reason, walked under the unscaled portion towards the manway. He received severe injuries in the region of the thigh and backbone, resulting in death March 16th.

Shaft Accidents

Four men were killed in shaft accidents during the year. At the Sylvanite mine, April 10th, an Austrian fell about twenty-five feet from a set of timbers to the bottom of the shaft. This accident was due to carelessness in using 7/8-inch instead of 3/4-inch nuts on 3/4-inch hanging rods, allowing wall plate to drop down.

Harry Yates, a Canadian, fell down the shaft from the third to the fifth level of the Levack mine, April 19th. Yates was employed as underground hoistman and had stepped out on a plank to shake the cable and attract the attention of the men below. In returning to the station he in some manner slipped from the plank and fell to the bottom.

Dalton Boomer was killed at the Jupiter shaft, McIntyre mines, on August 22nd. Boomer was one of a sinking crew and had returned to the bottom after

personally cleaning down the last three sets after a blast. He was an exceptionally careful miner, but in some way a small block of timber, used for wedging wall plates, had been loosely placed behind the lagging, and became dislodged when the crosshead struck the stop blocks.

At the McKinley-Darragh mine, on September 29th, a Russian was knocked from the skip at the loading pocket at the 300-foot level and fell to the 400-foot station.

Accidents from Explosives

Four fatalities underground, due to explosives, occurred in 1917. This is a reduction over previous years, due to greater care in the handling and storage of explosives, reporting of missed holes, etc. The Dome Lake accident on May 16th could probably have been prevented had the shift boss sent a helper with the young Austrian, who was killed, to assist in loading and firing the rounds.

The Bulgarian blockholer at the Creighton mine, on May 30th, prepared three sand blasts, waited for two to explode, and walked into the third blast.

The Hollinger accident, on August 31st, was due to the inexperience of deceased, who remained in a ladderway a short distance from a pop shot he had placed and lighted himself.

At the Crean Hill mine, on December 4th, an Austrian miner walked into a blast on the 528 sub-level. All approaches were guarded, and deceased had been warned with the other men, and how he got back to the face unnoticed is unknown.

Miscellaneous Accidents Underground

Seven fatalities, or 36.8 per cent. of the total accidents underground in 1917, may be classified under this heading. Four of these occurred in the large nickel mines of the Sudbury district, one at the Coniagas, one at the Teck-Hughes, and one at the Hollinger. Ore falling from chute, and being crushed between car and chute, accounted for two at the Creighton. The Crean Hill accident, on October 3rd, was due entirely to the use of a grab hook with a chain sling in lowering material, and this should be universally forbidden.

The Coniagas accident, on August 25th, was due to a stull breaking and permitting workman, who was crossing over an abandoned stope, to fall to the ore below, a distance of twenty-five feet. This timber had been in place two or three years and showed no signs of decay.

A second accident due to improper fastening of material when hoisting in a raise caused the death of a miner at the Crean Hill mine on January 2nd.

Falling down an ore pass at the Acme mine, of the Hollinger Consolidated Gold Mines, caused a fatality on December 11th, and at the Teck-Hughes, Kirkland Lake, a Finn named Hemmi, was struck by a large piece of ore rolling down the stope, receiving injuries which resulted fatally September 26th, six weeks after the accident.

Surface Accidents

Seven men were killed in surface accidents at the mines, six at metallurgical plants, and four at quarries during the year, making a total of seventeen fatalities on surface, as compared with nineteen underground, where it might be assumed

that the risk was considerably greater. At the mines the causes were various, only two being due to transportation. At the Hollinger, on October 20th, a workman stepped in front of a loaded skip on the tramway from the Central shaft to the mill; and at the Miller-Lake O'Brien the driver in charge of the small locomotive accidentally slipped under the front trucks and received injuries which resulted fatally.

A rather peculiar accident occurred at the Casey-Cobalt, where the hoistman was killed December 7th. The counterweight stuck in the guides and allowed the counterweight cable to slack down on the ground when the hoist was started. The hoistman was evidently stooping over the cable when the weight fell and threw him into the air. It is obvious that he should have reversed his engine and taken up the slack before leaving the engine room.

Other accidents on surface occurred; the causes were of the usual nature.

At the smelters and blast furnaces only one death occurred from asphyxiation, which is a very good showing. Railway cars in the yards accounted for two fatalities.

Two quarries furnished four fatalities, or 23.5 per cent. of the total surface accidents.

At the Bruce Mines trap rock quarry, on June 25th, two men were killed by an explosion of five cases of dynamite which were stored in an old shed near the working face. The cause of the explosion is unknown, but it is apparent that the accident would not have occurred had the magazine been removed to a proper distance from the quarry.

At the Dominion mines and quarries, at East Neebish, two fatal accidents occurred, one by fall of rock from the face, August 7th, and the other on June 29th, when an Austrian workman was caught in a conveyor belt.

Prosecutions

John Osmak, an Austrian, employed at the Garson mine of the Mond Nickel Company, was sentenced to three months in gaol at Sudbury on April 15th last for tampering with the bell signals in the Garson main shaft.

Table of Fatal Accidents in

No.	Date 1917	Name of Mine.	Name of Owner.	Name of Deceased.	Occupation of Deceased.
1	July 30	Baldwin	Baldwin Gold Mining Co.	Stephen Powers ..	Foreman .....
2	Jan. 2	Crean Hill	Canadian Copper Co. ..	Anti Tainen	Machine helper.
3	Mar. 12	Creighton	do do ..	Joseph Durak ...	Blockholer ....
4	May 30	do	do do ..	Simeon Michaleff.	do ....
5	July 12	do	do do ..	C. Nicholoff	Chute blaster .
6	July 24	do	do do ..	M. Storazuk	Trammer .....
7	Oct. 3	Crean Hill	do do ..	J. Chirkoski	Timberman ...
8	Dec. 4	do	do do ..	M. Bilinski	Trammer .....
9	Dec. 9	Casey Cobalt	Casey Cobalt Silver Mining Co.	H. Patriquin	Hoistman .....
10	Aug. 25	Coniagas	Coniagas Mines, Ltd. ..	A. Hakkala	Machine helper.
11	Aug. 25	do	do do ..	J. McAlpine	Millman .....
12	May 16	Dome Lake	Dome Lake Mining and Milling Co.	H. Filyx	Machine runner
13	Aug. 31	Hollinger	Hollinger Consolidated .	W. Dilinski	do do
14	Oct. 20	do	Gold Mines, Ltd.	F. Papin	Mechanic .....
15	Dec. 11	do	do do	G. Solentre	Trammer .....
16	July 14	Hudson Bay	Hudson Bay Mines, Ltd.	T. Bond	Teamster .....
17	Aug. 22	McIntyre	McIntyre Porcupine Mines, Ltd.	D. Boomer	Machine runner
18	Sept. 29	McKinley-Darragh	McKinley - Darragh-Savage Mines, Ltd.	N. Kirischuk	Trammer .....
19	Oct. 20	Miller Lake	Miller-Lake O'Brien	H. Hutt	Engineer .....
20	Mar. 18	Parson	Mond Nickel Co.	J. Kulyczyaki	Trammer .....
21	Apr. 19	Levack	do do	H. Yates	Hoistman .....
22	Jan. 12	Nipissing	Nipissing Mines, Ltd..	J. David	Machine helper.
		do	do do ..	L. Lauzon	do do
23	Apr. 10	Sylvanite	Sylvanite Gold Mines..	L. Gruby	Machine runner
24	Aug. 18	Teck-Hughes	Teck-Hughes Gold Mines	J. Hemmi	do do
25	Apr. 17	Trethewey	Trethewey Silver Cobalt Mine	A. De Leury	Trammer .....

Table of Fatal Accidents at

No.	Date 1917	Name of Works.	Name of Owner.	Name of Deceased.	Occupation of Deceased.
26	Jan. 23	Blast furnace	Algoma Steel Corp'n....	E. Prevost	Stove tender ..
27	Feb. 20	do do ..	do do	T. St. Jules	Labourer .....
28	July 7	do do ..	do do	R. Elder	Foreman .....
29	Feb. 24	Reverberatory ...	Canadian Copper Co. ..	G. Danis	Coal dryer.....
30	Jan. 24	Smelter	Mond Nickel Co.	J. Gardy	Ladle man .....
31	Feb. 21	Smelter yard	do do	A. Beauvois	Labourer .....

Table of Fatal Accidents

32	June 25	Quarry	Bruce Mines, Trap Rock Quarry	J. Deyell	Machine runner.
	do	do	do do	Chas. Munroe	Machine helper.
33	June 29	do	Dominion Mines and Quarries	T. Kuryi	Labourer .....
34	Aug. 7	do	do do	C. Bennett	Machine runner

or about the Mines, 1917

Nationality of Deceased.	Age.	Married or single.	Below ground.	Above ground.	Cause of Accident.
English-speaking ...	55	M	.....	1	Slide of lumber from loaded car.
Finn	25	S	1	.....	Struck by falling timber in raise.
German	39	M	1	.....	Caught by fall of rock in stope.
Bulgarian	30	M	1	.....	Returned before all sand blasts had exploded.
do	28	M	1	.....	Went into hung-up chute to blast.
Austrian	20	S	1	.....	Crushed between chute timber and train. Died August 11 from pneumonia.
English-speaking ...	26	M	1	.....	Fell down raise while helping to lower truck.
Austrian	33	M	1	.....	Walked into blast.
English-speaking ...	32	M	.....	1	Struck by cable of counter-weight.
Finn	30	M	1	.....	Fell about 25 feet when lagging broke.
English-speaking ...	36	M	.....	1	Killed while replacing belt.
Austrian	28	M	1	.....	Killed by explosion while blasting round.
Russian	24	S	1	.....	Struck by rock from blast.
English-speaking ...	39	S	.....	1	Struck by skip on tramway to mill.
Italian	43	S	1	.....	Fell down ore pass while dumping car.
English-speaking ...	47	M	.....	1	Kicked by horse while unhitching.
do do ...	35	M	1	.....	Struck by block of timber in shaft.
Russian	32	S	1	.....	Killed while riding skip.
English-speaking ...	30	M	.....	1	Slipped and fell under locomotive.
Austrian	43	S	.....	1	Thrown over dump while dumping car.
English-speaking ...	32	M	1	.....	Fell down shaft.
do do ...	36	M	1	.....	Caught by fall of rock while scaling in winze.
do do ...	24	S	1	.....	Same accident as above. Died from pneumonia Jan. 19.
Austrian	25	S	1	.....	Fell while timbering in shaft.
Finn	36	M	1	.....	Struck by rock rolling down pile. Died Sept. 26, 1917.
English-speaking ...	25	S	1	.....	Caught by fall of rock in stope.

Metallurgical Works, 1917

Nationality of Deceased.	Age.	Married or Single.	Cause of Accident.
English-speaking ...	24	S	Bolt closing door of stove broke when nut was being tightened.
do do ...	59	M	Run over by railroad car.
do do ...	58	M	Asphyxiated in gas-washing building.
do do ...	28	S	Fell from platform.
Austrian	23	S	Crushed by ladle.
English-speaking ...	19	S	Crushed against platform by passenger coach.

at Quarries, 1917

English-speaking ...	30	M	Powder in shed near men exploded.
do do ...	28	S	Same accident as above.
Austrian	45	M	Wound around drive shaft of conveyor belt.
English-speaking ...	44	M	Fall of rock from face of quarry.

MINES OF ONTARIO

Chief Inspector of Mines, T. F. Sutherland, Toronto; Inspectors, E. A. Collins, Cobalt; J. H. Stovel, Sudbury

I.—NORTHWESTERN ONTARIO

Iron Pyrites

Minitaki Lake.—James Whalen, of Port Arthur, did some work on his pyrites deposit, which is situated on the shore of Lake Minitaki, about 12 miles south, by water route, from Graham station, on the Canadian Government railways. The only outcrop on this claim occurs under the water. A shaft was sunk in the foot-wall to a depth of 75 feet, and a cross-cut run to the vein. Work was discontinued in October, 1917.

Northern Pyrites Mine.—Shipments from this property of the Nichols Chemical Company, Limited, at Northpines, during the season of 1917 amounted to 115,000 tons of pyrites. Ore is shipped only during the navigation season, and is sent from Northpines by rail to Fort William, thence by boat to the various manufacturing plants of the General Chemical Company in the United States. Mining operations are continuous throughout the year. In the winter months the excess ore broken in the mine is stock-piled at the rail-shipping point of the Canadian Government lines.

The production of 1917 was principally obtained from the third level east stopes. Development drifts were run both east and west on the fourth level. The shaft was sunk to a depth of 550 feet, on a 55° incline, and a station cut on the fifth level. It is planned to make such changes in the present equipment as will enable a large tonnage to be shipped in 1918.

G. B. Holderer was superintendent during the shipping season, and was succeeded in November by J. A. Battle, Jr. From 200 to 250 men were employed.

Mokomon.—The Nichols Chemical Company, Limited, concluded their diamond-drilling on the pyrites prospect at Mokomon, in Conmee township, during November, 1917. It is expected that the company will acquire this property. Dr. Warren S. Smith was in charge of the exploration work.

Copper

Port Arthur Copper Company.—This company did a small amount of development work on their property, which is situated south of the main line of the Canadian Northern railway, about four miles west of Mine Centre.

In October, 1917, a 100-h.p. boiler, a 500-cu. ft. air compressor and a 10 by 12-inch steam hoist were being installed. The shaft, a two-compartment one inclined at 80°, had been sunk to a depth of 55 feet. It was planned to sink farther and do considerable drifting as soon as the headframe and hoist were ready.

The company has a capitalization of $2,500,000. The officers of the company are: Fred M. Connell, of Toronto, president; J. F. Hewitson, of Port Arthur, vice-president; J. A. M. Alley, 904 Bank of Hamilton Building, Toronto, secretary-treasurer.

W. H. Connell was manager, employing about 15 men.

Tip Top Mine.—S. W. Ray, of Port Arthur, re-opened the Tip Top mine in 1917, shipping to the Trail smelter in British Columbia. The mine is located about 6½ miles south of the main line of the Canadian Northern railway from a point two miles west of Kashaboiwe station.

A narrow-gauge track was laid from the mine to the railway and the ore cars are hauled over this by a dinkey locomotive. The mine had previously been opened to a depth of 200 feet and drifts run every 50 feet of depth. Only the first and second levels (50 and 100-foot depths) had been de-watered up to October, 1917, the ore produced having come from above these levels. At that time the mine was shipping about 45 tons daily.

S. W. Ray, of Porth Arthur, is owner and operator, Mr. Flatt being in charge at the mine; 40 men were employed.

Gold

St. Anthony Mine.—The Thunder Mining Company continued development work on the St. Anthony mine until September, 1917, when the property was closed down for the winter months. Development work done by this company consisted of 1,500 feet of drifting, 100 feet of raising, and 150 feet of sinking. The mill was run for a short time for sampling purposes.

The Kerr Lake Mining Company, which operates the well-known silver mine of this name at Cobalt, holds approximately two-ninths' interest in the new company.

H. H. Lavery was superintendent, employing 60 men.

Rognon.—The Rognon Gold Mines, Limited, commenced operations in June, 1917, on the Rognon claim, which is situated on Contact bay, Wabigoon lake, about eight miles south of Dryden. A small boiler, compressor and hoist were installed, and 70 feet of sinking, 60 feet of drifting and 50 feet of raising done. A single Nissen stamp, with amalgamating plates, was installed and used for testing purposes.

The company is capitalized at $2,500,000. J. M. Beckley, Rochester, N.Y., is president; S. J. Madden, Toronto, vice-president and manager; and J. R. L. Starr, Toronto, secretary. S. J. Madden was in charge and employed about 10 men.

Tash Orn.—The description of this property, contained in the Bureau's Twenty-sixth Report, represented the work done up to June, 1917. The mine was closed shortly afterwards and has not been re-opened.

II.—SUDBURY, NORTH SHORE AND MICHIPICOTEN

Iron Ore

Helen Mine.—Operations at this mine, owned by the Algoma Steel Corporation, consisted in drawing off the caved hematite ore. At the end of 1917 only a portion of the seventh level and a small area on the eighth level remained to be drawn off, so that it seems probable that the Helen hematite ore body will be finished early in 1918. All ore hoisted was shipped to the Magpie mine, where it is roasted to eliminate the high sulphur content. During 1917, 2,825 tons of pyrites were mined and 99,238 tons of hematite.

In October, 1917, preparations were being made to drive a development tunnel underneath the large siderite deposit at this mine, which was diamond-drilled in 1916 and 1917. This deposit adjoins and also underlies the original hematite ore body. The entrance to the tunnel will be on the north side of the hill or deposit which is farthest from the present mine buildings. This tunnel will tap the ore body about 300 feet below the top of the hill, and a large tonnage will be available above it. It is planned to mine the portion of the ore body above the tunnel by open-pit method. Electric haulage to the roasting plant, which will be erected not far from the tunnel entrance, will be used.

G. R. McLaren, Helen Mine, Ont., is superintendent. About 100 men were employed.

Magpie.—The Magpie mine of the Algoma Steel Corporation produced 184,592 tons of roasted ore during 1917, and shipped 197,561 tons. Scarcity of labour prevented the mine from being operated to full capacity. The ore produced came from the second and third level stopes. Considerable development was done on the fourth level during the year. In the summer this mine, as well as the Helen mine of the same company, was put on an eight-hour working basis for underground work.

A. Hasselbring, general superintendent of mines for the company, is in charge at the Magpie mine. From 200 to 230 men were employed.

Dreany Bros.—Dreany Bros., of Toronto, did some surface stripping and trenching on a banded magnetite iron deposit near the Algoma Central railway, four miles north of Goudreau. Further testing was to be done by diamond-drilling. C. D. Daimpre was in charge.

Rand Pyrite Mine.—Early in 1917 the Rand Consolidated Mines, Limited, commenced opening up a pyrite deposit near Goudreau station, on the Algoma Central railway. Considerable surface work was done during the year and a trial shipment of two cars made. A 250-h.p. boiler had been installed, and a crusher and compressor were being put in.

The company is incorporated with a capitalization of $5,000,000, but permanent officers have not been elected. Allan W. Jackson, of Goudreau, was manager; about 25 men were employed.

Grace Gold Mine.—The Grace mine, a former gold producer, situated not far from Wawa station, on the Michipicoten branch of the Algoma Central railway, was pumped out during the latter part of 1917. The work was done for a Pittsburg (Pa.) syndicate, Robt. Patterson being in charge. No mining was done.

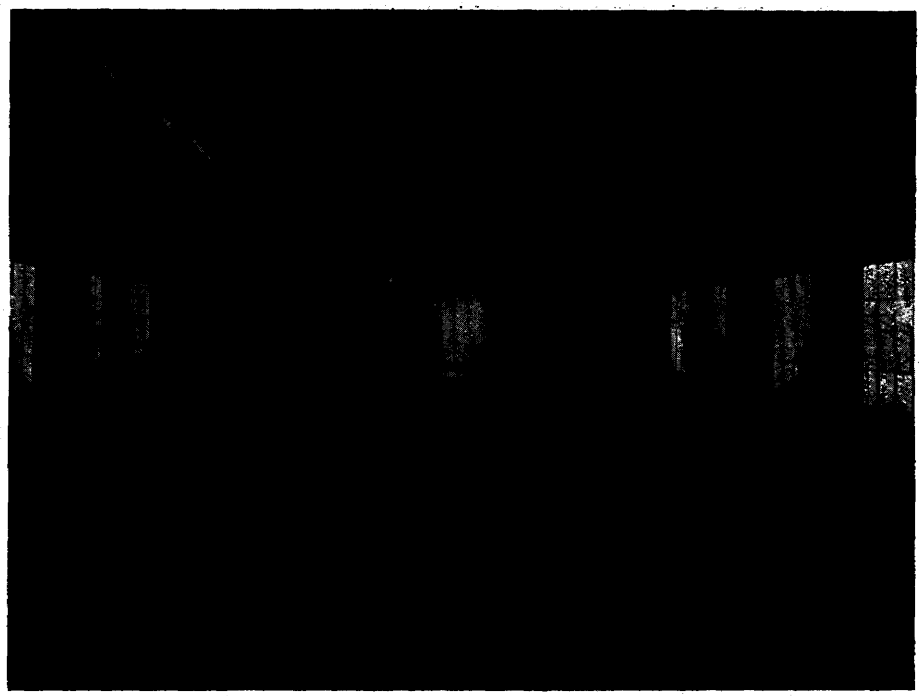
Nickel and Copper

The Canadian Copper Company

The Canadian Copper Company operated during 1917 the following mines: Creighton, Crean Hill and Dill quartz quarry.

The officials of the company are: President, A. D. Miles; general superintendent, J. L. Agnew; superintendent of mines, J. C. Nicholls; smelter superintendent, W. Kent; chief engineer, E. H. Jones; safety engineer, E. T. Corkill.

Copper Cliff Smelter.—The smelting capacity was enlarged by the addition of another furnace, No. 8. This furnace is the same size as No. 7, 25 ft. 6 in. by 50 in. The smelting capacity was further increased by the lowering and enlarging



One of the sorting floors, Creighton mine rock house.

of all the settlers. By this change the slag from the converters can be poured directly into the settlers instead of being sent to the furnaces. A sixth converter was added.

Creighton Mine.—During 1917 the Creighton mine shipped 1,003,816 tons of ore. Work was carried on in all levels from the second to the fourteenth, the main production coming from the tenth and twelfth levels. Most of the breaking was done in the twelfth level stopes. The fourteenth level was opened up by cross-cuts, and other development and stoping begun. The work above the tenth level was scattered over miscellaneous areas. During the first part of the year No. 3 shaft was completed and put into commission.

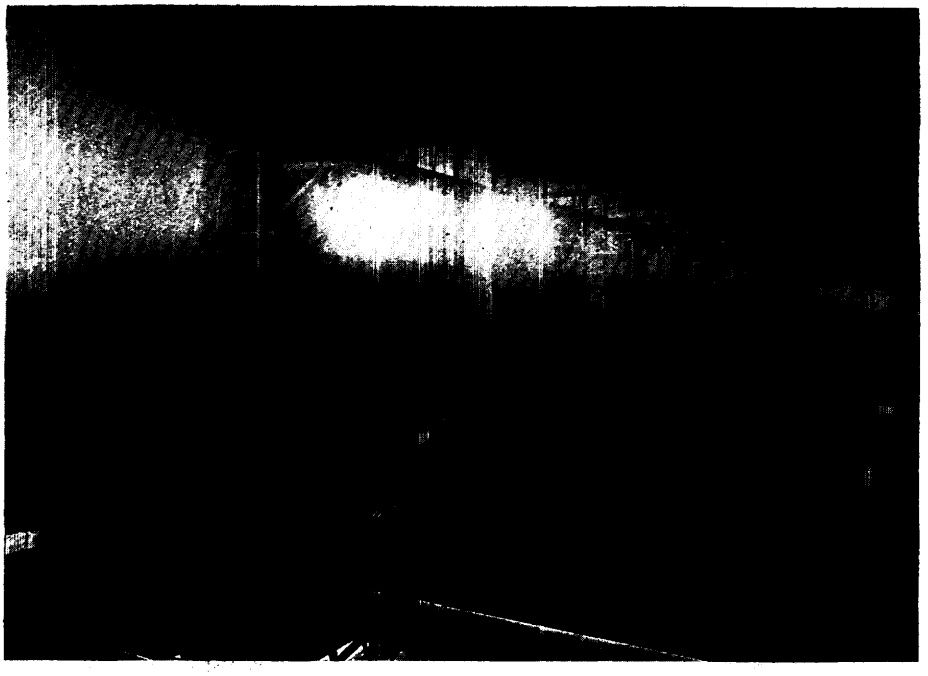
In the Twenty-sixth Report of the Bureau of Mines a description is given of the shaft, rock house, hoisting house and equipment, compressor equipment and change house; these have all been put into use during 1917.

All ore is now hoisted through No. 3 shaft and treated in the new rock house.

In No. 2 shaft two cages are used for handling men and material to the upper levels. The timbering and other equipment in No. 1 shaft were removed, and work was commenced to break the ore which surrounds a part of this shaft.

The new construction, begun two years ago, is completed, and this equipment is handling the increased output through one shaft and sorting plant, instead of through three shafts as during the previous year.

G. A. Morrison is superintendent; about 1,100 men are employed.



Part of washroom in change house, Creighton mine.

Vermilion Mine.—This property was closed down in January, 1917. No shipments were made last year.

Dill Quartz Quarry.—This quarry was operated from April to November of 1917, and shipped 61,584 tons of quartz to the smelter at Copper Cliff.

A small steam shovel was operated in this pit during a portion of the year.

H. Whitehead, who was superintendent at the beginning of the season, joined the Canadian Naval Service, and was succeeded by W. H. Roach. Forty-five men were employed.

No. 2 Mine.—This property was closed down at the end of January, 1917. The ore produced was 1,906 tons. W. J. Hambly was superintendent.

Crean Hill Mine.—The output for 1917 was obtained principally from the fifth and second levels, and amounted to 133,907 tons.

C. Collins is superintendent, employing from 250 to 300 men.

British America Nickel Corporation

The British America Nickel Corporation continued the development of the Murray mine, and began building operations on the smelter site during 1917.

The authorized capital stock of the corporation is $20,000,000, divided into 200,000 shares of common stock of a par value of $100.



View showing arrangement of lockers in change house, Creighton mine.

The officers of the company are: President, J. H. Dunn; vice-president, W. A Carlyle; secretary and treasurer, W. H. Coade; general manager, E. P. Mathewson. The head office is at the Royal Bank Building, Toronto.

In the spring of 1918, E. P. Mathewson severed his connection with the company, and W. A. Carlyle assumed the duties of manager. The head office was moved from Toronto to Ottawa, and the construction of a refinery was commenced near Hull on the Quebec side of the Ottawa river.

Murray Mine.—At the Murray mine the 3-compartment incline shaft was continued to the 900-foot level, with levels at 150, 300, 400, 500, 600, 700, and 800 feet, and ore pockets at the 300, 500, and 700-foot levels.

A shaft house is under construction. This building is of steel and reinforced concrete 60 feet by 64 feet, and is 102 feet high. The crusher is 36 inches by 48 inches. The waste bin is 400-ton and the ore bin 500-ton capacity.

From the shaft house the ore is conveyed by a 30-inch travelling belt to the rock house, a distance of 279 feet. The rock house is 88 ft. by 126 ft. of steel and gunnite construction on a concrete foundation. The bins are of reinforced concrete.



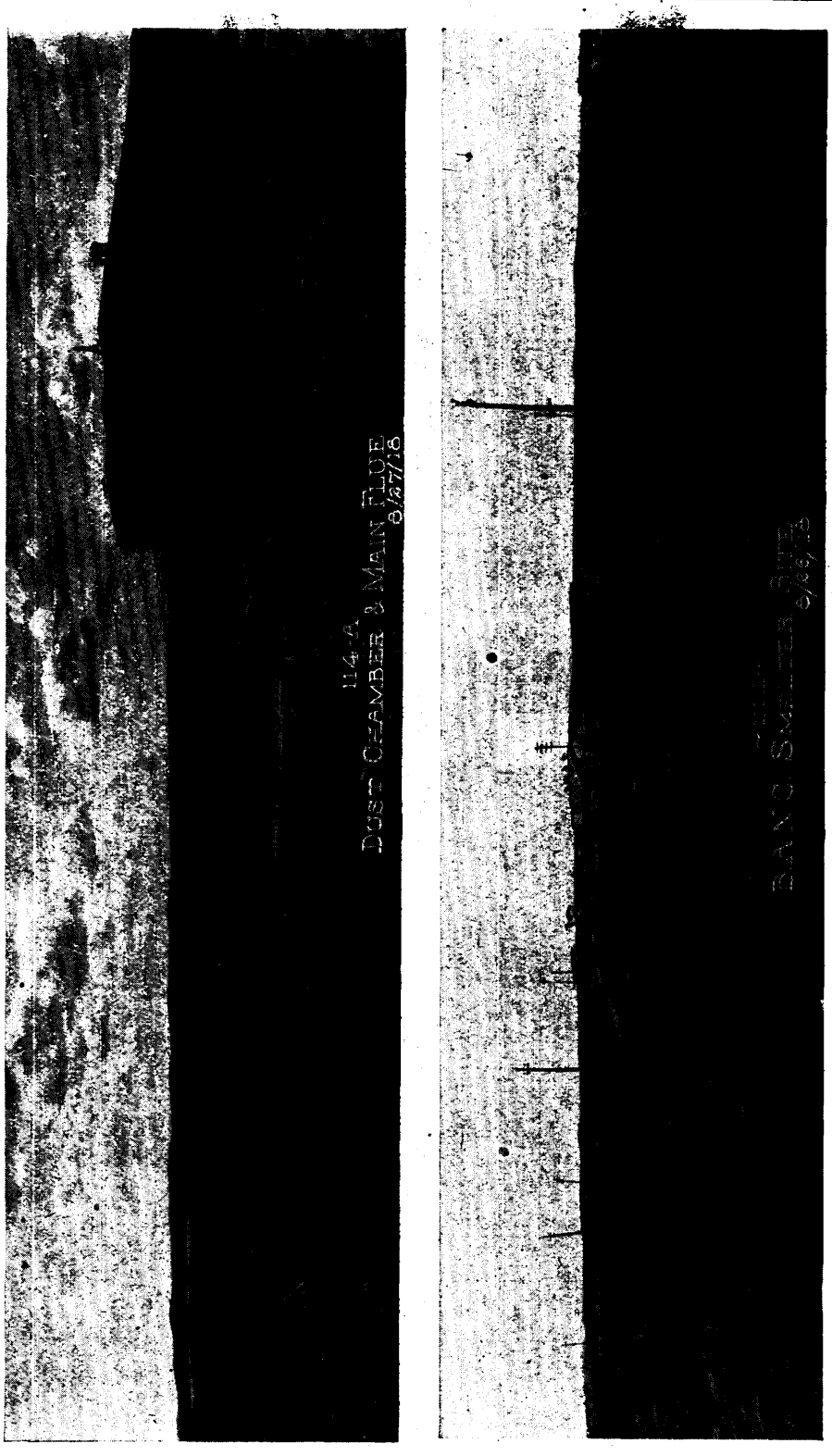
Ore hoist at Creighton mine.

The equipment comprises a 36-in. by 18-in. jaw crusher, a No. 5 gyrating crusher, picking belts, screens, etc. A one-storey brick change house, 97 ft. by 57 ft., is nearly completed. The power house at the mine is 107 ft. by 134 ft. The installation will include three 500-h.p. Babcock and Wilcox boilers.

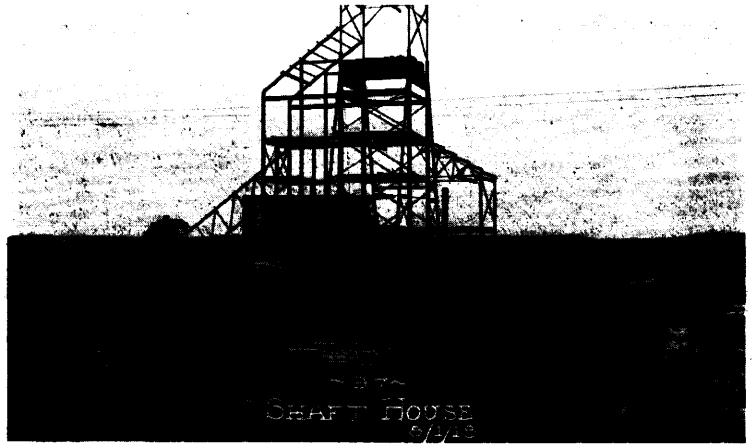
Smelter.—The smelter site is 1¼ miles from the mine. Eight miles of standard-gauge railroad have been built, connecting the mine with smelter yards. These tracks are connected with both the Algoma Eastern and Canadian Pacific railways.

The smelter buildings completed and those under construction include a warehouse 41 ft. by 144 ft. of steel and gunnite; machine shop, including boiler shop 50 ft. by 160 ft. of steel and gunnite; change house, 57 ft. by 113 ft., of reinforced concrete and brick; power house, 198 ft. by 83 ft., of steel and brick; smelter building, 378 ft. by 67 ft.; dust chambers, 77 ft. by 120 ft., of brick and steel.

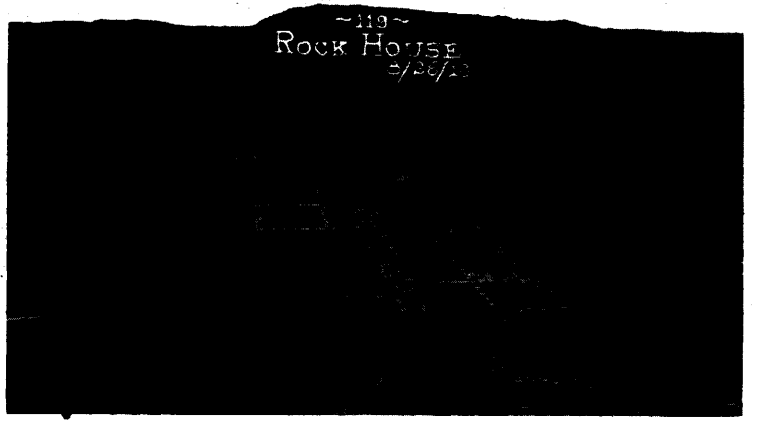
The equipment in the power house will include six Babcock and Wilcox boilers and two 2,500-cu. ft. Bellis and Morcum air compressors.



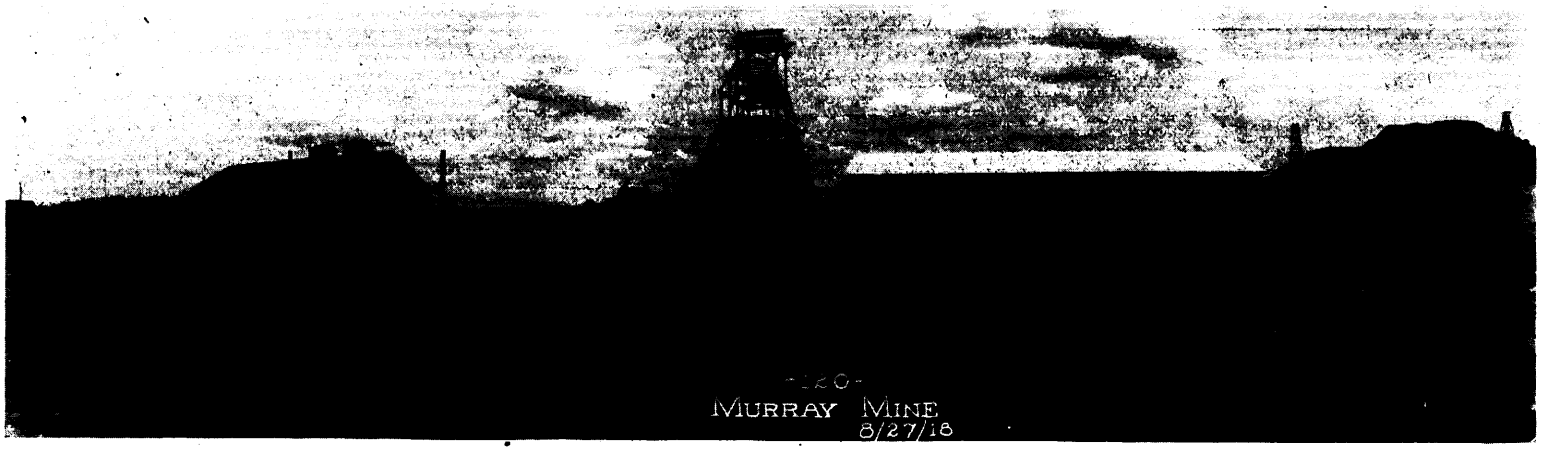
Views of smelter at Murray mine under construction by the British America Nickel Corporation.



Shaft house, Murray mine.



Rock house, Murray mine.



General view of Murray mine, showing shaft house in centre and rock house on right, British America Nickel Corporation.

Mond Nickel Company, Limited

The Mond Nickel Company, Limited, operated in 1917 the Victoria, Garson, Worthington and Levack mines, in the Sudbury field, and Bruce Mines, situated in the village of that name.

The head offices of the company in Canada are at Coniston. The officials are: C. V. Corless, manager and also a director of the company; J. F. Robertson, superintendent of reduction works; O. Hall, mines superintendent; W. L. Dethloff, chief engineer; W. H. Soule, electrical superintendent.

Bruce.—No. 1 mine shipped 32,500 tons to the smelter in 1917. The shaft was continued to the fifth level, a depth of 427 feet. A drift is being run from this point to connect with the workings at the bottom of the old No. 2 shaft, and it is planned to prospect this area more thoroughly.

At the No. 2 mine, formerly the Taylor shaft, development was continued on the 150-foot level during the year. About 1,000 feet of drift was driven. No stoping was done.

A. D. Carmichael, Bruce Mines, is superintendent. From 75 to 85 men were employed.

Garson.—The output from this mine in 1917 was 117,000 tons, this ore being obtained principally from the sixth level stopes. Development on the eighth level was continued and several stopes were prepared for mining by section-cutting on the sub-level. Development on the tenth level was confined to drifting and cross-cutting. The drifting, cross-cutting and raising done in the mine during the year was 4,000 feet. J. R. Thoenen is superintendent. About 300 men were employed.

Levack.—The Levack mine shipped 88,500 tons of ore to the smelter in 1917. This ore was mainly obtained from the second and third level stopes. During the year development was continued on the fifth level. The shaft, which is inclined at 65 degrees from the horizontal, was sunk to the seventh level, a vertical depth of 590 feet, and a station was cut at the seventh level. A club house and 13 more cottages were erected in the company village.

F. J. Eager is superintendent. About 300 men were employed.

Victoria No. 1.—This is still the deepest mine in Ontario. The shaft was 2,750 feet in depth at the end of the year 1917, and was to be continued to the 3,000-foot level before another station was cut. The mine produced in 1917 46,000 tons of ore. Stoping was carried on in nearly every level.

W. J. Mumford is superintendent; 145 men were employed.

Worthington.—This mine shipped 75,000 tons of ore to the smelter in 1917. Stoping was carried on above the second and third levels. The fourth level was developed by drifts and cross-cuts and the stopes opened up by section-cutting on the sub-level. The shaft was continued to a vertical depth of 750 feet, and a fifth level station was cut at that depth.

R. H. Palmer is superintendent; about 275 men were employed.

Reduction Works.—The production of the Coniston smelter during 1917 was about the same as in 1916. Two furnaces and two converters were operated con-

tinuously; the sintering plant and the concentrating test plant ran steadily. The roasting of ore in the roast yards was again confined to the late autumn and winter months.

An additional furnace and converter, with the necessary auxiliary equipment, were under construction and should be ready for operation early in 1918. The smelter will then have four furnaces and converters, so that the production of matte can be largely increased, when desired.

J. F. Robertson is superintendent of all reduction works; E. T. Austin, superintendent of the smelter; K. S. Clarke, superintendent of the sintering and concentrating plants.

Safety Organization.—At the Coniston reduction works safety matters are in the hands of two committees: Supervising, and Auxiliary. The former committee decides what changes are to be made. The chairman is the manager of the company, and the secretary is the head of the office staff. The six other members are the heads of departments together with the men next under them in direct charge of the work, viz.: the superintendents of reduction works, smelter, sintering and test plants, representing operations, and the chief engineer and mechanical and electrical superintendents, representing construction, maintenance and repair. These six men act in rotation as chairman of the auxiliary committee, the other members of which are foremen, sub-foremen or workmen, one from each of the following: Smelter, sintering and test plants, mechanical and electrical departments, and yard, each being selected by his own superintendent. Three of the members of the auxiliary committee are changed every fortnight, *i.e.*, each is a member for four weeks; thus in a short time a very considerable number of the men in the plant have been members of this committee. The inspection is in the hands of this committee, every second Monday afternoon being devoted to the work. Each unsafe practice, or unsafe piece of equipment detected, is made the subject of a brief report on a printed form, this report containing a recommendation as to the manner of removing the danger.

The supervising committee meets next day, and the reports of the auxiliary committee are presented by the member of the supervising committee who has acted as chairman of the auxiliary committee. After the reports are discussed a decision is made as to what action shall be taken. Practically all recommendations of the auxiliary committee have been passed as received, three or four only having been set aside as unnecessary, and a few amended as to the methods of eliminating the danger; no recommendation has been overruled on account of cost. The supervising committee also discusses recommendations from any of its own members and from a suggestion box hung near the time-check wicket. Once a month the accidents which have occurred during the preceding months are discussed, and the records compared with those of former periods. Should a serious accident occur, the auxiliary committee meets as soon as practicable and investigates, reporting to the supervising committee.

The above organization for safety has worked very effectively and smoothly. It has now been in operation for eighteen months, and the decrease in the number of accidents has been very marked.

The only change in procedure has been the reduction of the number of inspections and meetings from weekly to fortnightly after most of the points needing attention had been remedied.

The committee realizes the responsibility of its work. An important part of the scheme is the rotation of the foremen, sub-foremen and workmen through the auxiliary (*i.e.,* inspecting) committee. Each man goes through his own and other parts of the plant devoting all his attention to safety considerations, in most cases carrying back to his work a great deal of the safety point of view. The more important men are put on the auxiliary committee again after a considerable interval.

Another point in the same connection is the absence of any division of authority. The foreman, or sub-foreman, the man who must get the work done quickly and cheaply, is also, or has been, a member of the safety committee to make that work safe, and he knows that his superintendent is a member of the safety organization all the time and is depending on him, the foreman, to help keep the number of accidents at a minimum.

Miscellaneous Mines

Goudreau Pyrite.—The Nichols Chemical Company shipped from their mine at Goudreau, during the season of 1917, 110,000 tons of pyrites. Ore is shipped only during the navigation season, by rail from Goudreau to Michipicoten Harbor, and thence by boat to the various plants of the General Chemical Company in the United States. The ore shipped in 1917 was obtained from "C" deposit, which was the first opened and is about 1,000 feet from the mill. In the autumn of 1917 a second deposit, known as the "Bear," was being prepared for production in 1918. This deposit is over a mile from the crushing plant, and the ore from it will be handled to the mill over a narrow-gauge track. The crushing plant is being almost entirely changed, and the new installation includes a No. 12-K Gates gyratory crusher, which will greatly increase future production.

J. A. Battle, Jr., was superintendent until October, 1917, when he was transferred to the Northern Pyrites mine, which is also one of the properties of the Nichols Chemical Company, Limited. He was succeeded by Gerald G. Dobbs. About 200 men were employed throughout the season.

McDonald Copper.—The Cheney Copper Mines, Limited, did a small amount of work on the McDonald and Jackson claims, situated on lots 6, 7, 8, 9 and 10, in the fifth concession of Gould township, north of Thessalon. No ore was shipped.

Hudson Copper.—The Hudson Copper Company did some development work on a copper-quartz claim situated about two miles north of Havilah. A shaft 60 feet deep was sunk and considerable surface trenching done in the vein. One car of ore was shipped.

John Black was in charge, five men being employed.

Rutherglen.—The Mattawan River Mining and Milling Company, Limited, sank a 50-foot shaft and did about 50 feet of drifting on a claim which adjoins the main line of the Canadian Pacific railway, about two miles east of Rutherglen. A small boiler, compressor and hoist were installed. The mine was closed down in the autumn of 1917.

Sudbury Copper.—The Sudbury Copper Company, Limited, continued development of their property near Iron Bridge. The shaft was sunk to a depth of 250 feet and a small amount of drifting done on the 150-foot and 250-foot levels. A powder house, change house, and several cottages were built.

George E. Bent, Iron Bridge, was manager; from 15 to 20 men were employed.

Moose Mountain Iron Mine

Moose Mountain, Limited, has an authorized capitalization of $4,000,000 divided into 400,000 shares of a par value of $10.

The officers of the company are: President, Chas. E. Herrmann; secretary-treasurer, Gillison C. Lott; directors, L. B. Miller, Cleveland; John T. Mitchell, Chicago; Donald D. Mann, Toronto; James C. Hutchins, Chicago; Chas. H. Smith, New York; John B. Dennis, New York; William Mackenzie, Toronto; Chas. E. Herrmann, New York; Augustine L. Humes, New York; David Dows, New York; John F. Harris, New York. The head office is at 17 Battery Place, New York.

The mine officials are: A. J. Anderson, general manager; H. H. Hodgkinson, mine superintendent, Sellwood, Ont.

During the year the main tunnel and "B" drift (10 ft. by 11 ft.) was driven 451 feet, and "A" drift (5 ft. by 7 ft.) was driven 339 feet; "A" drift for a distance of 711 feet was enlarged from 5 ft. by 7 ft. to 10 ft. by 11 ft. The other underground work consisted of: winzes, 93 ft.; raises, 9 ft.; raises for chutes, 182 ft.; and level drifts (5 ft. by 7 ft.), 509 ft.; diamond-drilling amounted to 5,170 ft.

Ore sent to the mill amounted to 12,947 tons, of which 4,773 tons came from No. 1 dust pile; 5,500 tons from development work; 2,038 tons from the stopes, No. 2 tunnel; and 636 tons from No. 2 pit.

The results now being obtained in the mill are considered satisfactory by the company. The concentrates are pressed into bricks 8 in. by 4 in. by 2¼ in., weighing 7½ lbs. when burned. In the kilns the bricks are subjected to a maximum temperature of 2,200 F., and are of a sufficient hardness to stand transportation and smelting.

The machinery installed included a No. 86 Marcy mill, an 8 ft. by 36 in. Hardinge mill, a 4-mould No. 701 American clay machinery briquette press, and a 6 ft. by 6 ft. Oliver filter. Additional filters and moulds are being installed.

Quarries

Killarney.—Willmott and Company, of Toronto, sold their quartz quarry, located on Georgian bay, not far from Killarney, to Electro-Metals, Limited, of Welland. It was operated during the season of navigation by Willmott and Company, who had a contract for getting out the quartz. The shipments went to the ferro-silicon plant of Electro-Metals, Limited. Some changes and additions were made to the crushing and conveying machinery.

Dan Chisholm, of Killarney, was in charge, and employed 45 men.

Bruce Mines Trap Rock.—This quarry was operated until midsummer in 1917 by W. S. Edwards, trustee, of Sault Ste. Marie, Mich. The quarry was then shut down because boats to ship the product could not be procured.

E. Mitchell, Bruce Mines, was in charge; about 60 men were employed.

East Neebish Island.—This quarry, owned and operated by the Dominion Mines and Quarries, Limited, shipped 57,000 tons of quartz to Buffalo, N.Y., during the season of navigation. Additional equipment is to be added to enable the company to increase their shipments in 1918.

I. Appleton, of McLennan, was in charge; about 60 men were employed.

III.—DISTRICT OF TIMISKAMING

Gold

Boston Creek and Munro Township

Baldwin.—The Baldwin Gold Mining Company, Limited, owns the north half of lot 2 in the sixth concession of the township of Eby. The shaft and camps are located near the right-of-way at mileage 167½, T & N. O. railway. Work was carried out at intervals during the year and a vertical shaft sunk to a depth of 100 feet.

The plant included one 65-h.p. portable boiler; one 6 by 8 Jenckes hoist; and a small compressor, 300 cubic feet capacity.

Hugh Baldwin was manager of the mine, employing ten men.

Bourkes Mines.—Bourkes Mines, Limited, did considerable surface prospecting and trenching on their promising discovery near Bourkes station, in the first concession of Benoit township.

The vein strikes north about 20 degrees west, and when inspected on November 15th, 1917, had been open-cut for a distance of 100 feet, and in the vicinity of the original discovery showed considerable free gold.

It was the intention of the company to erect camps and diamond-drill during the winter.

The directors are: Charles Millar, Charles Gentles, and Archie Burton, all of Toronto; Alex. Gillies and John J. Byrne, Bourkes.

Burton-Munro.—Burton-Munro Mines, Limited, worked continuously during the year on their claims situated on the north half of lot 11, in the first concession of Munro township. The incline shaft was sunk to a depth of 318 feet, with stations at the 148 and 300-foot levels. On the first level 96 feet of cross-cutting and drifting was done, and on the bottom level 735 feet. Operations were suspended in February, 1918.

The head office address is 55 Yonge Street, Toronto. The officers and directors are: Charles Millar, president; Charles Gentles, Archie Burton. David Sloan was manager.

Croesus.—With the exception of a temporary shut-down in July, 1917, while the pumping capacity was being increased, the Croesus Gold Mines, Limited, worked continuously throughout the year. Underground development was practically confined to the 300-ft. level, where 700 ft. of cross-cutting and drifting was done. Ore stoped was produced on the two upper levels. The mine was closed down on February 15th, 1918. Julius Cohen, manager, resigned in September, 1917, to join the American overseas forces, and was succeeded by Charles Lobner, who had charge of operations until the mine closed in February.

The officers are: President, D. M. Steindler, New York; vice-president, Mortimer Davis, Montreal; secretary-treasurer, E. L. Steindler, Cobalt. The head office of the company is 42 Broadway, New York.

Hill.—The Hill Gold Mining Company own 160 acres in the township of Beatty, near Painkiller lake, and about seven miles from Matheson. Development began in the autumn of 1917 and a shaft was sunk to a depth of 125 feet. The plant includes two 60-h.p. boilers, one 25-h.p. boiler, and one Rand compressor, capacity 1,200 cubic feet.

A 70-ton mill is in course of erection, and will be ready for operation in the summer of 1918.

The officers are: President, W. H. Hill, Boston; directors, G. Smith, Boston; Senator Bowen, Providence, R.I.; and A. M. McEvoy. J. Hill is mine manager.

Murray-Mogridge.—The Murray-Mogridge Mining Company, Limited, own ten claims on lots four and five in the fifth and sixth concessions in the township of Maisonville. The mine is reached by wagon road from Bourkes station, T. & N.O. railway, a distance of four miles. The camp buildings are erected on the east shore of Wolf Lake.

The officers are: President, C. E. Jury, Toronto; vice-president, W. W. Sloan, Toronto; secretary-treasurer, C. J. Bielby, Toronto; head office, Union Bank Building, Toronto; directors in addition to above officers: F. C. Annesley, D. I. Grant, N. Schaeffer, all of Toronto; and J. J. B. Cooper, New York. Manager, G. G. Thomas, and mine captain, John McCallum.

Active development began on June 15th, 1917, and was continued to the end of the year. When visited in November the shaft had been sunk to a depth of 226 feet with working levels at 50, 100, and 200 feet.

A total of 250 feet of cross-cutting and drifting had been done on the three levels. Twenty-five men were employed.

Miller Independence.—Miller Independence Mines, Limited, carried on active development work throughout the year on their property, south half of lot 1, Concession VI., township of Pacaud. This was a veteran claim, originally owned by English interests, and purchased by F. M. Connell, of Toronto, when gold was discovered in 1915. The claim was then purchased by George J. Miller, of Ohio, who formed the above company. Several shafts have been sunk to varying depths, and the veins carried considerable values in free gold in many places. In the summer of 1918, a discovery was made near the north boundary which carries very

high values in tellurides and free gold, and a shaft designated as "D" shaft had been sunk to a depth of 100 feet in July, 1918. The vein at this point appears to have a definite east and west strike and dips to the south at about 40° from the horizon.

During the year "C" shaft was sunk to a depth of 110 feet, with levels at 44 feet and 100 feet. On the first level 200 feet of drifting was done, and on the 100-foot level cross-cuts were driven 112 feet to the south and 80 feet to the north.

A test mill run of 250 tons was made during the year.

The officers are: President, Geo. J. Miller; vice-president, N. W. Kirkpatrick, Dayton, Ohio; secretary, John C. Schaeffer, Germantown, Ohio; treasurer, Ed. Rettich, Germantown, Ohio; directors, O. B. Brown, Wm. Stroup, Geo. W. Ozias, J. A. Read, and J. A. Beagard, all of Dayton, Ohio.

Patricia Syndicate.—The property of the Patricia Syndicate, formerly known as the Boston-Hollinger, consists of two 40-acre claims in the north half of lot 3, in the sixth concession of the township of Pacaud, one mile south-east of Boston Creek station, on the Timiskaming and Northern Ontario railway.

The property was taken over under option by the Patricia Syndicate on August 15th, 1917.

The mine plant consists of two 50-h.p. locomotive boilers, one Canadian Ingersoll-Rand two-stage air compressor of a capacity of 500-cu. ft. of air per minute, and a Jenckes 6 by 8 hoist.

The work done to date has been confined to two of the 12 known veins; most of this work has been concentrated on the No. 7 vein, which is in the north central part of the west claim. This vein is in the Keewatin series, and strikes east with a dip of 74° south. It has been opened by trenching for a length of 700 feet and a two-compartment shaft has been sunk on it to 215 feet, with stations and pockets at the 100 and 200-ft. levels. On the first level 305 feet of drifting had been done to May 20th, 1918, and three stopes opened out above the level. The 200-foot level is now being opened up in the same manner. The vein consists of two and sometimes three sections of quartz with some calcite lenses on the foot and hanging-wall sides. The ore contains one or two per cent. sulphides, consisting mainly of chalcopyrite and chalcocite with patches of hornblende. The gold is for the most part free and is visible in much of the high-grade ore. The width of vein varies from 8 to 40 inches, with an average width of 26 inches of primary quartz.

The mill has been erected 225 feet north of the "A" shaft, and is now ready for operation. The ore is trammed from the shaft bin in one-ton cars, and as it enters the mill building is weighed on a Fairbanks scale. The ore is crushed in a 9 in. by 15 in. Blake-type crusher fitted with manganese jaw plates, and from there is elevated to the top of the 100-ton ore-storage bin. It passes through a trommel, which is fitted with a punched screen having one-inch openings, and the oversize returns to the crusher bin. From the storage bin it is fed by a belt-driven Challenge feeder to the feed box of the ball-tube mill. This mill is a 5 ft. by 6 ft. Allis-Chalmers type, fitted with cast-iron step-lifter liners. The ball charge is made up of 1, 1½, 2, and 3-inch balls, the total load being 7 tons. From the ball mill the pulp passes over a set of primary amalgamation plates to a Dorr

classifier, where the oversize is elevated to the feed box of the ball mill for further reduction. The undersize (minus 40-mesh) is sent over a set of secondary amalgamation plates and thence to three No. 6 Wilfley tables, where the sulphides are removed. The tailings are impounded for possible treatment at a future time. The concentrates are dried in a steam-drying pan and sacked for shipment to the smelter.

The mill has a capacity of 50 tons daily. Water is obtained from a small lake north of the mill.

Chas. A. O'Connell is manager, employing 50 men.

Kirkland Lake

Active development was carried on in the Kirkland Lake camp in 1917. Operations at the producing mines and development at the prospects received a decided impetus by the delivery of electric power early in the spring. Mill construction at the Kirkland Lake Gold Mines, Limited, operated by the Beaver Consolidated Mines, Limited, of Cobalt, was stopped after the foundations were in place in December, 1917, but it is stated that this mill will be completed during 1918. The Lake Shore company erected a 75-ton mill and made the first run on March 8, 1918.

Burnside.—Early in 1918, the Aladdin Cobalt Mining Company, Limited, acquired an interest in the Burnside Gold Mines, Limited, and began active development of the property adjoining the Tough-Oakes.

No. 2 shaft, 90 feet deep, was pumped out and re-timbered, and No. 3 shaft was down to a depth of 85 feet when visited in April, 1918.

Two upright boilers were installed for hoisting purposes, and air was supplied by the plant of Sylvanite Gold Mines, Limited. Charles Richardson, of the Aladdin Company, is manager.

Canadian Kirkland.—The Canadian Kirkland Gold Mines, Limited, own four claims in the township of Teck, known locally as the Killoran claims. Prospecting was started in January, 1917, under the direction of Robert R. Tough, and carried on throughout the year. Work consisted of trenching, sinking of test pits on several veins, and the erection of boarding camps. Rocks of the Cobalt series are found in this district, with the porphyry intrusives typical of the formation farther east.

When visited in March, 1918, surface prospecting was still being carried on, with the expectation of installing a mining plant in the summer of 1918.

The officers are: President, A. A. Amos, Cobalt; vice-president, George Tough, Haileybury; secretary-treasurer, G. T. Ware, Haileybury. The board of directors includes the above officers; W. E. Smith, Toronto, and B. G. Killoran, Haileybury.

Elliott-Kirkland.—Work was continued throughout the year on the two claims L1616 and L1617 in the township of Teck, owned by the Elliott Kirkland Gold Mines, Limited. On March 23rd, 1918, the shaft was 433 feet deep, with levels at 120, 220, 320, and 420 feet. The following work was done during the year:—

First level, cross-cutting 184 feet.

Second level, cross-cutting 60 feet.

Third level, cross-cutting 71 feet, drifting 158 feet.

Fourth level, cross-cutting to south 70 feet, drifting east 27 feet, drifting west 92 feet.

About 75 feet from the cross-cut in the west drift, fourth level, a well-defined vein carrying gold values was encountered in March, 1918. Considerable importance was attached to this discovery, as it extended the mineralized area for a considerable distance to the west.

The officers are: President, S. Harry Worth, Philadelphia; vice-president and managing director, R. H. Lyman, Cobalt; secretary, W. A. Gordon, Haileybury. The board of directors includes the above officers; John Wood, 801 Bank of Hamilton Building, Toronto, and E. W. Kearney, Haileybury. Thirty-five men were employed.

Fisher.—The Fisher Gold Mining and Milling Company, Limited (head office, Royal Bank Building, Toronto) did considerable surface trenching and development on their claims in Teck township. In November, 1917, camps were built and preparations were in progress for active development, shaft-sinking, and plant installation. Nothing further was done during the year.

The officers are: President, L. G. Glass, Montreal; secretary-treasurer, John A. Sullivan; manager, S. C. McLaughlin.

Kirkland Lake.—Before closing down, on December 31st, 1917, the Kirkland Lake Gold Mining Company, Limited, completed the main shaft to the 700-foot level, and performed a large amount of development work on the four lower levels. No. 2 shaft, which is more centrally located for mining purposes, was sunk to a depth of 150 feet. The foundations for a 100-ton mill were erected, three electrically operated Aldrich pumps installed, and everything left in readiness for development on a much larger scale when financial arrangements were completed.

Operations were in charge of Frank L. Culver and W. J. Moffatt, of the Beaver Consolidated Mines, Limited; Jay Elliott is resident superintendent, employing 60 men.

The Beaver Consolidated Mines, Limited, owns 1,743,050 shares of this company's stock. Approximately 8,000 tons of ore have been mined from development and are now on the surface ready for milling.

Kirkland Porphyry.—The Kirkland Porphyry Gold Mines, Limited, continued development of their property lying between the Teck-Hughes and Kirkland Lake mines. The shaft was sunk to a depth of 280 feet, and a small amount of cross-cutting and drifting done at the 150-foot and 280-foot levels. The vein was encountered at both levels, and values were sufficiently high to ensure further development. Twenty-five men were employed under the management of H. Cecil.

Lake Shore.—Active development was carried on throughout the year by the Lake Shore Mines, Limited. The main shaft was sunk to the 400-foot level, both No. 1 and No. 2 veins having been explored on this level.

Development work for the year ending November 30th, 1917, may be summed up as follows:—

Drifting and cross-cutting	200-foot level	2,000	feet.
" "	100 " "	200	"
" "	300 " "	250	"
" "	400 " "	180	"
Sinking shafts and sumps		150	"
Raising		85	"
	Total	2,865	feet.

Construction work on the new mill started September 1st, 1917, and the first run was made on March 8th, 1918. The ball and tube mill grinding plant has a capacity of 65 tons per day, and the cyanide end of the mill is equipped to treat 100 to 125 tons per day. The grinding capacity may be increased as desired without interference with the operations of the mill.

The officers are: President and managing director, Harry Oakes; vice-president, Arthur G. Slaght; treasurer, Dr. Conrad E. Wettlaufer; secretary, Kirkland Securities Corporation, Limited.

John W. Morrison was manager during the year. The mill was designed and built under the direction of D. J. Coffey, who succeeded Mr. Morrison as manager in April, 1918.

Minaker.—The Minaker Gold Mines, Limited, did a small amount of development on their group of claims lying south of the Lake Shore mine. No. 1 shaft was sunk to a depth of 45 feet, and No. 2 shaft to a depth of 25 feet.

Considerable surface trenching was performed. Work was in charge of T. J. Flynn, employing 5 men.

Sylvanite.—The Sylvanite Gold Mines, Limited, own the following claims in the township of Teck, adjoining the Tough-Oakes on the west: Nos. L 2100, 2101, 2256 and 2257.

A plant was installed in 1916 and mining operations resumed in April, 1917. Operations were suspended on the first of June, 1917, and since that date no work has been done. The plant consists of a 440-cu. ft. Ingersoll-Rand compressor, one 6 by 8 Jenckes hoist, one 75-h.p. motor and one 60-h.p. boiler.

A shaft was sunk to a depth of 120 feet, and 169 feet of cross-cutting and drifting done on the 100-foot level.

The officers of the company are: President, Harry Oakes; vice-president, Ralph Robbins, Timmins; secretary-treasurer, M. Green, 85 Bay Street, Toronto.

Work was in charge of J. W. Morrison, manager of the Lake Shore mine.

Teck-Hughes.—Development for the year ending August 31st, 1917, by the Teck-Hughes Gold Mines, Limited, was as follows:—

Shaft-sinking	200	feet.
Cross-cutting	775	"
Drifting	1,029	"
Winze-sinking	92	"
Stoping	2,495	"
Side-slicing	3,477	"

The mill treated 6,291 tons of an average value of $7.70, from March 24th, 1917, after the delivery of electric power, to September 1st, 1917. Proposed work

includes a supplementary steam plant for pumping and hoisting, steel shaft house and ore bins, addition to milling plant, and the erection of a number of dwellings for employees.

The main shaft is 400 feet deep, and a winze has been sunk to the 600-foot level.

The officers and directors of the company are: President, Chas. L. Denison, New York; vice-president, Robt. W. Pomeroy, Buffalo; secretary, A. D. Crooks, Toronto; treasurer, H. C. Clarke; Albert W. Johnston and J. F. Thompson, New York.

In February, 1918, L. W. Ledyard was succeeded as resident superintendent by Robert E. Dye, of Cobalt. Eighty men were employed.

Tough-Oakes.—The Tough-Oakes Gold Mines, Limited, has an authorized capital of 600,000 shares, par value $5 each, and is the pioneer producer of the Kirkland Lake camp.

During the year ending December 31st, 1917, underground development was as follows:—

Drifting	2,398.5	feet
Cross-cutting	1,500	"
Raising	496	"
Sinking	105	"
Total	4,499.5	"

Ore stoped amounted to 31,692 tons, and in addition 5,310 tons were produced from development.

During November, 1917, Charles A. O'Connell resigned as manager, and was succeeded by D. H. Angus, of Cobalt. C. E. Rodgers, formerly of the Trethewey mine, is resident manager.

Temiskaming Kirkland.—Prospecting of the Hohenaur claim in Teck township was started in November, 1917, by the Temiskaming Kirkland Gold Mines, Limited. The plant owned by the Temiskaming Mining Company, Limited, at the North Dome mine in Porcupine, was shipped to Kirkland Lake, and before operations were closed in February, 1918, the vertical two-compartment shaft had been sunk to a depth of 40 feet. The plant included one Sullivan compressor, capacity 420 feet, one 80-h.p. return tubular boiler, one 40-h.p. locomotive type boiler, one 8 by 10 Lidgerwood hoist, one 5 by 7 Jenckes hoist, and one 120-volt, Allis-Chalmers generator for lighting purposes.

Work was in charge of William Cooper, of the Temiskaming Mining Company.

Wright-Hargreaves.—The Wright-Hargreaves Mines, Limited, employed an average of 35 men during the year on development work. No. 2 shaft was sunk from the 100-foot level to 320 feet, and No. 3 shaft, which at last report was 100 feet deep, was sunk to the 300-foot level.

A new Ingersoll-Rand compressor, capacity 1,165 cubic feet, was installed during the year.

The officers are: President, Oliver Cabana, Jr.; vice-president, Edwin Lang Miller; secretary-treasurer, Gerhard F. Miller; manager, Albert Wende.

United Kirkland.—United Kirkland Gold Mines, Limited, was organized in the summer of 1917 to develop the Ellis and Dodge claims in the township of Teck. A vertical shaft was sunk to a depth of 90 feet by the contractor, James Harkness, and 23 feet of cross-cutting done at the 90-foot level. Camps were erected and considerable surface trenching and prospecting performed to determine the strike and character of the vein system. Operations were suspended in December, 1917, shortly after the completion of the shaft contract.

The head office of the company is at Haileybury. H. A. Day is secretary-treasurer, and the directors are: W. G. Ellis, Swastika; H. A. Day, Haileybury: Levi Dodge, Englehart; Edward Kert, Smooth Rock Falls.

Associated Goldfields.—The Associated Goldfields Mining Company, Limited, formerly Goldfields, Limited, operated continuously throughout the year 1917. The head office is at 12 King Street East, Toronto, and the officers are: Managing director, George A. MacKay; secretary-treasurer, Howard Webb; mine superintendent, Frederick MacCoy.

In 1914 the claims of the Reddick Gold Mining Company, Limited, were purchased. These claims lie about nine miles northeast of the Goldfields mine. Very little development has been done on the Harris-Maxwell claims. A shaft, inclined at 30 degrees from the horizontal, has been sunk to a depth of 85 feet. From this point the shaft is vertical, and when visited in October, 1917, had been sunk to a depth of 360 feet below the tunnel level, or 425 feet from the surface.

Electric power developed at Raven Falls, 13 miles from the mine, is supplied on a 3-wire (three-phase) system, 13,200 volts, transformed at the mine to 550 volts.

The mill equipment at the Harris-Maxwell mine includes 30 Jenckes stamps and three jaw crushers. The Reddick mine shaft is 90 feet deep, and it was the intention of the management to develop this property during 1918. The plant was repaired and a new compressor, 2,000 cubic feet capacity, installed during the winter.

Porcupine

Ankerite.—The Ankerite Gold Mines, Limited, continued active development of their claims in Deloro township. Originally three claims, ME 60, 61 and 62, were being developed, but during the year the company acquired the Maidens-Macdonald property, under option to the La Rose Company till March, 1917, and also an additional claim south of the Maidens-Macdonald. When visited on January 31st, 1918, a vertical, 3-compartment shaft had been sunk to a depth of 230 feet, and 68 feet of cross-cutting done at the 200-foot level.

The sinking contract was let to the E. J. Longyear Company.

The Ankerite Gold Mines property is owned by the Coniagas Mines, Limited, of Cobalt.

Clifford E. C. Smith is manager of the company.

Davidson.—The Davidson Gold Mines, Limited, continued during the year development of their property near South Porcupine, on lot 2, in the fifth concession of Tisdale township. The main shaft is 312 feet deep with three working

levels. The mine was closed from June, 1917, till January 18th, 1918, and during this interval 500 feet of diamond-drilling was done, chiefly on the first and third levels. A ten-stamp mill was purchased from the Eureka mine, Wine Harbour, Nova Scotia, and erected near the main shaft. Early in 1918 the mill was put in operation. Recovery is made by straight amalgamation.

From May 1st to August 20th, 1917, C. E. Rodgers was manager, and during the balance of the year F. D. Henderson had charge of operations.

Dome.—The Dome Mines Company, Limited, has an authorized capitalization of $5,000,000, of which $4,000,000 has been issued.

The officers of the company are: J. R. DeLamar, president and treasurer; W. S. Edwards, first vice-president; C. D. Kaeding, second vice-president; H. P. DePencier, third vice-president; Alex. Fasken, secretary; Alfred H. Curtis, assistant-secretary and assistant-treasurer. The directors are: J. R. DeLamar, W. S. Edwards, Alex. Fasken, G. C. Miller, J. S. Wilson, A. H. Curtis, Andrew V. Stout, J. S. Bache. The head office of the company is at 36 Toronto Street, Toronto. C. D. Kaeding is general manager.

One dividend, amounting to $100,000, was paid in June, 1917.

The seventh annual report of the company, covering operations for the fiscal year ending March 31st, 1918, divides the year into two periods, one of eight months during which the mill was kept running, and four months when the mill was shut down and development work only was carried on. During the year a total of 258,917 tons was mined and hoisted; of this, 247,000 tons was ore which was sent to the mill and treated, and 11,917 tons was waste which was dumped on the surface. In addition to the above 101,352 tons was mined and remained in shrinkage stopes. The 247,000 tons of ore treated in the mill yielded bullion worth $1,030,758.30, the average yield per ton being $4.173.

On December 1st, 1917, operations in the mill and mine were discontinued, and the main shaft equipped for sinking. On May 20th, 1918, the shaft had reached a depth of 1,200 feet, sinking from the 850-foot level. A large ore and waste pocket and loading station were cut at the 960-foot levels, and stations established at the 1,000 and 1,150-foot levels. Ore reserves as at March 31st, 1918, are estimated at 1,950,000 tons at $5.10, or $9,945,000.

A summary of the development done during the year ending March 31st, 1918, is as follows:—

Level	Drifts	Cross-cuts	Raises	Box Holes	Shafts	Stations	Pockets	Total	Diamond Drilling	Total
	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.
1st	.....	136.5	.....	.....	.....	.....	.....	136.5	.....	136.5
3rd	253.0	.....	.....	21.0	.....	.....	.....	274.0	1,390.5	1,664.5
4th	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
5th	178.5	12.0	111.0	93.5	.....	.....	.....	390.0	1,416.0	1,806.0
6th	262.5	254.0	206.5	103.5	.....	.....	.....	826.5	967.0	1,793.5
7th	532.5	883.5	218.5	346.0	.....	.....	.....	1,980.5	1,710.5	3,691.0
8th	1,370.5	663.0	61.0	.....	.....	.....	66.0	2,160.5	1,848.5	4,009.0
9th	.....	.....	.....	.....	.....	22.0	.....	22.0	.....	22.0
Shaft	.....	.....	.....	.....	178.0	.....	.....	178.0	.....	178.0
Totals	2,592.0	1,949.0	497.0	564.0	178.0	22.0	66.0	5,968.0	7,332.5	13,300.5

During the early part of the year, work was carried on in the Dome Extension, the No. 609 drift being carried ahead a total distance of 29.5 ft. to a point 240.5 ft. across the dividing line of the two properties, where 17.5 ft. of cross-cutting and 26 ft. of raising was done to make a drill station. A total of 1,755 ft. of diamond-drilling was done from underground, mostly toward the ore located south of the porphyry mentioned in the sixth annual report of the company. Four holes totalling 975.5 feet were drilled on the hill to the north of the Dome Extension shaft, but no indication of ore or payable zones was obtained from this work.

Dome Lake.—The Dome Lake Mining and Milling Company, Limited, operated their mine and mill continuously during 1917. Underground development was as follows:—

Drifting	927 feet.
Cross-cutting	304 "
Raising	45 "
Winzing	184 "
Diamond-drilling	3,904 "

The mill treated 16,388 tons during the year, having a gold value of $68,213.99 from which was recovered in bullion $45,029.56, representing an extraction of 66 per cent.

The cost of milling was $1.857 per ton and of mining exploration and development $4.957 per ton.

The 66 per cent. extraction was made by plate amalgamation only.

The officers are: President, George Taylor; vice-president, A. A. McKelvie; directors, T. McCamus, C. L. Sherrill, S. S. Ritchie, F. L. Bapst, S. J. Dark; secretary-treasurer, F. L. Hutchinson; consulting engineer, Douglas A. Mutch; manager, R. T. Regnell.

Hayden.—The Hayden mine, in Ogden township, operated by the Hayden Gold Mines, Limited, was closed most of the year. A vertical two-compartment shaft has been sunk to a depth of 375 feet, with working levels at the 100, 200, and 300-foot levels. The mine closed in May, 1917, and work after that date was confined to diamond-drilling.

W. H. Hayden, 101 North Street, Batavia, N.Y., is president of the company, and W. D. Spaulding, 509 Brisbon Building, Buffalo, N.Y., is secretary-treasurer. William Shovel was mine manager.

Hollinger Consolidated.—Hollinger Consolidated Gold Mines, Limited, has an authorized capital of $25,000,000, divided into 5,000,000 shares of par value $5 each. Outstanding shares January 1st, 1918, amounted to 4,920,000.

The officers are: President, Noah A. Timmins, Montreal; secretary-treasurer, David A. Dunlap, Toronto; managing director, P. A. Robbins; directors, Noah A. Timmins, L. H. Timmins, David A. Dunlap, John B. Holden, P. A. Robbins, and Jules R. Timmins. John McMartin, Cornwall, formerly vice-president and one of the founders of the company, died in April, 1918.

The following statistics regarding the operations for the year 1917 are taken from the company's seventh annual report:—

During the year 508,139 tons of ore were milled, yielding $4,261,938.72; $738,000 was paid in dividends. $1,202,854.97 was paid out for labour and $1,003,332.57 for stores. Total costs, including mining, milling and general charges, amounted to $4,439 per ton of ore milled. The average value per ton of ore milled was $8.67. Mine development amounted to 29,696 feet, as follows: —

Levels	Shafts	Drifts	Cross-cuts	Raises	Diamond Drilling	Timbering	
						Shafts and Winzes	Stopes
	ft.	ft.	ft.	ft.	ft.	ft.	ft.
100	.....	.....	.....	192	129	.....	521
200	.....	2,929	2,778	342	3,200	.....	2,177
300	.....	2,146	1,093	828	1,288	.....	1,660
425	125	2,908	3,927	1,152	1,414	175	3,043
550	232	1,716	829	233	947	233	1,282
675	221	1,555	986	345	1,022	218	120
800	66	1,451	2,489	265	24	185	30
950	.....	33	42	.....	.....	.....	6
1,100	.....	112	184	.....	.....	.....	.....
1,250	.....	124	393	.....	.....	.....	.....
Totals....	644	12,974	12,721	3,357	8,024	811	8,839

The stoping record for the year is shown in the following table:—

Levels	Broken ore in stopes Jan. 1st, 1917	Ore broken during 1917	Ore removed during 1917	Broken ore in stopes Dec. 31, 1917
	Tons	Tons	Tons	Tons
100	4,291	.....	3,026	1,265
200	72,292	105,479	84,047	94,354
300	36,663	143,555	157,966	22,252
425	82,713	162,148	129,965	114,896
550	10,590	37,908	24,917	23,581
675	.....	313	313	.....
800	.....	49	49	.....
Totals	207,179	449,452	400,283	256,348

The estimated gross value of ore reserves at December 31st, 1917, amounted to $40,231,435. The average number of men employed during the year was 1,045.

Keora.—The Keora mine is located on lot 6, in the Sixth Concession of the township of Whitney, and is owned by the Porcupine Keora Mining Company, Limited. Development consists of two shafts, one vertical 120 feet deep, and one incline 60 feet deep. Work during 1917 was confined to diamond-drilling, 2,312 feet being completed.

A. J. Brandt, South Porcupine, is general manager, and William B. Gunton, 304 Confederation Life Building, Toronto, secretary-treasurer.

McIntyre.—During the year ending June 30th, 1918, the McIntyre Porcupine Mines, Limited, milled 178,327 tons of ore, with a gold production of $1,717,309.88.

Underground development for the 12 months' period is shown in the following table:—

—	Pockets	Stations	Shafts	Sumps	Drifts	Cross-cuts	Raises	Winzes	Total	Diamond Drilling
July 1, 1917 to June 30, 1918	75.0	92.9	423.5	9.6	4,686.1	1,196.5	346.0	63.0	6,892.6	6,987.0
Total prior to July 1, 1917	....	997.1	4,786.6	131.7	22,540.0	11,304.8	4,497.4	393.2	44,651.0	19.920.2
Total to date..	75.0	1,090.0	5,210.1	141.3	27,226.1	12,501.3	4,843.4	456.2	51,543.6	26,907.2

The Jupiter shaft was completed to the 1,000-foot level, and the drift on this level to connect the main shaft with the Jupiter was driven 1,300 feet. At this point, about 1,000 feet from the Jupiter shaft, in the quartz-porphyry formation, heavy water was encountered and the drift was abandoned until an adequate pumping plant could be installed.

From the Jupiter shaft at the 475-foot and 1,000-foot levels, cross-cuts have been driven into the Plenaurum ground. In July, 1918, the cross-cut at the 1,000-foot level had been driven 250 feet in Plenaurum ground, and it was the intention of the management to diamond-drill from both the 475 and 1,000-foot levels. Two new electrically driven hoists were installed during the year. At No. 5 shaft, a Nordberg was ready for operation in July, 1918, and the headframe raised ten feet to permit of greater clearance and allow for installation of an 84-inch sheave. At the Jupiter shaft a large Welster, Camp and Lane hoist has been installed.

In the mill a duplicate clarification system has been added to the equipment.

A modern dry house to accommodate 250 men has been built at No. 5 shaft, and electric haulage installed on the 1,000-foot level.

The officers of the company are: President, J. P. Bickell; vice-president, Sir Henry M. Pellatt; secretary-treasurer, M. P. Van der Voort, all of Toronto; directors, W. J. Sheppard, Waubaushene, J. B. Tudhope, Orillia; E. F. B. Johnston, Toronto; H. D. Symmes, Niagara Falls; general manager, R. J. Ennis; mine superintendent, J. E. McAllister; mill superintendent, A. Dorfman.

An average of 332 men was employed during the year.

Newray.—The Newray Mines, Limited, operating the Rea property in Tisdale township continued development work chiefly on the 400-foot level, till November 1st, 1917. During this period the cross-cut on the 400-foot level was driven 1,150 feet in a southeasterly direction. The property was then optioned to the Porcupine Crown Mines, Limited, and work was continued by them until February 1st, 1918. The Porcupine Crown Company did about 700 feet of diamond-drilling and 600 feet of drifting, and abandoned their option.

On May 1st, 1918, the McIntyre Porcupine Mines, Limited, acquired an option and began sampling operations. Due to labour conditions, underground work was stopped on June 20th, 1918. The mill was operated for three months during the year by the Newray Mines Company, and from June 24th, 1918, to July 20th, 1918, by the McIntyre Company.

The officers of the Newray company are: President, Dr. Bixby, Buffalo, N.Y.; vice-president, Henry Tudor, New York; secretary-treasurer, J. E. Day, Toronto; managing director, C. P. Charlebois.

Night Hawk.—About eight miles south of Connaught station, on the Porcupine branch of the T. & N.O. railway, in the township of Cody, the Porcupine Night Hawk Mining Company, Limited, continued the development and prospecting of their claims on Night Hawk lake. A vertical shaft has been sunk to a depth of 90 feet, and 380 feet of cross-cutting and drifting done at the bottom level. During the year 500 feet of diamond-drilling was completed. The plant includes one compressor, capacity 300 cubic feet, one Jenckes 5 by 7 hoist, 2 locomotive boilers, 60 and 80-h.p.; blacksmith shop and camps. Work was carried on continuously during 1917 till October 1st, when operations were suspended because of high operating costs and shortage of labour.

The officers are: President, O. B. Wilcox, New York; treasurer, J. H. Black, Toronto; directors, Charles Auer, Timmins, and F. D. Forbush, Detroit. William Watson was mine manager.

North Davidson.—The North Davidson Gold Mines, Limited, did 1,500 feet of diamond-drilling on their property on lot 3, in the sixth concession of Tisdale township.

A wagon road was also partly completed between the Davidson mine and the North Davidson claim.

The officers are: President, R. T. Jeffrey; managing director, L. G. Harris, Royal Bank Building, Toronto.

F. D. Henderson was in charge of operations at the property, and the company planned to sink a 300-foot shaft during the summer of 1918.

McEnaney.—McEnaney Gold Mines, Limited, operated at intervals during the year. The property was formerly known as the Hollinger Reserve, and is located on lots 2 and 3, in the fifth concession of Ogden township. Development during 1917 included 250 feet of drifting and cross-cutting on the 100-foot level, sinking winze east of the shaft from 300-foot level to 440-foot level, and raising from the 200 to 100-foot level. The mine was de-watered in January, 1917, and operations were suspended in September, 1917. Work was resumed on November 1st and again closed on February 12th, 1918.

The late Bernard McEnaney was president of the company and principal owner of the property. William Sixt was mine manager.

Porcupine V.N.T.—During 1917, underground operations by the Porcupine V.N.T. Gold Mines, Limited, were confined to the North Thompson section, from which 27,805 tons of ore were mined. No ore was produced from the Vipond section, operations there being postponed until the connection has been completed

between the North Thompson and Vipond shafts at the 600-foot level, when the underground operations will be centralized at one shaft. The mill on the Vipond property was run continuously, producing 19,360.27 ounces of bullion, worth $205,914.29. A new electrically driven Ingersoll-Rand compressor, capacity 7,050 cubic feet, was installed. A new transformer station was built on the North Thompson section of the property of sufficient capacity for all the power that will be required in the future. During the early part of the year operations were greatly hindered by the uncertain labour conditions.

The company has an authorized capital of 3,000,000 shares of par value $1.00.

The officers are: President, H. H. Ward, New York; vice-presidents, F. H. Hamilton and P. W. Furber, London, England; secretary-treasurer, R. J. Ward, New York; directors, R. T. Shillington, Haileybury; James J. Hill, St. Paul; D. J. Jackson, New York; Henry Pellatt, Toronto. N. J. Evered, Box 189, Timmins, is general manager, and the head office of the company is 50, East 42nd Street, New York.

Porcupine-Crown.—Porcupine-Crown Mines, Limited, has an authorized capital of 2,000,000 shares of $1 par value each. The officers are: President, John W. Carson; first vice-president, William I. Gear; 2nd vice-president, James G. Ross; secretary-treasurer, James Cooper, all of Montreal. The directors include the above officers and C. A. Smart, J. W. Ross, A. G. Gardner, F. S. Meighen, Ziba Gallagher, and R. W. Reford. S. W. Cohen is general manager and Maurice W. Summerhayes, manager.

During 1917, 32,722 tons of ore were milled of an average value of $10.97. The net value of the production after deducting charges was $363,793.34.

The underground development during the year was practically all done below the 500-foot level. Ore reserves at the close of the year were estimated to be about 60,000 tons.

No dividends were paid after July 1st, owing to curtailment of production. For the first half of the year dividends amounting to $120,000 were paid, bringing the total amount paid in dividends to date $840,000.

Premier.—Porcupine Premier Gold Mines, Limited, operated their mine on lot 6, in the sixth concession of Deloro township, for the first half of the year only.

No. 1 shaft was completed to the 200-foot level, and a cross-cut driven to the south 170 feet, at which point a promising vein was encountered. No. 2 shaft was raised from the 100-foot level to the 60-foot, giving an auxiliary exit from the 100-foot level to the surface.

The officers are: President, George W. Field; secretary, Frank J. Wright, both of 19, Congress Street, Boston, Mass.; general manager, A. S. Fuller, South Porcupine. B. M. Walton is mine superintendent.

Rypan.—The Rypan Porcupine Mines, Limited, began work on their four claims in Deloro township on May 15th, 1917. Prospecting by surface trenching and open-cuts on the outcrops continued till August 23rd, 1917, when operations were suspended.

The officers are: President, John Patterson, Toronto; secretary, J. W. Ryder, Toronto. C. L. Heath was in charge of the development.

Schumacher.—The Schumacher Gold Mines, Limited, has an authorized capital of 2,000,000 shares of par value $1 each.

The officers are: President, F. W. Schumacher; vice-president, F. L. Culver; secretary-treasurer, J. Y. Murdoch; manager, T. J. Harwood.

For the year ending March 31st, 1918, the following development was performed:—

Drifting	1,420 feet.
Cross-cutting	1,096 "
Raising	178 "
Diamond-drilling	705 "
Stoping	36,446 tons.

Shortage of labour resulted in the mine and mill being closed from June 26th to August 20th, 1917. During the remaining ten months of the year the mill treated 39,822 tons of ore, with a production of bullion valued at $202,387.35. Extensive additions and improvements were made in the mill, involving an expenditure of $39,554.90; additions to mining plant cost $13,090.59.

Stanley A. Wookey resigned as manager to enlist with the Canadian Engineers, and was succeeded by T. J. Harwood, formerly of La Rose mine.

West Dome.—West Dome Consolidated Mines, Limited, worked continuously throughout the year. Total development at the several shafts to March 15th, 1918, was as follows:—

No. 1 or main shaft, 358 feet deep on incline;
100-foot level, cross-cutting 645 feet;
300-foot level, cross-cutting 1,457 feet, drifting 2,352 feet.
No. 3 shaft, 115 feet deep, vertical; cross-cutting 300 feet; drifting 180 feet.
No. 4 shaft, 98 feet deep, vertical; drifting 15 feet;
No. 2 shaft, 30 feet deep, vertical;
Central shaft, 35 feet deep, vertical.

During 1917, work was practically confined to development at the 300-foot level of the main shaft, and the sinking of the new central shaft to a depth of 35 feet. In the spring of 1918 stoping was commenced on the 300-foot level, main shaft, and about 600 tons were broken. Of this amount 300 tons were hauled to the Dome Lake mill, during the month of May, 1918, and a test mill-run made.

The officers are: President, Henry Pellatt; secretary-treasurer, C. H. Manaton, Traders' Bank Building, Toronto; consulting engineer, Frank G. Stevens, Toronto. The manager, W. J. Trethewey, was succeeded in February, 1918, by Frank Hamilton, formerly mine captain.

Thirty-five men were employed during the year.

Whelpdale.—The Whelpdale mine is situated near Timmins, and comprises the Whelpdale veteran claim of 160 acres, being the north half of lot 11, in the third concession of Tisdale township. Development in the early stages was carried on by the Porcupine Whelpdale Mining Syndicate. Late in 1917 the Porcupine Whelpdale Mines, Limited, was organized, with the following officers: President, J. A. Kilpatrick, Toronto; vice-president, Frank P. Jones, Montreal; secretary-treasurer, B. J. Simons, Toronto; directors, George Tamblyn, R. M. Gray, J. O.

Gadsby, S. B. Dawson, C. M. Dineen, R. L. Marks, all of Toronto. The head office address is 910 and 911 Royal Bank Building, Toronto, and H. Max Guenther, Box 391, Timmins, is manager. When inspected on February 13th, 1918, a vertical shaft had been sunk to a depth of 114 feet, with a station at the 100-foot level. About 30 feet of cross-cutting had been driven at this level.

Miscellaneous Mines

Alexo Nickel.—During 1917, the Alexo Mining Company, Limited, shipped 6,003.3 tons of nickel ore to the Coniston smelter of the Mond Nickel Company. The company own five claims in the townships of Clergue and Dundonald, the chief development being in the N.E. quarter of S. half of lot 1, concession III., township of Clergue, about two miles from Porquis Junction, on the Timmins branch of the T. & N. O. railway.

The officers of the company are: President, G. F. Hanning, Toronto; vice-president, Major E. F. Pullen, France; treasurer, H. N. Roberts; director, Capt. F. Pullen; manager, William Anderson.

During 1917 the main shaft was sunk from the 125-foot level to a depth of 326 feet, and about 70 feet of drifting done at the bottom level. All the production came from the 125-foot level.

The plant consists of one locomotive type 60-h.p. boiler, one upright 30-h.p. boiler, one Canadian Westinghouse compressor, and one 6 by 8 Jenckes hoist.

The decreased production during the year was due to car shortage.

Premier Langmuir Barite.—The Premier Langmuir Mines, Limited, own seven patented claims in the township of Langmuir, on the east branch of the Night Hawk river. By water route the property is 30 miles from Connaught station, on the T. & N. O. railway.

The geology of this deposit has been fully described in previous reports of the Bureau of Mines, and it is the only mine in the Province producing barite on a commercial scale. A vein of barite, varying from 5 to 10 feet in width, has been traced for a distance of 1,000 feet on the property. A tunnel, driven on the vein for a distance of 100 feet, shows native silver in several places. When inspected on February 1st, 1918, a shaft had been sunk at the portal of the tunnel to a depth of 55 feet, and it was the intention of the management to sink to the 120-foot level and develop the ore body there.

The officers are: President, J. A. McIntosh, 454 Markham Street, Toronto; secretary-treasurer, J. B. Aikenhead, London, Ontario; mine manager, Charles W. Dalby.

An average of 17 men was employed during the year.

Colorado Ontario.—In the spring of 1918, the Colorado Ontario Development Company began active exploration and development of the Otisse and Robb gold claims in Powell township. A wagon road was built from Elk Lake to the claims, a distance of 30 miles, and supplies were taken in for the summer. Diamond-drilling started May 21st, 1918.

Walter J. Boland, No. 2 Toronto Street, Toronto, is secretary-treasurer of the company, and T. J. Flynn, superintendent.

Cobalt Silver Mines

Adanac.—The Adanac Silver Mines, Limited, worked continuously throughout the year on their property in southeast Coleman, formerly known as Pan Silver.

Work was practically confined to the 310-foot level, cross-cutting north to encounter veins discovered by diamond-drilling. In April, 1918, the cross-cut heading was 500 feet from the shaft. Developments proved satisfactory to the owners and will be continued during 1918.

The officers are: President, R. A. Cartwright; vice-president, E. N. Campbell; treasurer and managing director, Morgan R. Cartwright, Haileybury; secretary, James Aitchison, Toronto; directors, R. A. Cartwright, E. N. Campbell, Morgan B. Cartwright, J. L. Wheeler, Marion, South Carolina, and A. B. Hind.

Aladdin.—The Aladdin Cobalt Company, Limited, operated continuously throughout the year. Work was confined to No. 4 shaft of the Chambers-Ferland, west of the railway, and the discovery of several promising ore shoots materially added to the production.

Development during the year was as follows:—

Drifting and cross-cutting	2,323 feet.
Sinking	113 "
Stoping	3,970 cubic yards.

The greatest production came from stoping operations, on an extension of No. 15 vein, 275-foot level.

The ore was milled at the Northern Customs concentrator.

The officers are: President, Major Conrad Jorgenson; secretary-treasurer, F. F. Fuller; directors, Major Charles Gold, Dennis Herbert, H. B. Sedgwick, all of London, England; Canadian advisory board, Charles A. Richardson, Arthur Ferland, and R. T. Shillington, all of Haileybury; Alex Fasken, Toronto, secretary.

Head office for Canada, Excelsior Life Building, Toronto. J. A. McVichie, Cobalt, is manager of the company.

Beaver.—Beaver Consolidated Mines, Limited, has an authorized capital of 2,000,000 shares, of par value $1 each. The officers are: F. L. Culver, President and general manager; F. C. Finkenstaedt, vice-president; H. E. Tremain, secretary-treasurer. The directors are: F. L. Culver, F. C. Finkenstaedt, F. L. Lovelace, Wm. T. Mason, Wm. E. Stevenson, H. E. Tremain, J. H. Black. Head office, Lumsden Building, Toronto. The following is a synopsis of development during the year ending February 28th, 1918:—

Drifting	2,245.1 feet.
Cross-cutting	1,453.3 "
Sinking	75.1 "
Raising	1,178.4 "
Total	4,951.9 "
Stoping	4,187.7 cubic yards.

Most of the work during the year was done on No. 2 and No. 3 vein systems. The annual report of the company states that in No. 2 vein system a body of ore has been opened up which has greatly augmented the ore reserves of the mine. Regarding development on the 1,600-foot level, the annual report states as follows:—

"Milling values have been proven for a distance of 67 feet below the 1,600-foot level by sinking a winze on the vein. Anticipating that the highest values would be found at or near the contact between the diabase and Keewatin formations, the vein was followed up by a raise for 147 feet above the 1,600-foot level and milling values established for this distance. However, not having reached the contact on account of the dip of the sill, and the expense of raising beyond this point, together with the danger attached thereto being very great, work was discontinued in this raise and a cross-cut is being driven from the main shaft on the 1,400-foot level to intercept the vein in hopes of locating the contact at or about this point."

The total production for the year amounted to 372,973 ounces of silver.

The Beaver Auxiliary property was not worked during the year.

Buffalo.—The Buffalo Mines, Limited, operated continuously during the year. Underground operations were as follows:—

—	Raising	Drifting	Stoping
	ft.	ft.	cubic ft.
1st Level	.....	265	200,500
2nd "	295	375	251,700
3rd "	20	140	.....
Total	315	780	452,200

The tonnage broken in raising was 1,312 tons, in drifting 2,275 tons, and in stoping 37,683 tons. Total tonnage broken 41,270, less waste rock 800 tons. Net ore tonnage, 40,470 tons.

The above figures are for the fiscal year ending April 30th, 1918. For the eleven-month period ending March 31st, 1918, there were recovered in jig and table concentrates, 280,790 ounces of silver, and in flotation concentrates from the treatment of 82,328 tons of sand, 356,361 ounces of silver, making a total of 637,151 ounces. The Holt-Dern furnace installation for the treatment of flotation concentrates was abandoned early in the year, and the concentrates were thereafter shipped to Denver.

The officers are: President, Charles L. Denison, New York; vice-president, Robt. W. Pomeroy, Buffalo, N.Y.; 2nd vice-president, Harland B. Crandall, New York; secretary-treasurer, George C. Miller, Buffalo; director, Albert W. Johnston, New York. Tom R. Jones, Cobalt, is general superintendent.

Casey-Cobalt.—The Casey-Cobalt Silver Mining Company, Limited, continued active development of their mine in Casey township throughout the year. Until March 5th, 1917, work was confined to de-watering and repairing No. 6 shaft, and reconstructing the surface plant destroyed in the fire of August 22nd, 1916. The following progress was made underground:—

Stoping	10,932 cubic feet.
Development	774 lineal feet.
Exploration	1,723 " "

A concentrating mill was built during the winter of 1917-18 and put in operation in March, 1918.

The average number of men employed from March, 1917, to the close of the year was 59.

The officers are: President, W. R. P. Parker; vice-president, J. P. Watson; secretary, W. W. Perry, all of Toronto. Head office, 1,514 Traders' Bank Building, Toronto; manager, John W. Shaw, New Liskeard.

Casey Mountain.—The syndicate operating the Casey Mountain Mining Company, Limited, on lot 6, in the second concession of the township of Casey, continued development during the greater part of 1917. A cross-cut on the 345-foot level was driven about 90 feet, when operations were suspended to permit of diamond-drilling underground.

The officers of the operating syndicate are: President, J. D. Martin, Regina; vice-president, H. M. Richardson, Fort Qu'Appelle; secretary-treasurer, A. J. Cameron, Regina; directors, Geo. Speers, Regina; A. Cunningham, Moose Jaw; manager, R. G. Williamson, Judge P.O., Ontario.

The Toronto office is 115 Stair Building, Toronto, and Wm. A. Staples is secretary-treasurer; R. G. Williamson, president, and James Thompson, Havelock, vice-president.

Coniagas.—The Coniagas Mines, Limited, has an authorized capital of 800,000 shares of par value $5 each. The officers are: President and general manager, R. W. Leonard; vice-president, Alex. Longwell; secretary-treasurer, J. J. Mackan; superintendent, Fraser D. Reid. Included with the above officers on the board of directors are: R. P. Rogers, F. J. Bishop, R. L. Peek, and W. D. Woodruff. Head office is at St. Catharines, Ontario.

The total distribution in dividends to the shareholders to date aggregates $8,740,000.

For the year ending October 31st, 1917, underground development was confined to the following of small veins and stringers on all levels, exploring the contact on the eastern boundary and driving numerous cross-cuts through unexplored areas. This work disclosed some patches of high-grade and a considerable tonnage of low-grade milling ore. The further discovery of ore shoots of any importance is considered unlikely, as practically all the mine has been prospected.

Statistics of mine development are:—

	Total to Oct. 31, 1917	Total to Oct. 31, 1916	Work during 1916-17
	ft.	ft.	ft.
Shaft-sinking	879	875	4
Drifting	18,834	17,611	1,223
Cross-cutting	10,295	9,527	768
Winzing	632	632	.....
Raising	1,396	1,067	329
Total	32,036	29,712	2,324

Total ounces of silver shipped to Thorold during the year, 1,344,267.43.

The concentrating mill treated 60,929 tons, or an average of 3.07 tons per stamp per 24 hours.

The Callow flotation plant was put in operation February 6, 1917, and has effected a material reduction in the value of the mill tailings. Ore reserves at October 31st, 1917, were estimated to contain 4,487,590 ounces of silver.

An average of 110 men was employed during the year.

Crown Reserve.—The Crown Reserve Mining Company, Limited, has an authorized capital of 2,000,000 shares, of a par value of $1 each. The officers and directors are the same as for the Porcupine Crown Mines, Limited. S. W. Cohen is general manager and J. H. Stewart, mine superintendent.

During the year 1917 the production amounted to 329,670 ounces, making the total production of the mine 19,690,676 ounces.

Underground development was as follows:—

Sinking and raising	354 feet.
Drifting	1,849 "
Cross-cutting	595 "

At the Cochrane mine 938 feet of development was driven at the 550-foot level, practically all on the vein. Good ore was encountered in several places in this development, and some spots of high-grade were found. The work demonstrated that the probabilities of opening up ore of commercial value were limited, and work was discontinued.

The Drummond Fraction was operated only part of the year, owing to severe weather and shortage of labour.

About 400 feet of development was done on the Silver Leaf lease, at the 300-foot level on the extension of the north vein of the Crown Reserve mine. Milling ore of fair grade was opened up.

Dickson Creek.—The Dickson Creek Mining Company, Limited, operated the first two months of the year on their property, lots 9 and 10 in the fifth concession of Bucke township. Work was confined to shaft-sinking. In March, 1918, operations were resumed, and on May 21st, 1918, the shaft had been sunk to a depth of 160 feet.

The company is composed of London, England, capitalists. H. Holland-Hurst, Haileybury, is manager.

Dominion.—The Dominion Reduction Company continued to operate the Dominion mine, formerly known as the Nova Scotia. Work—wall-slashing for mill rock—was confined chiefly to the main or Bilsky vein. At No. 3 shaft, 150 feet of drifting was done at the 75-foot level.

Fifteen men were employed during the year.

Dominion Reduction.—The 40-stamp custom mill operated by the Dominion Reduction Company worked continuously throughout the year. Ore, treated as in previous years, was supplied chiefly by the Kerr Lake and Crown Reserve mines, with small tonnages from the Chambers-Ferland and Hargrave. For the fiscal year ending September 30th, 1917, 56,558 tons of ore were milled, having an

average silver content per ton of 24.24 ounces, total silver produced being 1,370,861 ounces.

The Holt-Dern equipment for treating flotation concentrates was increased to four furnaces. The roasted concentrates are leached with an acid brine solution and the silver precipitated on copper.

The officers are: President, D. M. Steindler, New York; vice-president, Mortimer B. Davis, Montreal; secretary and general manager, Eugene L. Steindler, Cobalt; assistant manager, P. L. Blodgett, Cobalt; mine superintendent, H. R. Bischoff, Cobalt.

Edwards and Wright.—Messrs. Edwards and Wright, Toronto, acquired the Green-Meehan and Red Rock properties by purchase, and during the summer of 1917 the shafts were de-watered and the workings thoroughly sampled.

At the Green-Meehan the shaft is 200 feet deep and has been further developed by a winze 45 feet deep. In April, 1918, a promising vein was encountered on the 245-foot winze level.

The dump at the Green-Meehan shaft is being milled at the Northern Customs concentrator, and drifting on the new vein is in progress towards the Red Rock workings.

John Edwards is in charge of operations with E. J. McMillan as mine captain. Twenty-five men are employed.

Genesee.—The Genesee Mining Company, Limited, worked continuously throughout the year, on their lease from the United States Cobalt Mining Company, of the southwest quarter of the south half of lot 9, concession 1, township of Bucke. At the close of the year the shaft had been sunk to a depth of 572 feet, and stations cut at the 350, 450, 500 and 550-foot levels; about 400 feet of cross-cutting and drifting had been done on the 500-foot level.

The officers are: President, Ralph H. Gorsline, Rochester, N.Y.; secretary-treasurer, Alex. Russell, Rochester, N.Y.; A. A. Amos, Cobalt; manager, Leonard F. Steenman, Cobalt.

Gifford.—The Gifford Cobalt Silver Mining Company resumed operations on their property adjoining the Beaver in August, 1917. The shaft is 200 feet deep, and at the close of the year a winze located 400 feet northeast of the shaft had been sunk to a depth of 150 feet, and 100 feet of cross-cutting done at the bottom level.

Difficulty was experienced in handling the water, and early in 1918 the mine was closed.

Frank B. Mosure of Toronto was manager, and J. Bedford mine captain; employing 12 men.

Hargrave.—The Hargrave Silver Mines, Limited, operated continuously throughout the year. Following is a summary of the underground work done:—

Drifting	421	feet.
Cross-cutting	235	"
Raising	664	"
Sinking	124	"
Total	1,444	"

Ore hoisted amounted to 2,556 tons, yielding 75,202.14 ounces of silver, of a gross value of $52,324.02. Operating expenses amounted to $53,254.64.

The officers are: President, James A. Aitchison; secretary-treasurer, Geo. H. Sedgwick; manager, J. T. Shaw. Head office, Excelsior Life Building, Toronto.

Hudson Bay.—The Hudson Bay Mines, Limited, operated their mine and mill continuously during the year. Underground development was as follows:—

Drifting	655.7 feet.
Cross-cutting	359.7 "
Raising	637 "

This work opened up several small veins; one known as the "Branch vein" was picked up on the first level west of the shaft and stoped on for a length of 140 feet.

During the year the mine produced 261,887.09 ounces at a total cost of production, including selling cost, of 43.57 cents per ounce. The mill treated 18,247 tons of 17.3-ounce ore, and recovered 262,863.7 ounces of silver, equivalent to an extraction of 83.2 per cent. The cost of treatment was $2.09 per ton or 14.5 cents per ounce recovered.

No work was done at No. 2 mine, or on the Gowganda and Kirkland Lake claims owned by the company.

The officers are: President, George Taylor; vice-president, A. A. McKelvie; secretary-treasurer, F. L. Hutchinson; manager, Douglas A. Mutch; directors, S. S. Ritchie, T. McCamus, William H. Kinch, C. L. Sherrill, F. L. Bapst.

Kerr Lake.—The Kerr Lake Mining Company has an authorized capitalization of $3,000,000, divided into 600,000 shares of par value $5 each.

The officers are: President, Adolph Lewisohn, New York; vice-president, Sam A. Lewisohn, New York; secretary-treasurer, E. H. Westlake, New York; mine manager, H. A. Kee, Cobalt.

Underground development for the fiscal year ending August 31st, 1917, was as follows:—

Drifting	1,268 feet.
Cross-cutting	588 "
Raising	1,197 "
Sinking	52 "

Total development, 3,105 feet; total stoping, 34,597 square feet, total side-cutting, 114 square feet.

The gross production from all ores amounted to 2,551,345.94 ounces of silver and 89,453.63 pounds of cobalt. The ore reserves at the close of the year were estimated to contain 3,120,400 ounces of silver.

Production from the Drummond Fraction amounted to 67,112 ounces, taken chiefly from a smaltite vein which is the easterly extension of the Fleming vein, also from a vein which is the westerly extension of the Comet vein. Work on the Drummond was discontinued January 31st, 1917.

The costs of production per ounce were as follows:—

Mining and development	11.65 cents.
Shipment and treatment	14.52 "
Administration and general	00.58 "
Total	26.75 "

La Rose.—The capital stock of La Rose Mines, Limited, was reduced by letters patent dated November 12th, 1917, from the sum of $6,000,000, divided into 6,000,000 shares of $1.00 each, to the sum of $1,500,000 divided into 1,500,000 shares of $1.00 each. Pursuant to a resolution passed by the stockholders of La Rose Consolidated Mines Company on December 10th, 1917, all the liabilities of the Consolidated Company were assumed by La Rose Mines, Limited, and all the assets of the Consolidated Company except 1,500,000 shares of La Rose Mines stock, are now vested in La Rose Mines, Limited. The Consolidated Company will be dissolved.

The officers are: President, D. Lorne McGibbon; vice-president, Shirley Ogilvie; secretary-treasurer, S. J. LeHuray; general manager, G. C. Bateman. The directors are: D. Lorne McGibbon, Edwin Hanson, E. W. Nesbitt, W. A. Black, Victor E. Mitchell, K.C., Wm. Dobell, Shirley Ogilvie, David Fasken, S. J. LeHuray. Head office, 260 St. James Street, Montreal.

Development work during the year was as follows:—

——	Trenches	Shafts	Drifts	Cross-cuts	Raises	Stopes
	ft.	ft.	ft.	ft.	ft.	cu. yds.
La Rose.....	88	.....	934.5	304	270	334
Lawson	60	.....	115.5	467.5	42	221
Violet	.....	382.5	.....	.....	.....	.....
	148	382.5	1,050	771.5	312	555

The total silver obtained from all sources was 478,639 ounces, having a gross value of $371,583.84, and produced at a total cost of $300,211.42, the profit on which was $71,372.42. The average price received for silver during the year was 82.94 cents. No work was done on the Princess, Fisher-Eplett, and University mines. A new shaft was sunk on the Violet, which adjoins the O'Brien on the east. The Keewatin-diabase contact was cut at 383 feet, and the shaft continued to the 425-foot level. Cross-cutting encountered veins showing considerable values.

Exploration work was done on two gold properties held under option, but results were not encouraging, and the options were dropped.

McKinley-Darragh-Savage.—During the year 1917, the McKinley-Darragh-Savage Mines of Cobalt, Limited, recovered 908,756 ounces of silver from their mining and milling operations, bringing the total production up to 17,323,102 ounces. The average price received for silver during the year was 83.20 cents per ounce, and the total costs 57.09 cents. The ore reserves on January 1st, 1918, were estimated to contain 1,076,182 ounces.

The tailing mill was not operated, due to non-delivery of grinding machinery. Underground development was as follows:—

Cross-cutting	1,876.5 feet.
Drifting	2,408.0 "
Raising	374.5 "
Shaft-sinking	14.5 "
Winzing	12.0 "
Total	4,685.5 "

The mill treated 68,142 tons of ore, yielding a total recovery of 796,298 ounces.

The officers are: President, J. R. L. Starr, Toronto; vice-president, Thos. W. Finucane, Rochester; treasurer, Harper Sibley, Rochester; secretary, J. H. Spence, Toronto; manager, T. R. Finucane, Cobalt. The head office of the company is at the Trusts and Guarantee Building, Toronto.

Mining Corporation of Canada.—The Mining Corporation of Canada, Limited, own the Cobalt Townsite, Cobalt Lake, City of Cobalt, Townsite Extension and Little Nipissing mines. The Cobalt Reduction Company is also controlled by the Corporation, which is capitalized at 2,075,000 shares of $1 each, all issued. The officers and directors are: Sir Henry M. Pellatt, president; J. P. Watson, first vice-president: W. R. P. Parker, second vice-president; G. M. Clark, J. G. Watson, D'Arcy Weatherbe, Capt. R. E. G. Van Cutsem; D'Arcy Weatherbe, consulting engineer; C. E. Watson, resident manager; M. F. Fairlie, superintendent of reduction works. The head office is at 1512-1520 Traders' Bank Building, Toronto.

The following statistics of operation are taken from the annual report of the Corporation for 1917:—

Production	Hoisted	Broken	Treated
	tons	tons	tons
Townsite	24,900	10,266	43,074
City	37,527	27,097	37,527
Lake	3,484	1,587	3,484
Total	65,911	38,950	84,085

Of the total tonnage hoisted 416.78 tons of high-grade were treated in the high-grade plant of the Cobalt Reduction Company; 179.07 tons of lower grade shipping ore went direct to the smelter, and 83,488 tons were concentrated. From all sources a total of 4,485,542 ounces of silver was produced, as compared with 4,457,440.80 for 1916. The net profits carried forward amounted to $2,557,091.89. Of this amount, $1,556,296.86 was paid in dividends, and $1,000,795.03 was carried to surplus, which at December 31st, 1917, amounted to $3,448,377.68. High-grade ore treated averaged 3,007.06 ounces per ton, and milling ore averaged 36.99 ounces per ton.

DETAILS OF UNDERGROUND WORK IN 1917

——	Drifts	Cross-cutting	Sinking	Raising	Total	Stoping
	ft.	ft.	ft.	ft.	ft.	cu. ft.
Ore extraction	.....	.....	.....	.....	.....	468,091
Development	716	.....	12	121	849	.....
Exploration	785	6,206	327	327	7,645	.....
Total	1,501	6,206	339	448	8,494	468,091

Diamond-drilling amounted to 86 feet.

The total footage of drifts, cross-cuts, raises, winzes and shafts in the workings of the Corporation aggregated 21 miles at the end of 1917.

The Cobalt Lake mill was not operated during the year.

The Cobalt Reduction Company's concentrating mill and cyanide plant ran continuously, excepting holidays, during the year. Stamps dropped 95.47 per cent. and the ball mill ran 97.84 per cent. of possible time. The use of the ball mill was discontinued in January, 1917, tube mills were introduced, and the flow sheet somewhat altered during the autumn of 1917.

Extraction from milling ores and slimes was 92.11 per cent. as against 88.34 per cent. in 1916. The high-grade plant has proved an unqualified success. The direct saving over the previous practice of shipping products to the smelter, has more than paid twice the cost of the plant during the year.

The high-grade plant treated during the year 1,546.68 tons of high-grade material, which produced 3,716,611.63 ounces of silver. During 1918, sands from Cobalt Lake will be pumped to stock piles, classified and treated.

The cost of concentrating and cyaniding was $2.53 per ton treated.

CONCENTRATION AND CYANIDING

—	Tons ore concentrated	Tons Concentrates produced	Ounces contained	Tons Slime Cyanided	Ounces Bullion produced by Cyaniding
Townsite and City	80,127.94	1,162.16	2,466,592.21	41,509.31	479,936.34
Lake.....	3,360.84	58.46	119,301.31	1,730.62	22,643.89
Total	83,488 78	1,220 62	2,585,893.52	43,239 93	502,580 23

The total costs including royalties, head office, etc., per ton of ore treated amounted to $19.26, and 36.11 cents per ounce of silver produced. The average number of men employed was 326.

The total consumption of powder amounted to 180,100 pounds.

Ore reserves at the close of the year were as follows:—

High-grade ore	690,600 ounces.
Milling ore	854,770 "
Total	1,545,370 "

A total of 90 properties in Canada and the United States were examined during the year. In the Cobalt district, the Alexandra and Waldman were optioned in the fall of 1917. Both shafts were de-watered in November, 1917, and development continued until May 1st, 1918, when the Alexandra was abandoned. Work on the Waldman was continued under the direction of Capt. Fancy.

National.—The National Mines, Limited, continued underground development of their mine near Cross Lake, formerly known as the King Edward, up to the end of June, 1917. For the balance of the year, operations were confined to pumping and milling tailings from Cross lake. On December 17th, 1917, the

mill was closed and all operations suspended till April 15th, 1918. On that date milling of King Edward tailings was resumed, and it is the intention of the company to install a second sand-pumping unit, and mill Silver Cliff tailings during the summer of 1918.

The officers are: President, H. E. Jackman; secretary-treasurer, Ernest Whitbeck, both of 17 Ellwood Building, Rochester, N.Y.; manager, C. A. Filteau, Box 749, Cobalt.

Nipissing.—The Nipissing Mining Company (the operating company) has an authorized and issued capital of $250,000, divided into 2,500 shares of par value of $100 each. The officers are: David Fasken, president; E. P. Earle, vice-president; Alexander Fasken, secretary; P. C. Pfeiffer, treasurer. The directors are: W. H. Brouse, David Fasken, E. P. Earle, Richard T. Greene, R. B. Watson is general manager; Charles Butters, consulting metallurgical engineer; Hugh Park, manager; James Johnston, mill manager; James J. Denny, manager research department. Head office, Excelsior Life Building, Toronto.

The stock of the Nipissing Mining Company is held by the Nipissing Mines Company, Limited, of Ontario, which on September 29th, 1917, acquired the assets of the old holding company, known as the Nipissing Mines Company. The officers of the holding company are: E. P. Earle, president; Alexander Fasken, secretary; P. C. Pfeiffer, treasurer; directors, W. H. Brouse, R. T. Greene, E. P. Earle. August Heckscher, David Fasken, J. H. Black, R. B. Watson. Head office, 165 Broadway, New York.

The yearly average price at which silver was sold was 83.19 cents per ounce at Cobalt, which was nearly two cents per ounce higher than the New York yearly average quotation. The total dividends paid to January, 1918, amounted to $16,750,000.

The production of fine silver was 4,212,247.89 ounces having a gross value of $3,756,889.77.

Production costs were $1,057,987.49, equivalent to $14.26 per ton of ore milled, and 25.117 cents per ounce of silver produced, an increase of about one cent per ounce over 1916.

The ore reserves are estimated to contain 8,076,540 ounces of silver as compared with 9,153,139 ounces at the close of 1916.

Underground work done in 1917 is summarized as follows:—

Shaft No.	Drifting	Cross-cutting	Raising	Sinking	Total	Stoping
	ft.	ft.	ft.	ft.	ft.	cu. yds.
14	.....	.....	.....	.....	.....	208.7
64	.....	.....	33.0	.....	33.0	192.0
73	1,027.0	2,082.5	286.0	89.5	3,485.0	8,471.0
80	6.0	1,118.5	49.5	.....	1,174.0	726.8
81	1,827.5	1,278.5	1,102.0	.....	4,208.0	15.5
96	221.5	611.5	268.5	.....	1,101.5	2,447.6
Total	3,082.0	5,091.0	1,739.0	89.5	10,001.5	12,061.6

Notwithstanding continued heavy increases in the cost of materials and supplies, especially chemicals and articles of iron and steel, the company had one of the most prosperous years in its history. The net value of production was $3,665,405, which was $710,000 more than in 1916, heretofore the highest year for net value received.

Northern Customs Concentrator.—The Northern Customs Concentrators, Limited, situated at mileage 104, T. & N. O. railway, ran continuously in 1917. The ore treated was shipped by La Rose, Right-of-Way, Chambers-Ferland, and a small quantity by Edwards and Wright from the Green-Meehan dump.

The officers are: President, A. J. Young, 702 Excelsior Life Building, Toronto; vice-president, C. J. Booth, Ottawa; general manager and secretary-treasurer, F. J. Bourne, Cobalt; directors, M. J. O'Brien, Renfrew; Dr. C. W. Haentschel, Haileybury.

O'Brien.—Development at the O'Brien mine during 1917 was as follows:—

Drifting and cross-cutting	6,710 feet.
Raising and sinking	410 "
Stoping	42,550 tons.
Hoisted to surface	69,950 "

A new low level was established at 720 feet below the collar of the main shaft and ore mined at this level.

A new shaft, No. 33, was sunk on the southwest quarter of the property, and levels established at 150 and 180 feet. About one-half of the total production came from the Keewatin formation. In the mill, changes were made to effect greater concentration. After concentration the entire tailing product is slimed and cyanided. The mill treated 47,850 tons.

The mine is now owned and operated by M. J. O'Brien, Limited, a new corporation organized during 1917.

The officers are: President, M. J. O'Brien, Renfrew; vice-president, J. A. O'Brien, Renfrew; manager, J. G. Dickenson, Cobalt; mining engineer, Angus Campbell; mine secretary, A. E. McKee.

Ophir.—The Ophir Cobalt Mines, Limited, has a capitalization of 1,500,000 shares of a par value of $1.

The directors of the company are: H. H. Lang, A. D. Crooks, H. H. Hutson, Wm. Linton, W. Murray Alexander, all of the City of Toronto; the head office is 608 Lumsden Building, Toronto.

The Ophir mine operated continuously during the year 1917. The arrangement whereby the underground development is done through the shaft of the People's Mining Company was continued during the year. Most of the underground work was done on the 440-foot level. A winze was started to prospect the downward continuation of a promising ore shoot on this level.

Balmer Neilly of the Penn-Canadian mine is consulting engineer of the company.

Penn-Canadian.—The Penn-Canadian Mines, Limited, operated continuously throughout the year 1917, though on a reduced scale. Very little development

work was done. The mill treated 34,000 tons of ore, produced largely from the old workings. On May 10th, 1918, the power plant was destroyed by fire.

The officers are: President, Wm. J. Haines, Philadelphia; directors, Spencer D. Wright, Philadelphia; Robert B. Haines, Jr., Philadelphia; Jansen D. Haines, Des Moines, Iowa; Elliott C. P. Laidlaw, New York. Balmer Neilly, Cobalt, is manager of the company.

People's.—The working agreement between the People's Silver Mines, Limited, and the Ophir Cobalt Mines, Limited, mentioned in the last annual report of the Bureau of Mines, was continued throughout 1917. Development of the Ophir ground has proved satisfactory and some promising veins have been encountered.

Cross-cutting and drifting were done by contract, let to Messrs. Cain and Smith, under the direction of mine captain Donaldson.

Balmer Neilly, manager of the Penn-Canadian is consulting engineer for the company.

The officers of the People's company are: President, G. P. Bithell, 773 St. Lawrence Boulevard, Montreal; vice-president, James Robertson, Millerton, N.B.; secretary-treasurer, T. Jones, 773 St. Lawrence Boulevard, Montreal.

Ten men were employed by the contractors.

Peterson Lake.—The Peterson Lake Silver Cobalt Mining Company, Limited, worked continuously during 1917. The cross-cut to the northwest at the 200-foot level of the Susquehanna shaft was extended, and in July a vein was encountered. Further developments were not encouraging, and work was suspended. The force was moved to the Cart Lake section at the Gould No. 2 shaft, where work was continued. Total development at the Susquehanna and Gould shafts in drifting, cross-cutting, sinking and raising for the nine months ending January 31st, 1918, amounted to 1,050 feet.

The officers are: President, W. A. Lamport; vice-president and managing director, S. G. Forst; secretary-treasurer, P. M. Goff, all of Toronto; directors, W. A. Lamport, S. G. Forst, Chas. M. Nickel, Max B. Borg, New York; Irving L. Ernst, New York. Head office, 909 Excelsior Life Building, Toronto.

Prince-Davis.—Operations through the Lumsden shaft by the Prince-Davis Mining Company, Limited, on the Prince lot in southeast Coleman, were discontinued in April, 1918. A cross-cut was run over 850 feet on the Prince ground, but developments were not encouraging.

Underground work was in charge of Captain Donaldson. Balmer Neilly, manager of the Penn-Canadian is consulting engineer for the company.

Eight men were employed by contractors Gordon and Robert Cameron.

Provincial.—Under the direction of John Redington, the mill of the Cobalt Provincial mine was enlarged, and during the winter of 1917-18, 1,000 tons of tailings were treated. No. 2 shaft was de-watered to the 175-foot level and work resumed in the cross-cut to No. 1 shaft. There is considerable ground on the south side of the property, as yet not prospected, and it is the intention of the management to carry on active underground development during the coming year.

Right-of-Way.—The Right-of-Way Mines, Limited, did a small amount of development work during 1917. Operations were confined to No. 2 shaft at the north end of Cobalt lake. Development during the year at No. 2 shaft was as follows:—

Sinking	82	feet.
Raising	110	"
Drifting	352	"
Cross-cutting	88	"
Total	632	"

Work on the 465-foot level to the close of the year had not proved satisfactory, but development was still in progress. The net value of ore produced during 1917 amounted to $45,506.61.

The officers are: President, E. Seybold; secretary-treasurer, E. A. Larmonth; director, C. Jackson Booth, all of Ottawa. A. W. Fraser, K.C., of Ottawa, who had been a director and vice-president of the company since its incorporation, died on August 11th, 1917. D. H. Angus, Cobalt, is superintendent, and the head office of the company is at Central Chambers, 46 Elgin Street, Ottawa.

Shamrock.—The Shamrock Consolidated Mines, Limited, worked with a small force for the greater part of the year, and closed in November, 1917. Development consisted of drifting on the 200 and 300-foot levels, and a small amount of stoping on the latter.

H. S. Anderson, 93 Queen St. East, Toronto, is secretary of the company, and J. P. Cleveland was in charge of operations at the property.

Silver Queen.—In June, 1917, the Silver Queen mine was leased to Geo. A. Irwin, of Cobalt, who worked it with a small force of men during the balance of the year. A car of ore was shipped in September, and a second car in March, 1918. The ore was obtained mostly from the old dumps and from wall-slashing on the first level. There is considerable milling ore in sight, and if proper milling arrangements can be made, the output for 1918 should be considerably increased.

Temiskaming.—The following information is taken from the eleventh annual report of the Temiskaming Mining Company, Limited, for the fiscal year ending December 31st, 1917. This report was issued by the old board of directors, as given in the last annual report of the Bureau of Mines. During the year 1917 Frank L. Culver was president and general manager of the company. Head office is at Lumsden Building, Toronto.

The main shaft was sunk to the 1,600-foot level, through the diabase sill, and considerable development work at that level failed to disclose commercial ore. Development is being continued.

Production during the year amounted to 958,669.88 ounces of silver. The cost of production was 31.56 cents per ounce.

Following is a summary of development:—

Drifting	1,371.0	feet.
Cross-cutting	2,677.5	"
Sinking	117.1	"
Raising	701.5	"
Winzing	28.4	"
Total	4,895.5	"
Stoping	4,455.5	cubic yards.

Four dividends of $75,000 each were paid during the year.

Three Stars.—The Three Stars Silver Mines, Limited, was organized early in 1918 and resumed work March 1st, 1918, on the Cyril lake or Airgoid property, worked during 1916 by the Calumet and Montana Consolidated Mining Company, Limited. The capitalization of the new company is $3,000,000, divided into 600,000 shares par value $5 each.

Operations were suspended in May, 1917, by the Calumet company.

The north cross-cut on the 90-foot level is being extended, and drifting is in progress on a promising vein running directly east from the cross-cut.

The officers are: President, Henry A. Oswald, Cobalt; vice-president, K. J. Schumacher, Chicago; secretary-treasurer, H. R. Mendis, Chicago. The board of directors includes the above officers, R. G. Collins, and Chauncey W. Martyn, of Chicago.

Trethewey.—The mine and mill of the Trethewey Silver Cobalt Mining Company, Limited, operated throughout the year. Very little new ground remained for exploration, and as a result development was discontinued in June, 1917, and work confined to the old stopes. Drifting and cross-cutting amounted to 463 feet, raising and winzing to 12 feet. The net decrease in tonnage of ore reserves at the close of 1917 amounted to 13 per cent., while the estimated ounces of silver in the ore reserves decreased from 361,482 to 264,044 ounces, a net decrease of 27 per cent. A total of 23,013 tons of ore was broken in the stopes, at a cost of $2.60 per ton. Most of this production came fom the walls of old stopes. The mill treated 34,722 tons of ore, having an average content of 13.3 ounces, at a cost of $1.744 per ton treated, including all charges from the shaft-house bins. From this ore, 341,278.23 ounces of silver were obtained. The average assay of the tailings was 3.2 ounces, giving an extraction of 75.2 per cent. High-grade concentrates were shipped to Deloro and Thorold, and low-grade ones to Denver. The net value of ore produced was $259,208.60, leaving a profit of $114,977.33. The total cost per ton produced, including marketing charges, was $4.827.

Rochester Mine.—Operations were discontinued at the Rochester, March 1st, 1917. The third level was considered fully explored, and it was decided to make no further expenditures. The total expenditures on the Rochester during the year amounted to $14,549.17.

Cane Silver Mine.—The Trethewey company secured an option on three claims known as the Caroux claims in Cane township, in June, 1917, and carried on operations for a period of six weeks. Considerable stripping was done and a

shaft sunk to a depth of 40 feet. There were several strong fractures on the surface showing good values, but operations were closed in August.

The officers are: President, S. R. Wickett, Toronto; vice-president, J. B. Tudhope, Orillia; secretary-treasurer, L. J. Pashler, Toronto; directors, Gordon Taylor, Toronto; J. P. Bickell, Toronto; W. J. Sheppard, Waubashene; T. E. Leather, Hamilton. The head office is at 1428 Traders' Bank Building, Toronto.

I. S. McReavy, Cobalt, is manager, succeeding H. S. Robinson, who returned to the United States in August, to join the overseas forces.

Gowganda and Elk Lake Silver Mines

During 1917 the Gowganda area received considerable attention from mining companies in search of new properties. This interest was no doubt due to the discovery in 1916 of high-grade ore on the O'Brien property at Miller lake, and the increased selling price of silver. A large number of claims have been patented and held since 1910 by the older operating companies of Cobalt and Porcupine, and it is probable that some of these claims may become producing mines through systematic prospecting and development.

In the Elk Lake section some work was also done.

Bishop.—The Bishop Silver Mines, Limited, operated only part of the year on their claim L.O. 313, situated on the east side of Calcite lake, township of Lawson. The winze near the end of the main drift was sunk to the 100-foot level, and a small amount of cross-cutting done. Previous development is described in the Twenty-sixth Report of the Bureau of Mines. The mine was closed on April 30th, 1917, and no further work was done during the year.

Wm. J. Shields was manager of the mine.

Castle.—At the beginning of the year the Trethewey Silver Cobalt Mining Company, Limited, secured an option on the control of the stock of the Castle Mining Company, Limited. The holdings comprise eleven claims near Miller lake, in the Gowganda district. Eight of these claims lie along contacts very favourable for ore deposition.

Prospecting and surface development were carried on during the summer and fall of 1917, and during the winter a plant was taken in and installed. The plant includes two 60-h.p. boilers; one 8 by 10 Jenckes hoist; one Rand compressor, 720 cubic feet capacity. Sinking operations were started in May, 1918.

R. E. Margenau was superintendent for the Trethewey Company.

Crews-McFarlan.—Early in the year the Crews-McFarlan Mining Company, Limited, purchased the Bartlett property in the township of Milner, in all about 132 acres. On this property were two vertical shafts, No. 1, 110 feet deep, and No. 2, 110 feet. Most of the force from the Hewitt Lake workings were transferred to the Bartlett, and active development commenced July 15th, 1917. Both shafts were de-watered and re-timbered and sinking was resumed.

At the Hewitt Lake property shaft No. 1 was sunk to a depth of 150 feet, and work on this claim was stopped. On claim J.S. 280, No. 2 shaft was 140 feet deep with sinking in progress, when last inspected in October, 1917.

The officers are: President, C. H. Streit, Nutley, N.J.; secretary, Henry Crews, Paterson, N.J.; treasurer, W. J. McFarlan, Paterson, N.J.; manager, J. G. Wheaton, Gowganda P.O.; 25 men were employed during the year.

Kenabeek.—During 1917, the Kenabeek Consolidated Silver Mines, Limited, worked intermittently, and did a small amount of development on their property, south half of lot 2, in the sixth concession of Auld township. The shaft was sunk to the 150-foot level, and 82 feet of cross-cutting and drifting done, chiefly on No. 2 vein. A small prospect winze was sunk on the intermediate vein.

The head office of the company is at 232 St. James Street, Montreal, and the officers are: President, Frank Thompson; director, E. Champagne; manager, Capt. W. H. Jeffrey. George Pyke, formerly secretary-treasurer, died during the year.

Miller-Lake O'Brien.—Production at this mine during 1917 placed it among the first half-dozen silver producers of Canada.

Development during the year was as follows:—

Drifting and cross-cutting	1,907 lineal feet.
Raising and sinking	90 " "
Stoping	12,324 tons.
Hoisted to surface	18,200 "

A fine new office building, with sleeping quarters for the staff, was built during the year.

The mine is owned and operated by M. J. O'Brien, Limited, with the same officers as given for the O'Brien mine at Cobalt, with the addition of B. C. Crowe as resident superintendent.

Reeve-Dobie.—The Reeve-Dobie Mines, Limited, resumed operations in April, 1917, and worked with a small force for the balance of the year. A shipment of high-grade ore was taken from an open-cut about 450 feet from the main shaft. During the summer the mill was repaired, and in September the main shaft was de-watered. The mill equipment includes four Nissen stamps, four Deister tables, one Risdon-Johnston concentrator, and one jaw crusher.

Mr. A. S. Crowe, formerly of the Porcupine Crown staff, took over the management on November 1st. During the winter one machine crew was employed cross-cutting on the 100-foot level.

The officers are: President, Charles Ward, Livonia, N.Y.; vice-president, H. Marvin, Rochester, N.Y.; secretary, J. C. Roche, Rochester, N.Y.; treasurer, Dr. J. H. Fennessey, Rochester, N.Y.

The property comprises claims S.W. 3, 4, and 5, on the Mann ridge, west of Gowganda lake. S. Christopherson was in charge of operations until November 1st.

T.C. 177.—The T.C. 177 Mining Company, Limited, worked continuously on their claims south of the Miller-Lake O'Brien property.

Camps were erected in February, 1917, and when visited on September 27th, 1917, a vertical shaft had been sunk to a depth of 77 feet, with sinking in progress. In May, 1918, the shaft had reached the 200-foot level and cross-cutting had been started. The plant includes one 40-h.p. locomotive boiler, one 4 by 5 hoist, and a small compressor.

Miles Simpson, Elk Lake, was manager, and Joseph Brevier, mine captain.

Walsh.—What were known locally as the Walsh claims, in the Miller Lake section of the Gowganda district, were optioned during the year to the Crown Reserve Mining Company of Cobalt. A small plant was installed, a shaft sunk 100 feet, and a small amount of lateral development performed during the year. Work was under the direction of H. J. Stewart, manager of the Crown Reserve.

Lorrain and South Lorrain

During 1917 the chief operating company was the Pittsburg-Lorrain Syndicate, working on the Currie mine. The Bellellen was closed for several months of the year. From March 20th to July 15th there was no development work carried on, although the pumps were kept running. The Lorrain Consolidated, formerly known as the Harris property, closed down on June 15th, 1917. The Pittsburg Lorrain shipped considerable high-grade ore, and late in the year took over the Wettlaufer mill and mine under lease.

In the spring of 1918 the Keeley mine, formerly one of the chief producers, was examined, and a shipment made of ore in stock from previous operations. It is probable that this mine will be worked during 1918.

Bellellen.—The syndicate operating the Bellellen, on claim R.L. 470, South Lorrain, continued development from the first of the year to March 20th, 1917, when all operations except pumping were suspended. On July 15th work was resumed until the close of the year.

The winze on the 100-foot level was sunk to a depth of 275 feet, and at the 200-foot winze level a drift was run to the south, a distance of 100 feet.

The members of the operating syndicate are as follows: Charles Richardson, Haileybury, manager; Arthur Ferland and R. T. Shillington, of Haileybury, and J. H. Black, Toronto.

Sylvester Carroll was in charge of operations, employing ten men.

Curry.—Development of the Curry mine, in South Lorrain, was continued during 1917 by the Pittsburgh-Lorrain Syndicate. Some high-grade ore was stoped on the fourth level. In August, 1917, the syndicate acquired the Wettlaufer mine and mill under lease. Operations at the Curry mine were suspended, and during the autumn of 1917 the Wettlaufer dump was milled. At the Wettlaufer about 750 feet of drifting and cross-cutting were done on the third and fourth levels, but no new veins were discovered. Underground work at the Curry mine was resumed and the mill has since been treating Curry ore.

The mill has been enlarged and the grinding capacity increased by the addition of one 5 ft. by 3 ft. ball mill. An experimental Groch flotation unit was installed. Exploration by diamond-drilling was carried on extensively at the Curry mine during the year.

H. F. Strong is superintendent, employing 40 men; John A. Rice is consulting engineer. Thomas B. Rice, who had been superintendent for the past three years, left in September, 1917, to join the American overseas forces training in Texas.

Maple Mountain Area

White Reserve.—Work was continued throughout the year by the White Reserve Mining Company, Limited, on its claims in the Maple Mountain area, Timagami Forest Reserve.

The main shaft is 147 feet deep, with levels at 70 and 140 feet. Development on the 70-foot level consists of 215 feet of cross-cutting and drifting, and on the 140-foot level north of the shaft, 492 feet of cross-cutting and drifting; south of shaft, 330 feet of cross-cutting and drifting. No. 21 shaft is 90 feet deep, with 110 feet of drifting at the 30-foot level. No. 10 shaft is 50 feet deep, and No. 14 shaft, 30 feet deep.

J. A. McAndrew, 408 Lumsden Building, Toronto, is president and general manager of the company.

IV.—EASTERN ONTARIO

Iron Pyrites

Bannockburn.—The Bannockburn Pyrite Mining Company has opened up what is known locally as the "Mundic" mine, on lot 25, con. VI., Madoc township. The open pit on this property is about 50 feet wide by 100 feet in length and 60 feet in depth. The equipment includes two small boilers and a hoist. J. A. Anderson, Bannockburn, is manager.

Caldwell.—Development was continued during the year on the pyrite property owned by T. B. Caldwell, of Lanark, on lots 1 and 2, in the first concession of Blithefield township. The shaft was continued to the 100-foot level, and 250 feet of cross-cutting and drifting done at this level. In October, 1917, the property was optioned to the Grasselli Chemical Company. During the winter and spring of 1917-1918 about 2,500 feet of exploration by diamond-drilling was done by the Sullivan company. In June, 1918, a wagon road was being built from Clyde Lake siding to the mine, and preparations were under way for extensive development by the new owners.

D. S. Tovey is superintendent for the Grasselli Chemical Company.

Sulphide.—The Nichols Chemical Company, a subsidiary of the General Chemical Company of New York, operated its pyrites mine and chemical plant at Sulphide, Hastings county, to full capacity during the year. The mine and plant are located on lot 23, in the eleventh concession of the township of Hungerford. The same company operates pyrites mines at Northpines and Goudreau, in the Lake Superior region of Ontario.

The enlargement of the chemical plant continued during 1917, the increased demand for acid being met by the installation of additional pyrites burners. The consumption of crude sulphur also increased during the year.

At the mine there was no addition to the equipment. The ore was extracted from the first, second, third, and fourth levels.

During the year a recreation hall, including bowling alleys, billiard tables and moving picture fixtures, was built at the plant for the company's employees. This

recreation club is operated by a committee of the employees, which pays the company interest on the capital expenditure and is in full control of the operation of the club.

W. H. DeBlois is manager, employing 150 men at the chemical plant and 35 men at the mine.

Queensboro Mine.—This mine, near Queensboro, in the township of Madoc, is owned and operated by the Canadian Sulphur Ore Company.

Sinking was continued to the 400-foot level and will be continued to the 500-foot level during the year 1918. The fourth level was extended east and west to the extent of the ore bodies in No. 3 shaft.

Good-sized ore bodies have been blocked out in No. 2 shaft, and No. 3 workings connected with No. 2 by means of a winze from No. 2 and a raise to connect from No. 3.

The officers of the company are: Alex. Longwell, Toronto, president; Geo. H. Gillespie, Madoc, vice-president; H. F. Smeaton, Queensboro, superintendent. Eighty men were employed during the year.

Copper

Cashel Copper Mines, Limited.—This company, operating on the east half and the south 20 acres of the west half of lot 31, in the first concession of Cashel township, near Gilmour, Hastings county, continued sinking a shaft to a depth of 80 feet, when work was discontinued.

C. S. Crysler is president and manager; W. Younger, vice-president; E. W. Storer, treasurer; S. B. Dawson, secretary.

Gold

Cordova Mines, Limited.—The Cordova mine is situated in Belmont township, Peterborough county, 12 miles by wagon road northeast of Havelock, and 112 miles east of the city of Toronto. After the disastrous fire on March 13th, 1917, which destroyed the shaft-house, mill, etc., rebuilding operations were commenced, but, owing to labour conditions and the difficulty of procuring supplies, it was not considered advisable to attempt to replace the plant at the present time.

Peter Kirkegaard is managing director; the head office is at Cordova Mines, Ont.

Cobalt-Frontenac Mining Company, Limited.—Mining rights owned by this company in Eastern Ontario include the following properties:—Lots 24 and 25, concession VI., township of Kaladar, known and described in previous reports as the Golden Fleece mine; north half of lot 26, and the southwest quarter of lot 27, concession VII., township of Kaladar, and lot 33, concession 1, township of Barrie, a total of about 700 acres.

On the Scootamatta river, near the village of Flinton, the company has completed the construction of a hydro-electric power plant, which has been developed as a source of electrical energy for the Golden Fleece mine. The erection of a 200-ton ore bin has just been completed, on the top of which has been installed a

14 by 24 Mitchell crusher with a capacity of 300 tons in ten hours. The ore will pass through the crusher into the ore bin, thence by means of an automatic feeder will be fed through a small Dodge crusher into a 60-ton ore bin. A stamp mill and a 5 by 16 tube mill in closed circuit with a Dorr classifier will be used for the further reduction of the ore. A Dorr continuous decantation cyanide plant with a capacity of 200 tons per twenty-four hours has been ordered, shipment of which will be made about the first of June. A two-stage, belt-driven Ingersoll Rand air compressor has been purchased and is being installed. Two 100-h.p. electric motors (power for which will be furnished by company's own hydro-electric power plant) have been installed for the operation of the mine and mill. The ore will be treated by amalgamation until such time as the cyanide plant is completed.

On the 1st of May, 1918, the company's head office was moved from Hamilton to the Golden Fleece mine, Flinton, Ontario.

The officers of the company are: George W. Millen, president, Winona, Ontario; M. G. Notz, secretary-treasurer, Hamilton, Ontario; D. H. Fletcher, managing director, Hamilton, Ontario; W. E. Simpson, consulting engineer, Flinton, Ontario.

Ore Chimney.—This mine, situated near Northbrook, in the township of Barrie, Frontenac county, is operated by the Ore Chimney Mining Company.

Up to January 1st, 1918, there had been 2,000 feet of cross-cutting and drifting done on the six several levels. The raise to the second or auxiliary shaft is almost completed.

At the mill, since the last Report, which gave a list of the machinery installed, there has been added one No. 2 Ding magnetic separator and a 200-h.p. generator.

The officers of the company are: A. E. Fletcher, president, and O. E. Dores, secretary-treasurer.

Iron

Playfair.—The Playfair hematite mine, which had been abandoned for upwards of forty years, was re-opened in the autumn of 1917 by the Canadian Union Iron Mines Company. Head office, Dominion Express Building, St. James Street, Montreal. H. L. Coombs, president.

A contract was let to L. Lemoine, of 524 Lafontaine Park, Montreal, to de-water the shaft, and mine 1,000 tons of ore. The property is located near Playfairville, in the township of Bathurst, Lanark county. When inspected on June 11th, 1918, the shaft, said to be 110 feet deep, was de-watered to a depth of 75 feet, and ore was being shipped from Perth, a wagon haul of twelve miles.

The vein where exposed varies from 2 to 4 feet in width, and Mr. Lemoine stated that the ore was of excellent quality for blast-furnace use.

Talc

Connolly Mine.—The Anglo-American Talc Corporation, Limited, owns and operates what is known as the Connolly mine on the northwest quarter of lot 15 in the fourteenth concession of the township of Huntingdon, adjoining the village of Madoc in Hastings county.

H. S. Predmore is president of the company; R. J. Gilchrist, secretary; Thos. Carswell, resident manager; on an average 20 men were employed during the year.

The underground work during the year consisted in sinking the shaft to a depth of 188 feet, and drifting on this level east 275 feet and west 100 feet. On the 127-foot level the east drift was continued to a point 288 feet and the west drift to a point 100 feet from the shaft.

The mill commenced grinding in May, 1917, and was run continuously throughout the remainder of the year. Some crude talc was shipped in addition to the mill product. The mill has a daily capacity of 25 tons.

Geo. H. Gillespie and Co.—This company operates a talc-grinding plant at Madoc station on the Grand Trunk railway, the talc being all obtained from the Henderson mine operated by Cross and Wellington.

The plant ran continuously throughout the year, although part of the time at only about two-thirds the capacity, due to shortage of railway cars in which to ship the refined product.

Eighteen men were employed in the mill during the year; Geo. H. Gillespie is general manager.

Henderson Mine.—Messrs. Cross and Wellington, who have this mine under lease, operated continuously during the year. The mine is situated near Madoc in Hastings county. The greater part of the production is supplied to George H. Gillespie and Company, Limited, at Madoc, though some crude ore is shipped.

The production, which amounted to about 11,000 tons, came entirely from the sub-levels between the second and third levels, where the top-slicing and re-treating method of mining is followed.

No. 2, or the east shaft, was sunk to the third level at a depth of 231 feet, and a connection made on this level with No. 1 shaft. A plant was installed at the shaft consisting of a 235-cu. ft. compressor, a 40-h.p. motor and an 8 by 10 hoist. The ore will be hoisted in a 24-cu. ft. skip.

Fourteen men were employed on an average during the year. Stephen Wellington is manager.

International Pulp Company.—On lot 16 in the fourteenth concession of Huntingdon township the International Pulp Company of Gouverneur, N.Y., is prospecting for talc. An incline shaft has been sunk to a depth of 50 feet, and it is the intention to cross-cut from this level.

A small plant, including compressor, hoist and boiler, has been installed. D. Brownson is manager, employing eight men.

Fluorspar

Fluorspar was found in 1918 on the Schickler farm on lot 8, concession XXII, Cardiff township, near the village of Harcourt on the Canadian Northern railway in Haliburton county. The vein is of good width, the fluorspar, which is of the violet-blue variety, being associated with calcite. Crystals of apatite were also noticed in the vein material.

P. J. Dwyer, of Wilberforce, has the property under option.

Bailey.—The Bailey property is situated on lot I in the fourth concession of Madoc township. The shaft is 40 feet deep, and 35 feet of drifting has been done at the 40-foot level.

This deposit was opened up late in 1916 by the Hungerford Syndicate (Harry Hungerford and Robert Gilchrist). Robert Phillips was in charge of operations.

The vein matter is well crystallized, and some first-rate spar was taken out during development.

Canadian Fluorite, Limited.—This company, through J. W. Bradley, is operating the Kane property, lot 9 in the fourteenth concession of Huntingdon township, from which shipments are being made to the new steel plants of British Forgings, Limited, at Toronto. The shaft is 25 feet deep on a vein about 9 feet wide. The vein matter is largely calcite. At the 25-foot depth there is considerable fluorite in the vein.

The plant consists of a 325-cu. ft. compressor, 35-h.p. upright boiler, and an 8 by 12 hoist.

E. D. Hall is superintendent, employing 10 men.

Noyes.—Canadian Industrial Minerals, Limited, is the name of the company operating the property formerly known as the Noyes and owned by Wellington and Munro. The company has a capitalization of 500,000 shares of a par value of $1.00. The officials of the company are: J. P. Watson, president; W. R. P. Parker, vice-president; G. M. Clark; and W. W. Perry, secretary-treasurer. The head office of the company is at 1512-1520 Bank of Hamilton, Toronto.

The company owns the following parcels totalling about 800 acres: lot 13, con. XII; lot 14, con. XI; lot 15, con. X; lot 16, con. IX, and the N. ½ of W. ½ of lot 12, con. XI, all in the township of Huntingdon.

The present workings are confined to part of lot 13, con. XII. An incline shaft has been sunk to a depth of 100 feet on a vein of fluorspar which averages from 8 to 12 feet in width at this point. On the 50-foot level drifts were run 85 feet to the south and 55 feet to the north.

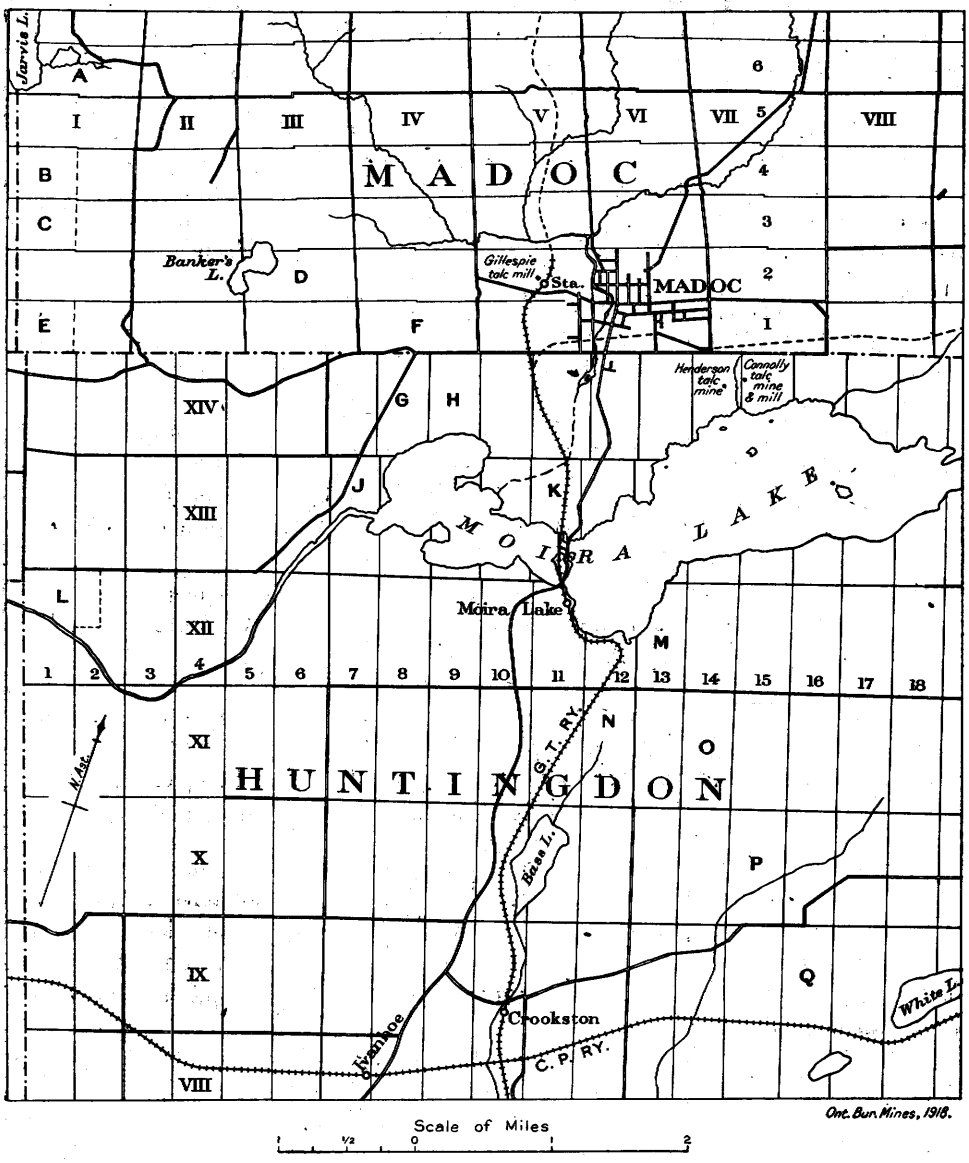
The present equipment includes a small boiler and a hoist and small compressor. A 784-cu. ft. compressor, electrically driven by a 125-h.p. motor, is being installed. The company has a railway siding at Moira Lake station about half a mile from the property. A. W. Grierson is resident manager, employing 18 men.

Cross and Wellington.—From the Perry property, on lot 11 in the thirteenth concession of Huntingdon township, about 2,000 tons of ore were shipped during the year.

No. 1 shaft, on the shore of Hog lake, is 35 feet deep. No. 2 shaft is 1,050 feet north of No. 1 shaft. No. 3 shaft, 175 feet north of No. 2, was sunk to a depth of 95 feet during the year. This property was shut down on December 1st, it being decided not to attempt any further mining until an adequate pumping plant was installed.

The power house contains a 470-cu. ft. compressor, a 75-h.p. motor and an 8 by 10 hoist.

Stephen Wellington is manager, employing 10 men.



Map of parts of the townships of Madoc and Huntingdon, showing location of fluorite properties near Madoc, Ont.

MADOC TP.

A.—Lot 6, Con. 1—O'Reilly.
B.—Lot 4, Con. 1—Wallbridge.
C.—Lot 3, Con. 1—Ponton.
D.—Lot 2, Con. 3—McIlroy.
E.—Lot 1, Con. 1—Lee.
F.—Lot 1, Con. 4—Bailey.

HUNTINGDON TP.

G.—Lot 8, Con. 14—North Reynolds.
H.—Lot 9, Con. 14—Canadian Fluorite, Ltd.
J.—Lot 7, Con. 13—South Reynolds.
K.—Lot 11, Con. 13—Perry.
L.—Lot 1-2, Con. 12—Herrington.
M.—Lot 13, Con. 12—Canadian Industrial Minerals, Ltd.
N.—Lot 12, Con. 11—Canadian Industrial Minerals, Ltd.
O.—Lot 14, Con. 11—Canadian Industrial Minerals, Ltd.
P.—Lot 15, Con. 10—Canadian Industrial Minerals. Ltd.
Q.—Lot 16, Con. 9—Canadian Industrial Minerals, Ltd.

Herrington.—The Herrington property, lots 1 and 2 in the twelfth concession of Huntingdon township, has been leased by Chas. Henrotin. Thirteen tons have been shipped. The vein, which is about 18 inches in width, has been stripped for 250 feet.

Lee.—The Lee property, which is situated on the west half of lot 1 in the first concession of Madoc township, is held under lease by Chas. Henrotin. Five cars have been shipped from an open cut. The vein is 3 feet wide at its widest part. The open cut is 500 feet long and is in places 8 feet deep.

McIlroy.—This property, situated on lot 2 in the fourth concession of Madoc township, is operated by Mineral Products, Limited. The vein, which is one to three feet wide, is developed by a shaft and an open pit.

Perry.—From the Perry property, lot 2, concession XIII, Huntingdon township, operated by Cross and Wellington, about 3,000 tons of fluorspar has been shipped. The property is shut down at present owing to water trouble. It is the intention of its operators to install a double-action, motor-driven Cornish pump to overcome the difficulty.

There are three shafts which are respectively 35, 80 and 95 feet deep.

The plant consists of a 50-h.p. boiler, a 470-cu. ft. compressor driven by a 75-h.p. motor, and an 8 by 12 hoist.

Reynolds.—The South Reynolds property, situated on lot 7, concession XIII, Huntingdon township, is under option to Chas. Henrotin. Two carloads of fluorite have been shipped from an open cut on the vein; this vein is narrow, being under 18 inches wide. About 150 feet has been exposed in the open cut.

Wallbridge.—The Wallbridge property, situated on the west half of lot 1 in the fourth concession of Madoc township, has produced 380 tons of spar. The vein has been stripped 500 feet. It varies from one to three feet wide. A second vein, 700 feet west of the first, has been uncovered for 100 feet. In a pit 15 feet deep on this second vein at the boundary with the Ponton property, the vein is six inches wide.

On the Ponton property, the west half of lot 3 in the first concession of Madoc township, a vein stripped for 300 feet is up to 3 feet wide.

Lead

Galetta.—The Galetta lead mine and smelter, belonging to the Estate of James Robertson, are situated on Chats island, on lot 22 in the sixth concession of the township of Fitzroy.

The mine developed favourably during the year. On the second, or 185-foot level, the vein was drifted on to the east 394 feet and to the west 66 feet.

No. 2 shaft, which is a vertical, 3-compartment one, located 60 feet south of No. 1 and in the hanging-wall side of the vein, was sunk to a depth of 225 feet. From the bottom a drift was driven to the east 100 feet and stoping commenced. The mill was brought up to a capacity of 50 tons per day.

The smelter, which has a capacity of 18 tons of pig lead every 24 hours, operated about 50 per cent. of the time. The open Scotch hearth with automatic rabble is used. The grey slag from the hearth is stock-piled for future treatment in blast furnace.

During the year 18 dwelling houses were built for the employees. A. G. Munich is general manager, and C. M. Thompson mine superintendent; employing on an average 65 men.

Feldspar

Card.—The Card feldspar and flint quarry near Verona, owned by Senator Richardson, of Kingston, was opened in October, 1917. About 20 cars of feldspar and flint rock were shipped and the quarry closed in May, 1918.

Sam Hunter was in charge of operations, employing six men.

Feldspars, Limited.—Work was continued throughout the year 1917 in the Desert Lake quarry operated by this company near Verona in Frontenac county. The proposed changes in methods of transportation to track, mentioned in the Twenty-sixth Report, were not made during the year, and when inspected in June, 1918, the ore was being transported to Glendower siding in scows as before

Hoisting by derricks in open buckets has been abandoned, and all ore is lifted to the rock house in skips on the incline track, the loading pocket being located in a central position in the pit.

The entire spar production is now being utilized by the United States military authorities in the manufacture of insulating material. The ore was formerly transhipped from cars to boats at Kingston, but now crosses the lake on the Grand Trunk ferry operating between Cobourg and Genesee dock, where the grinding plant is located.

The officers of the company are: S. Harry Worth, president; Fred Zoller, Rochester, vice-president; R. F. Segsworth, Toronto, secretary-treasurer; the head office is at 103 Bay St., Toronto. Ralph Scott is superintendent, and George Gray assistant superintendent. An average force of 75 men was employed during 1917.

Feldspar Milling Company, Limited.—The feldspar grinding plant near Parham station, Canadian Pacific railway, is operated by this company, which was organized in 1917. During the year the plant was remodelled and grinding stones and a pebble mill added. The product is ground to 200-mesh and shipped to the trade in bags.

A. W. Adams was superintendent in 1917, and since March 1st, 1918, Geo. W. Hurlburt has been in charge.

The officers are: F. H. Hurlburt, president; Geo. W. Hurlburt, manager; Dr. Morrison, secretary-treasurer; head office, 33 Richmond Street West, Toronto.

Feldspar Quarries, Limited.—The quarry owned by this company, situated on the west half of lot 16 in the tenth concession of the township of Portland, was operated continuously during 1917. The product is teamed to Verona on the Canadian Pacific railway. The manager reports shipments of 6,000 tons of high-grade spar during the year 1917.

The pit when last inspected, on June 4th, 1918, was 150 feet long and 80 feet deep. A considerable body of spar was exposed, but a large tonnage of capping on the hanging-wall side required to be removed to permit of its recovery.

The head office of the company is at 33 Richmond Street, Toronto. George W. Hurlburt is manager, employing 15 men.

Eureka Flint and Spar Company.—This is an American corporation with head office and works at Trenton, N.J. For some years it has been one of the largest producers and purchasers of spar and flint rock in the United States and Canada.

Operations were commenced in October, 1917, on the Emery farm near Verona, on part of lot 16 in the tenth concession of the township of Portland. On June 4th, 1918, the open pit measured 125 feet long by 35 feet wide and 30 feet deep. The quarry adjoins the Hurlburt property. The plant consists of one upright boiler, 22-h.p., one Beatty hoist and one stiff-leg derrick.

Shipments are made from this quarry to the company's plant at Trenton, N.J., and the Canadian representative, John C. Wilkes, also purchases spar and flint for use in the pottery trade.

The officers of the company are: John E. Throp, president; Thos. H. Throp, vice-president; Frank W. Throp, treasurer; Peter D. Throp, secretary. Operations in Canada are in charge of John C. Wilkes, Verona.

National Potash.—The National Potash Corporation, Limited, has an authorized capitalization of 1,500,000 shares of a par value of $1.00. The directors are: E. L. Wettlaufer, Toronto, president; William Calder, Durham, general manager; D. J. Benham, Toronto, secretary; W. S. Milne, Toronto, treasurer; H. T. Whaley, Toronto. The head office of the company is at 178 Spadina Avenue, Toronto. The works and quarry are at Gravenhurst (Muskoka Wharf). S. J. McCarthy is works manager, employing 45 men.

The quarry is at present being operated for crushed rock for road material. The face of the quarry is about 60 feet in height. The work is done under contract and about 200 tons of rock are crushed daily. As shipped, the product runs from 3/8-inch to 2½-inch. The feldspar is being stockpiled until the smelting plant is completed.

The plant being installed comprises a blast furnace 192 in. by 42 in. with a capacity of 200 tons a day; one 175-h.p. engine; two 600-cu. ft. blowers, two 25,000 induction fans; two 325-h.p. B. and W. boilers; one 300-cu. ft. compressor, and one set of evaporators. It is electrically operated.

Orser and Kraft.—The feldspar quarry on lots 12 and 13 in the fifth concession of the township of South Sherbrooke, was worked at intervals during 1917. A siding was built at Mud Lake station on the Canadian Pacific railway, one and one-half miles from the quarry, and in the spring of 1918 regular shipments amounting to 100 tons per week were going forward.

In this quarry the radium-bearing mineral euxenite was found which is described by Dr. W. G. Miller and C. W. Knight in the Twenty-sixth Report of the Bureau of Mines.

Mica

Lacey.—The Lacey mine, near the village of Sydenham in Loughborough township, worked continuously during 1917. From July to December operations were carried on in the open pit, which is now 200 feet deep. During the winter months work was continued in the "milky-vein" stope, a parallel ore body connected with the main shaft by a cross-cut about 60 feet to the southwest. This stope averages 16 feet wide and 200 feet long, and from the floor to the back in the deepest part of the stope is 80 feet. The ore is hand-cobbed underground and roughly trimmed in the shop at the shaft collar, before shipment to the company works at Sorel, Quebec, where it is finished for the market.

Henry Smith, for many years superintendent of this mine, died December 14th, 1917, and was succeeded by his brother, Richard Smith. The mine is owned and operated by the Loughborough Mining Company, Limited. George M. McNaughton is manager, and an average force of 25 men was employed during the year.

Sydenham Mica and Phosphate Mining Company, Limited.—The mica pit operated by this company in 1916 on lot 7 in the eighth concession of Loughborough township continued production till September, 1917, when work was stopped. The shaft was sunk about 50 feet, and the mica was trimmed at the company's shop in Sydenham. A hoist, gasoline engine and pump were installed.

The officers of the company are: Harry N. Kraft, president and treasurer; Jacob J. Stein, vice-president; A. B. Potter, secretary.

Molybdenite

International Molybdenum Company.—The only mine operated by this company in 1917 in Ontario was the Moran in Brougham township adjoining the O'Brien mine. Most of the ore mined was taken from an open cut, and the shaft was continued to a depth of 40 feet. The company is also a purchaser of molybdenite ores, having a custom concentrator at Renfrew and a smelter and refinery at Orillia.

At the concentrating plant at Renfrew three additional flotation machines were installed, and the capacity increased about 30 per cent.

The smelting plant at Orillia was operated for seven months when all equipment was transferred to a new plant, an additional electric furnace, new transformers and other equipment being added, thereby doubling the capacity of the old plant.

The officers of the company are: J. L. Murray, president; H. A. Jordan, secretary-treasurer and manager; B. C. Lamble, superintendent of smelter at Orillia; W. M. Weigel, superintendent of mining and milling. The head office of the company is in Renfrew.

The company manufactures molybdic acid, ammonia molybdate and ferromolybdenum.

Renfrew Molybdenum Mines, Limited.—The mine and concentrating mill of this company, situated on lots 8 and 9, concession XI, township of Brougham, operated continuously during 1917.

The officers of the company are: President, Jean Vanophen, 24 Rue Batallière, Paris, France; A. E. Goyette, vice-president, Montreal; secretary, R. LeAprohon; treasurer, P. C. Neault, Grand Mère, Que.; Chas. G. Titus, assistant vice-president and general manager, Mount St. Patrick.

During the year the 2-compartment shaft was sunk 75 feet to the 150-foot level, and about 600 feet of lateral development done.

Owing to lack of fuel for power, the mill ran only about 34 per cent. of the possible running time. The total production of molybdenite for the year was about 58,000 pounds. The concentrates averaged 95 per cent. MoS_2. A 96 per cent. recovery was made on ore averaging .74 per cent. MoS_2. The concentrates are shipped to France in barrels, the weight being about 1,000 pounds each. The mill has a daily capacity of 40 tons.

Owing to the difficulty of obtaining fuel, a transmission line was built to the power development on the Madawaska river at Calabogie and the plant electrified. One 5-h.p. and two 25-h.p. motors were added to the mill and a 100-h.p. motor to the compressor. Forty men are employed.

Spain.—The Spain mine, on lot 31 in the fourth concession of the township of Griffith, operated intermittently during the year. The production came principally from the open pit.

The mine address is Dacre, Ont., and the head office of the company is at 417 Fifth Avenue, New York. Ten men were employed.

Steel Alloys Corporation.—The Sunset mine, situated on lots 35 and 36, concession XIV, township of Brougham, is being operated by a company known as the Steel Alloys Corporation, of which H. E. Clarke, 27 William Street, New York, is president.

The ore body has been opened up by an open cut 10 feet wide, 100 feet long, the greatest depth of which is 35 feet.

The plant includes a 100-h.p. boiler, a 5 by 7 hoist and a 686-cu. ft. compressor. J. E. Cole, Dacre, Ont., is superintendent.

Molybdenum Products Company, Limited.—This company has a capitalization of 1,075,000 shares of a par value of $1.00. The head office of the company is at Wilberforce. M. B. R. Gordon is manager, employing 40 men.

The mine is located on lot 33 in the sixteenth concession of the township of Monmouth in Haliburton county, about half a mile from the village of Wilberforce. A 75-ton mill is in course of construction.

W. E. Joiner and Company.—W. E. Joiner is opening up a promising molybdenite property on the north half of lot 3 in the twentieth concession of the township of Cardiff, 1½ miles east of the town of Wilberforce. The work so far done consists of stripping and blasting and has exposed some very fine molybdenite ore. A small steam plant is being installed.

Paudash Lake Molybdenite Mines, Limited.—Mr. Joiner has also done some work on a molybdenite deposit on lot 18 in the ninth concession of Cardiff, the Mooney farm, about 15 miles southeast of Wilberforce. This property is known as the Paudash lake molybdenite mine.

Wilberforce Molybdenite Company, Limited.—On lot 33 in the fifteenth concession and on part of lot 33 in the fourteenth concession of the township of Cardiff, the above company is opening up a molybdenite prospect. P. J. Dwyer is manager. A concentrator is being erected at Wilberforce.

Graphite

The demand for all grades of Ontario graphite was very satisfactory to the producers throughout 1917.

Since January 1, 1918, the crucible trade has fallen off materially owing to adjustments in the iron and steel business, and this in turn affected the demand for crystalline flake graphite and broke the market price for that product. The crucible makers, on account of a lack of demand for their product, demanded a higher grade of graphite. As a result the producers of crystalline flake in New York, Alabama and Pennsylvania had large quantities of this grade rejected, and the same condition prevailed with regard to the Ontario product.

The demand for lubricating flake has also fallen off to a considerable extent, and large stocks have accumulated.

With regard to the intermediate and low-grade graphite products, which are consumed largely by foundries and the iron trade, the demand has also materially fallen off since the beginning of the present year, owing to unsettled conditions in the iron industry in the United States. This state of affairs is due to the inability of the foundries to secure raw material for any but essentially war production.

The effect has been to put the small foundries devoted to commercial production practically out of business, and as they consumed the bulk of foundry plumbago for facing purposes, the demand has greatly fallen off.

Black Donald.—The Black Donald Graphite Company, Limited, had in 1917, the largest production of refined graphite in the history of the company. The mine and mill are situated about 14 miles from Calabogie, in Renfrew county. The company owns mining rights on lots 17 to 20 in the first, second and third concessions of the township of Brougham.

In the autumn of 1917 the open pit was lagged over, and work was continued throughout the winter in the old workings under Whitefish lake. The ore shoot has widened out considerably and continues to be high-grade milling ore.

New plant installations included three General Electric transformers, 4,400 to 550 volts; one Ingersoll-Rand compressor, 500 cubic feet capacity, one Universal jaw crusher. A new blacksmith shop and machine shop were built and equipped, and 33 dwellings for employees were erected during the year 1917. The hauling capacity to the track at Calabogie was increased by the purchase of five motor trucks, hauling from 2,500 to 3,500 lbs. each per load, and making two round trips per day.

The officers of the company are: R. F. Bunting, president; G. H. Bunting, vice-president; J. N. Snead, secretary; John Patno, superintendent; 75 men are employed at the mine and mill.

Globe.—The Globe Graphite Mining and Refining Company, Limited, operated their mine continuously during 1917. The mine is situated on lots 21 to 23,

inclusive, in the sixth concession of the township of North Elmsley, and the ore is teamed to the mill on the Tay river at Port Elmsley, a distance of three miles. Considerable diamond-drilling was done during 1917 by Smith and Durkee of Sudbury. No. 3 vertical shaft was sunk to a depth of 100 feet, with 40 feet of drifting to the north at the 60-foot level and 40 feet at the 100-foot level.

The mill is equipped with the dry process of concentration, using the Sutton, Steele and Steele tables and air flotation. In the spring of 1918 experiments were in progress for the installation of an oil flotation unit. The drying kilns were improved and a large Telsmith ore crusher was installed. When inspected, June 11th, 1918, work on the No. 3 shaft had ceased, and the old workings were being de-watered.

The company produces three grades of finished graphite designated as: M. flake, containing 90 per cent. graphitic carbon and over; F. flake, containing between 65 and 85 per cent. graphitic carbon; D. grade dust, containing from 30 to 40 per cent. graphitic carbon.

The officers of the company are: Chas. A. Lux, president; George G. Fryer, secretary-treasurer; George H. Beebe, manager, all of Syracuse. The head office of the company is 410 Dillaye Building, Syracuse, N.Y. George N. Brewer, Port Elmsley, is superintendent, employing 55 men.

National.—National Graphite, Limited, did a small amount of development work on their property on lot 24 in the thirteenth concession of Monteagle township; the mill at Munfords, near Harcourt on the I. B. and O. railway, is being remodelled at the present time.

W. A. P. Schorman is president of the company, the head office of which is in the Royal Bank Building, Toronto. George Gill is superintendent of the mine and mill at Munfords.

Corundum

Manufacturers Corundum.—The Manufacturers Corundum Company, Limited, mined various small deposits of corundum in the townships of Raglan, Radcliffe and Brudenel during 1917. Most of the operations were conducted during the winter months, and the ore was stockpiled at the company's concentrating plant at Palmer rapids on the Madawaska river, lot 24, concession XVIII, township of Raglan.

The officers of the company are: D. A. Brebner, Toronto, managing director; A. W. Holmsted, Toronto, secretary; H. E. T. Haultain, Toronto, consulting engineer; E. B. Clarke, Jewellville is superintendent, employing on an average 35 men.

Quarries

Canada Cement Company.—The quarry and clay pit operated by the Canada Cement Company at Point Anne near Belleville was closed for the greater part of 1917. On August 1 work was resumed and carried on till the close of the year, when it was again closed till March 1, 1918. The working face is now 50 feet in depth, and all drilling is done by two Loomis power drills, using a 5⅝-inch bit. The broken stone is loaded on 8-ton cars by a Marion steam shovel,

and hauled to the crusher by a dinky locomotive, on a standard-gauge track. The Fairmont jaw crusher has a capacity of 1,000 tons per day.

H. L. Shock is manager, employing 20 men.

Point Anne.—The Point Anne Quarries, Limited, operated continuously during 1917. Ground-storage capacity for 75,000 tons was installed during the year with belt conveyor to boats and cars. The quarry is one-half mile long by 300 feet wide. Drilling is done with an Armstrong power drill, the holes being six inches in diameter and drilled to an average depth of 32 feet. The material shipped varies in size from ½-inch screenings to 8-inch lump for blast-furnace work. The officers are: M. J. Harvey, president; J. F. M. Stewart, manager; A. N. Harnwell, secretary-treasurer; A. G. Bennett, superintendent.

Hydro-electric power is used throughout the crushing plant and quarry. Fifty men were employed during the year.

V.—SOUTHWESTERN ONTARIO

Quarries

Beachville White Lime Company.—The quarry and lime kilns operated by this company near Beachville, adjoining the property of the Standard White Lime Company, were in continuous operation during 1917. The limestone, which in this district has a very high lime content, is quarried in two benches with a total face of 28 feet. At present only the bottom bench 8 feet in depth is being worked. A large percentage of the output is shipped to the Cyanamid Company at Niagara Falls, and to the Hamilton blast furnaces.

The officers of the company are: M. S. Schell, president; J. W. Blow, secretary-treasurer; C. E. Downing, manager.

Forty-two men are employed.

Canada Cement Company.—The cement plant and quarry operated by this company at Port Colborne worked with reduced capacity in 1917, and closed down completely in January, 1918, due to power shortage. The plant is well located close to the source of power at Niagara, but the large number of munition plants in the district have gradually absorbed all available power and forced other industries to close.

The quarry has a working face of 20 feet, drilling being done with a power drill. The broken rock is loaded into cars by two Marion steam shovels, a third Vulcan shovel being used for stripping.

S. R. Preston is manager, and L. M. McDonald, superintendent.

Canada Crushed Stone Corporation, Limited.—The large quarry and crushing plant operated by this company near Dundas, in the township of West Flamborough, was in continuous operation throughout the year. Its output of crushed limestone is the largest in the Province. The quarry is now worked in two benches, with a total working face of 54 feet, drilling being done by Cyclone Electric power drills. A large percentage of the output is used for fluxing purposes by the Steel Company of Canada, Hamilton. No additions were made to the plant during the year.

C. M. Doolittle is president and general manager, and J. B. Hart secretary-treasurer and assistant manager.

Christie-Henderson.—The Christie-Henderson quarry near Milton in the township of Nassagaweya, concession two, operated for the greater part of the year. The quarry is 700 feet long, and the working face is 40 feet in height, the stone being quite uniform in quality. Grey lime only is manufactured. Only sufficient force is employed to keep one kiln burning, with an output of 20 tons per day.

D. D. Christie, Guelph, is president of the company, and David Henderson, Acton, is associated with him in the ownership of the quarry.

Elora White Lime Company.—The quarry and hydrating plant operated by the above company near Elora, concession XII, township of Nichol, worked with increased output during 1917. Fifty tons of white lime per day is burned in the kilns and practically the whole of this output is hydrated.

The quarry has a working face of 25 feet, and during the year a Cyclone drilling rig was added to the quarry equipment, and the plant equipped with new hydrating machines.

The company is owned and managed by the Alabastine Company of Paris. J. Cameron is superintendent.

Hambleton.—The quarry owned by Robert Hambleton, near Hagersville, in the township of Oneida, operated for a short period during 1917. For the past two years, the quarry has been closed except for short periods during which the crushing plant was in operation supplying stone for country roads.

E. Harvey and Son.—The quarry owned by E. Harvey & Son, at Rockwood, near Guelph, operated for nine months during 1917. One kiln with a capacity of 20 tons of grey lime per day was in operation.

E. Harvey is manager, employing 15 men.

Interprovincial Brick Company.—This company was one of the few brick companies in the Province to operate continuously during 1917. The pressed brick plant, working with reduced capacity, has an output of 22,000 per day manufactured from the red shales and clays which occur throughout Halton county.

The quarry has a working face of 15 feet.

The officers are: A. O. Dawson, president, Montreal; E. G. Glenn, secretary, Toronto; F. B. McFarren, manager; K. Stillwaugh, superintendent.

The quarry and plant are situated at Cheltenham village, concession V, township of Chinguacousy, and the head office address is 30 Toronto Street, Toronto.

Michigan Central Quarry.—This quarry near Hagersville was in steady operation during 1917, the entire output being used by the Michigan Central railway for ballasting track. The quarry is worked in two benches with a total face of 20 feet. In 1917, fifteen miles of track in the vicinity of Hagersville were ballasted with material from this quarry. D. E. Cronin is superintendent for the railway company, and 65 men are employed.

Milton Pressed Brick Company.—This company is one of the largest manufacturers of pressed brick in the Province. Operations were carried on continuously during 1917, although the output was curtailed, due to scarcity of labour. Plant No. 2 in the township of Nassagaweya, near the town of Milton, formerly owned by the Toronto Brick Company, was closed during the year, but plant No. 1 operated steadily. From the mixture of clay and Medina shales found throughout this district the company make red and buff pressed brick, rough texture rug and wire-cut brick.

The officers are: J. S. McCannell, president; A. W. Holmsted, secretary; R. Wheeler, treasurer; C. E. Hill, superintendent.

Oneida Lime Company, Limited.—On the townline between Oneida and North Cayuga townships near the village of Nelles Corners, the Oneida Lime Company operates a quarry for the production of silica sand. The silica rock overlies the limestone in beds varying in thickness from 4 to 14 feet. The rock is crushed, ground and washed for shipment to the glass trade and ferro-silicon plants.

In April, 1918, the Canada Crushed Stone Corporation took over the quarry under lease, and operations are now under the direction of Mr. Doolittle.

In 1917, about 18,000 tons of silica sand were shipped from this quarry. Thirty-five men are employed.

Patterson Sand Company.—This company, successor to the Clifton Sand and Gravel Company, Stamford township, operated continuously during 1917. Robert Patterson is manager, employing about 12 men.

Building sand and gravel for concrete work are shipped from the old workings. During the past few years a large trade has been worked up in moulding and pipe sands. The moulding sand is shipped to all parts of Ontario and even as far east as Quebec, while a large trade in New York State is also supplied.

Queenston Quarry Company.—The limestone quarry owned and operated by this company is situated near St. Davids in the township of Niagara, lots 47, 48 and 49. During 1917, the crushing plant ran for three months only, and for the balance of the year building and dimension stone was shipped. The building stone plant is equipped with a set of gang saws and diamond saw, and blocks of large proportions are cut to required sizes.

The crushing plant consists of one No. 5 Austin gyratory crusher, followed by a Simons disc crusher and screening plant.

Charles Lowrey is president and manager of the company, and T. W. McKeown, secretary; 25 men are employed.

Robertson Quarry.—The quarry owned by D. Robertson & Co., Limited, lot 4, concession VII, township of Nassagaweya, operated continuously throughout the year. Work is being carried on in the extreme west end of the quarry, and the stone is hauled in carts to the kilns. Grey lime is manufactured, and only one kiln with a capacity of 20 tons per day is in operation.

D. Robertson, Milton, is president of the company, and J. R. Robertson, secretary.

F. Rogers and Company.—The quarry operated by this company is situated in Chinguacousy, on the east half of lot 30, concession VI, and the east half of lot 31, concession V. The chief production is in the form of flag stone, coursings and rubble stone. The quarry was worked during the summer months only because of slack demand in the building trade.

Dan Hastings is superintendent for the above company.

Standard White Lime Company.—This company, with headquarters at Guelph, operates quarries at Guelph, Beachville and St. Marys. White lime, high-grade fluxing stone, and hydrated lime are produced. At St. Marys, one kiln, with a



A blast at the quarry of the St. Marys Cement, Limited, resulting in 21,000 tons of broken limestone.

capacity of 25 tons of white lime per day, was in operation during seven months in 1917. The Guelph quarry and hydrating plant operated continuously with a working force of ten men. The principal operations of the company are carried on at Beachville, where two quarries are operated steadily. What is known as the West quarry produces stone for fluxing purposes, which is loaded directly into cars for shipment to Hamilton. This quarry has a working face of 25 feet. Stone from the East quarry is used in the kilns for the production of white lime. Two kilns, with a capacity of 20 tons per day, were in operation during the year.

The officers are: D. D. Christie, president; John Kennedy, manager; Wm. Culford, secretary-treasurer; W. P. Gamble, superintendent.

St. Marys Cement, Limited.—The quarry and cement plant owned by this company, formerly known as the St. Marys Portland Cement Company, was in steady operation during the year. By reason of power shortage the plant is now running at one-third capacity. Extensive additions to the crushing equipment were being installed in June, 1918. The No. 8 Kennedy crusher is being replaced by a 48 by 60-inch Blake jaw crusher, manufactured by the Taylor Engineering Company. This crusher has a capacity of 3,000 tons per day. Following the jaw crusher is a No. 7 Mammoth Williams hammer mill, manufactured by the Williams Patent Crusher and Pulverizer Company of St. Louis.

The officers of the company are: Geo. H. Gooderham, president; Hedley Shaw, vice-president; Mark Irish, secretary-treasurer; John G. Lind, manager.

St. Marys Horseshoe Quarry.—This quarry was operated for five months during 1917, the entire output being shipped to the National Portland Cement Company at Durham. Drilling is done by a power drill, the average hole being 40 feet deep, leaving a 4-foot bench at the bottom. The stone is crushed in a No. 6 Austin gyratory crusher, followed by a set of 22 in. by 24 in. rolls.

John Bonis is in charge of operations.

Toronto Lime Company.—The quarry owned by this company at Dolly Varden, concession IV, township of Esquesing, operated during the summer months of 1917. The stone is manufactured into grey lime, only one kiln being operated with a capacity of 15 tons per day. The quarry has a working face of 40 feet, and a much greater production could be maintained if trade were normal.

The Limehouse quarry and plant owned by this company were closed during the year.

The officers are: F. D. Brown, president; W. L. Scott, secretary-treasurer; W. Gowdy, superintendent; head office, 26 Queen Street East, Toronto.

Wentworth Quarry Company, Limited.—The quarry operated by this company is situated near Vinemount Station, T. H. & B. railway, on lot 4, concession V, township of Saltfleet. During 1917, operations were carried on continuously. The quarry has a working face of 19 feet, and drilling is done with a cyclone power drill. A set of Garfield rolls 42 in. by 16 in. has been added to the crushing plant.

F. W. Schwendiman is manager.

Gypsum

Ontario Gypsum Company, Limited.—This company is an amalgamation of the Crown Gypsum Company of Lythmore and the Alabastine Company of Caledonia.

The mine and grinding plant of the Crown Gypsum Company were operated during the year. At the present time a shaft is being sunk beside the grinding plant at Lythmore to avoid the rail haul of 3½ miles from the old mine.

The Caledonia plant and mine operated continuously during the year, manufacturing hardwall plaster, plaster of Paris, sand plaster and bug finish, supplying the markets of Ontario and Quebec, and shipping as far west as Winnipeg. The surplus is shipped to New York State.

The Carson mine is worked only during the winter months.

At the Caledonia mine the production is from the second, or 70-foot level, where the gypsum bed is about 6 ft. 6 in. in thickness. A third level, 14 feet below this, was opened up during the year, but this bed was only 4 feet thick. The production of this mine is about 200 tons daily.

W. C. Case, Buffalo, is president of the company; R. C. Haire, Paris, secretary-treasurer. The head office is at Paris and the works office at Caledonia. A. J. Parkhurst is general manager; about 75 men were employed on an average during the year.

VI.—Blast Furnaces and Refineries

Blast Furnaces

Algoma Steel Corporation.—The Algoma Steel Corporation has an authorized capital of 300,000 shares of a par value of $100 each. The officers of the company are: J. Frater Taylor, president; T. Gibson, secretary; J. Hawson, treasurer. These with the following constitute the board of directors: W. C. Franz, W. K. Whigham, H. Coppell and W. E. Stavert.

During the year 1917 a fourth blast furnace was installed; the No. 2 blast furnace of the Canada Iron Foundries, Limited, at Midland being purchased and re-erected at Steelton. This furnace has a capacity of 400 tons a day. The furnaces were operated continuously during 1917 as well as the Greenawalt sintering plant.

J. H. Bell is superintendent of blast furnaces, employing 300 men. V. H. Taylor is superintendent of the Greenawalt plant, employing 20 men.

Canadian Furnace Company.—The blast furnace of this company, situated at Port Colborne, operated continuously throughout the year with the exception of a ten-day shut-down due to coke shortage. Owing to the difficulties of securing a sufficient supply of coke, it was necessary to operate at a decreased production during part of the year.

The two large ore bridges were destroyed by wind-storms; No. 1 in October, 1917, and No. 2 in February, 1918; both are being rebuilt.

The officials of the company are: Frank B. Baird, president; Harry Yates, first vice-president and treasurer; C. A. Collins, second vice-president; F. C. Slee, secretary; B. Marron, manager; F. E. Deschenes, superintendent; D. J. Higgins, mechanical superintendent; 135 men were employed during the year.

The head office of the company is at 51 Hamburg Street, Buffalo, N.Y. The works office is at Port Colborne, Ont.

Steel Company of Canada.—Due to coke shortage, blast furnace "A" operated by this company at Hamilton was out of blast for 61 days during 1917. The larger furnace "B" operated continuously during the year. A large coking plant is in course of erection near the blast furnaces. One hundred and eighty-five men were employed in the blast furnace department.

Robert Hobson is president of the company; R. G. Wells, general superintendent; and Charles Grimes, superintendent of blast furnaces.

Standard Blast Furnace.—The blast furnace at Deseronto, owned by the Standard Iron Company, remained in blast throughout 1917. The Parry Sound furnace remained closed. Charcoal pig is produced at Deseronto, chiefly from Mesabi range ores, although some experiments have been carried on with a view to using Ontario magnetites.

The officers of the company are: R. J. Mercer, president; S. F. Belknap, secretary-treasurer; O. O. Laudig, works superintendent; 70 men were employed during the year. The head office of the company is at 318-321 Coristine Building, Montreal.

Tivani Steel.—The plant at Belleville owned by the Tivani Electric Steel Company was operated steadily during the year. The two electric furnaces, having a capacity of four tons each per day, and installed for the manufacture of tool steel, were used in the manufacture of ferro-molybdenum. At the beginning of 1918, owing to the scarcity of molybdenum concentrates, the manufacture of this product was discontinued, and the production of low phosphorus pig iron for munition work was undertaken. This has been successful. The charge consists of scrap—shell turnings—coke and lime.

Plans for a new 15-ton furnace, to replace the two small ones at present in use, have been drawn, and it is anticipated that this furnace will be in operation during 1918.

The officers of the company are: J. W. Evans, president; H. F. Ketcheson, vice-president; J. M. Wallace, manager; directors: R. J. Graham, H. Ackerman, H. F. Ketcheson, J. M. Wallace, J. W. Evans, J. A. McFee.

The capitalization of the company is $20,000, divided into 200 shares of $100 each, all issued.

Ten men were employed during the year.

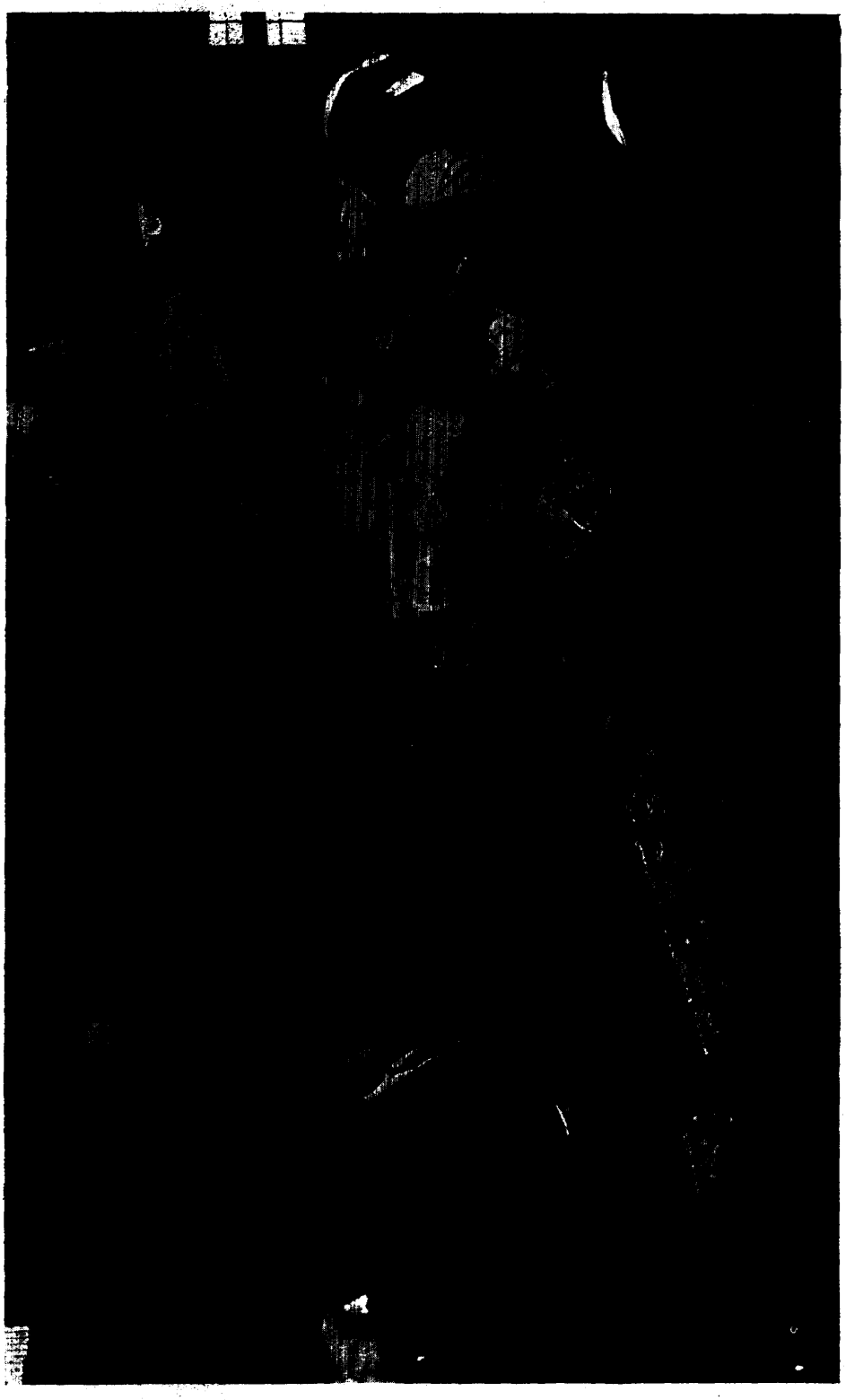
Refineries

Coniagas Reduction Company.—This company operates a silver smelter and refinery at Thorold. The officials are: R. W. Leonard, president and general manager; R. L. Peek, superintendent; J. J. Mackan, secretary. The head office of the company is in St. Catharines.

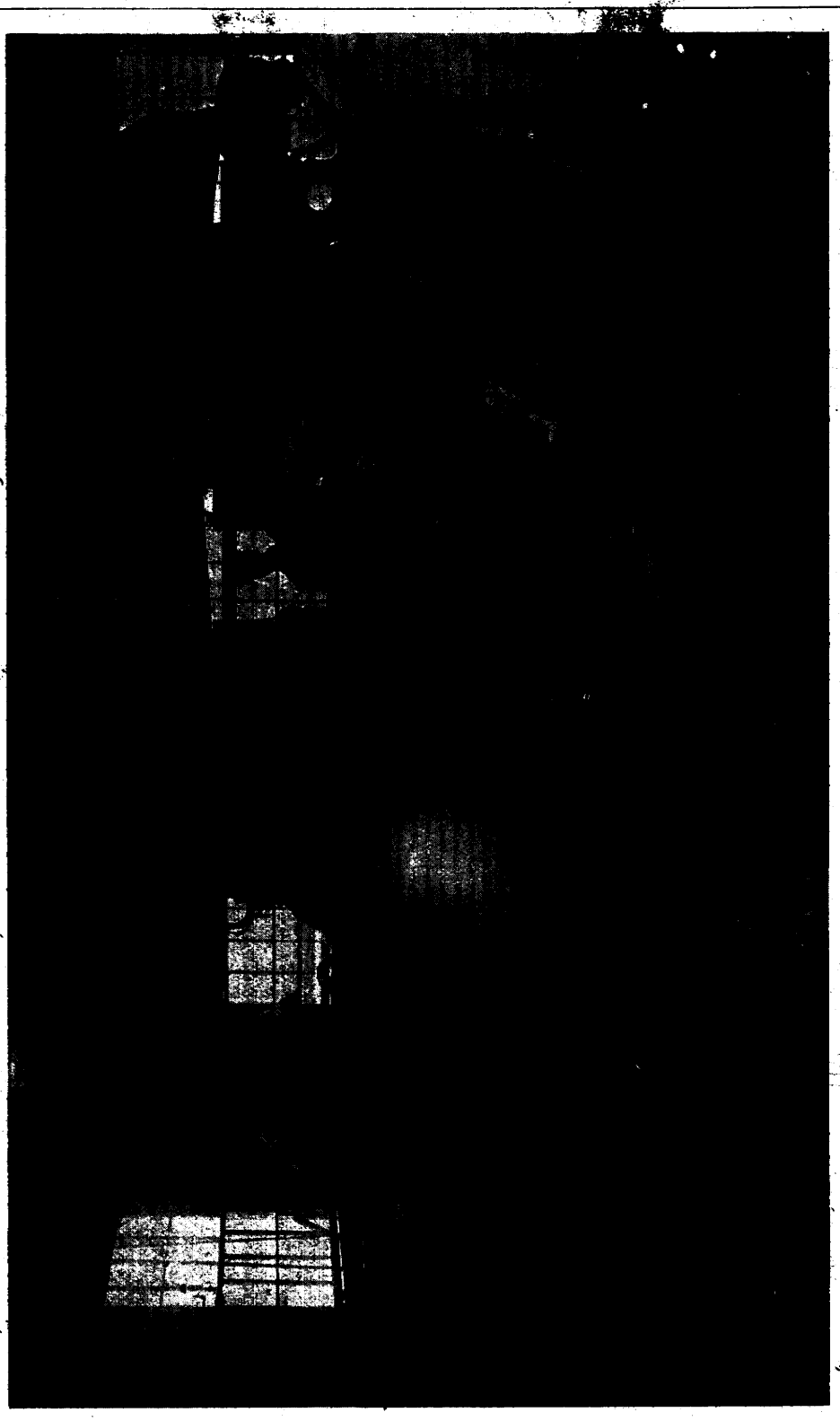
In addition to treating the production of the Coniagas mine and concentration works, custom ores of the Cobalt district are purchased. The company produces cobalt oxide, nickel oxide, metallic cobalt, metallic nickel, white arsenic and bar silver electrically refined.

The additions to the plant during the year were a Cottrell installation in connection with the speiss roast furnace. This is a 96-pipe treater capable of handling 15,000 cubic feet of fumes per minute; a new bag house was built with a capacity of 20,000 cubic feet per minute, and a new transformer added to the power sub-station. About 150 men are employed.

Deloro Smelting and Refining Company, Limited.—The smelting and refining works of this company at Deloro, Hastings county, operated to full capacity during 1917. Various additions were made to the plant with a view of increasing



Pouring silver at the Deloro plant of the Deloro Smelting and Refining Company, Ltd.



Casting "stellite" at the Deloro plant of the Deloro Smelting and Refining Company, Limited.

the output of manufactured metals and of providing facilities for experimental work in the metals branch.

The company manufactures refined silver, metallic cobalt, cobalt oxide, metallic nickel, nickel oxide, refined arsenic and stellite. Metallic cobalt and nickel are supplied to the trade in the form of grain, cube, shot and ingot.

The output of stellite, the cobalt-chromium-tungsten alloy, was greatly increased during the year.

Additions to the plant included a new office building, bag house, metal building and warehouses.

The officers of the company are: M. J. O'Brien, president; Thomas Southworth, vice-president and managing director; S. B. Wright, general manager; S. F. Kirkpatrick, consulting metallurgist; F. A. Bapty, secretary-treasurer. Four hundred men were employed during the year.

Metals Chemical, Limited.—This company operate a refinery at Welland on residues purchased from the Cobalt mills.

Nickel oxides (grey and black), nickel carbonate, nickel sulphate, cobalt oxides (grey and black), cobalt sulphate, cobaltic hydrate, crude arsenic and bar silver are manufactured. About 60 men are employed.

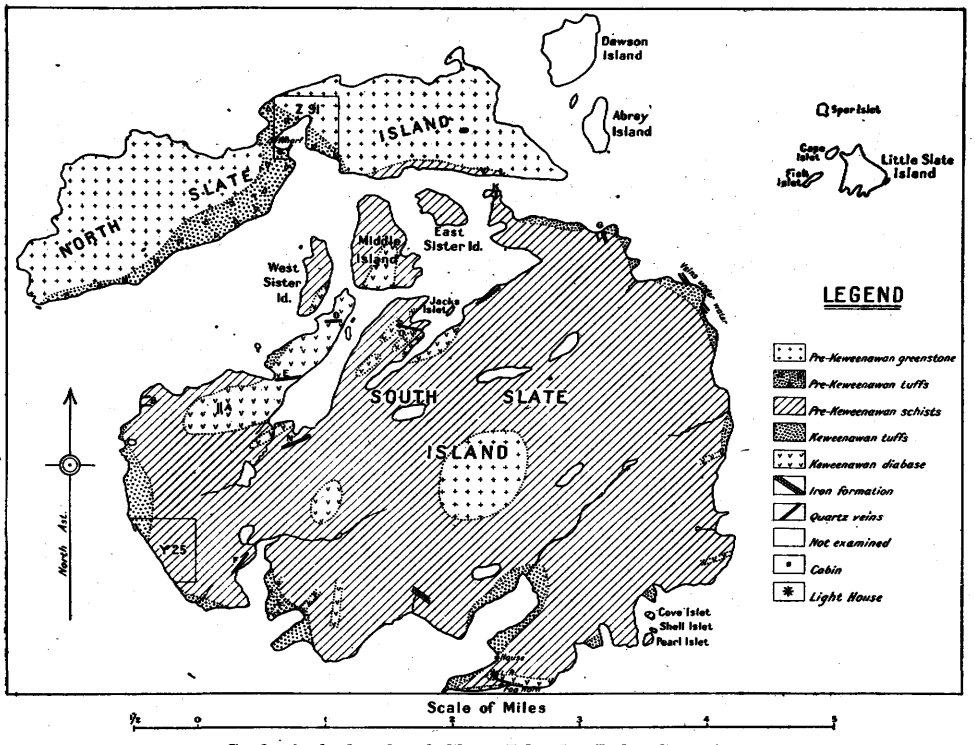
J. S. Gillies is president of the company and J. H. Charles, secretary-treasurer and general manager.

SLATE ISLANDS, LAKE SUPERIOR

By Arthur L. Parsons

Introduction

In view of the fact that several reports indicated that high-grade gold ore was to be found in considerable quantity on the Slate islands near Jackfish, the writer visited these islands twice during the summer of 1917 with a view of investigating the economic possibilities of the deposits. The first visit was solely



Geological sketch of Slate Islands, Lake Superior.

for the purpose of sampling the principal known veins, so that the later work might be carried out in a more intelligent manner. The second visit was made in the latter part of August and the first part of September, and comprised about two weeks' field work. At this time a more detailed study of the geology of the islands was made.

Considering the accessibility of these islands, remarkably little has been written concerning their geology; in fact, so far as the writer is aware, no attempt has been made to differentiate the various types of rock. This is less surprising when one sees the character of the rocks, for with few exceptions they are so decomposed and altered that it is extremely difficult to secure satisfactory specimens for study.

Location

The Slate islands consist of a group of some eight or ten islands located about seven miles south of the village of Jackfish on the north shore of Lake Superior. The total area covered by these islands is somewhere in the neighbourhood of 10,000 acres, of which about 2,000 acres are in North island and 7,000 acres in South island.

At the present time the islands are totally uninhabited except by the keeper of the lighthouse on the south side of South island, though some years ago there were mining camps at several locations on the islands.

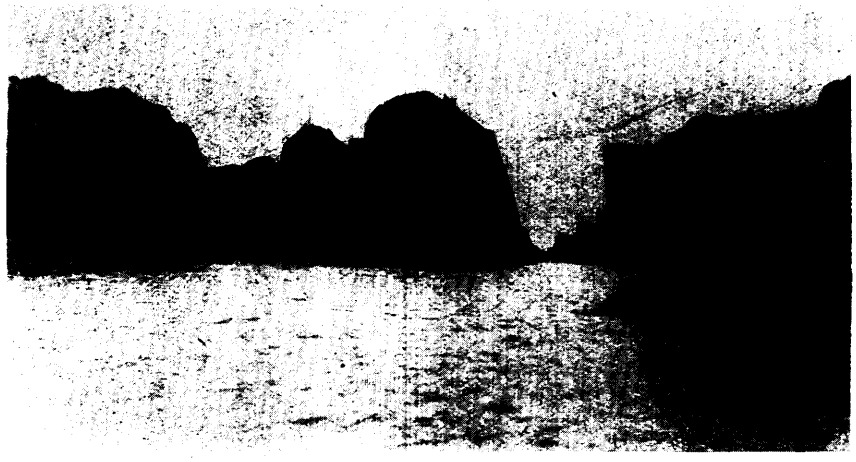


Fig. 1—Rugged shore, South Slate island.



Fig. 2—Southwest point of South Slate island, showing shoals.

A few years ago fire swept over a large portion of South island, so that the rugged character of the country is emphasized. On the unburned portion of this island as well as upon North island there is a good growth of the ordinary forest trees of this region, including spruce, balsam, Banksian pine, birch and poplar and some red pine.

Topography

The shore line of the islands is extremely rugged (fig. 1) and to a large extent precipitous, but in most cases no idea of the depth of the water at the base of the cliffs can be obtained, as is so frequently the case in regions where Keewatin rocks are prominent. Very frequently there is a broad irregular shelf of rock a few feet beneath the water's surface, and sometimes protruding above the water (fig. 2), so that it is extremely dangerous to try to keep near the shore in a boat except in calm weather. The rock has been much eroded by wave action, hence the shore is very similar to that in the Keweenawan rocks at Maimanse.

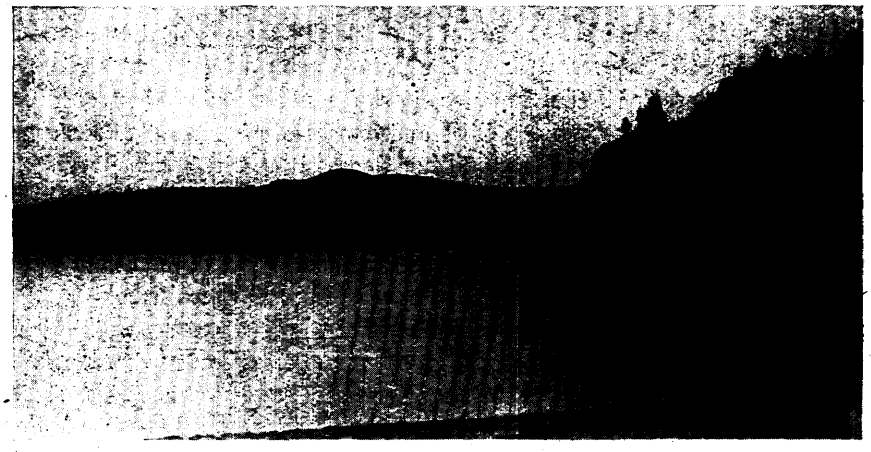


Fig. 3—Volcanic neck, South Slate island.

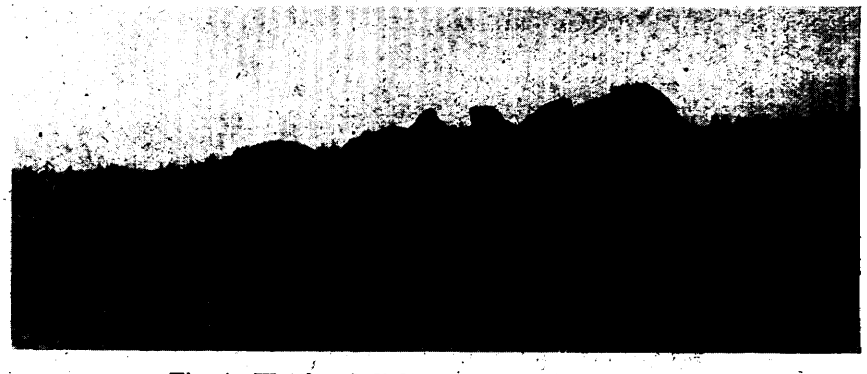


Fig. 4—Weathered diabase dike, South Slate island.

The surface of the islands is possibly not so rugged as might be expected in view of the character of the shores, yet on going to the highest peak of South island eight lakes were seen, while several others were found which are invisible from this point. Several of these lakes, possibly all of them, appear to be crater lakes, while the highest point on the island seems to be an old volcanic neck, (fig. 3). Another similar volcanic neck is found near the northwest

point of South island. Dikes are frequent, and are often partially decomposed, leaving jagged peaks protruding above the ground level (figs. 4 and 5). The lighthouse is located upon the highest point of one of these dikes (fig. 6).

Geology

In general it may be said that there are two great epochs of rock formation represented on South island, though both appear to be volcanic. The rocks vary from the coarsest volcanic tuff to the most compact igneous rock. The older series appears to have been similar to the later one, but has been subjected to pressure so that schistosity has developed to a large degree. The remarkable variation in the character of the rocks presents a most complex problem in mapping, and it is only when the highest point of the island is reached that a possible solution of the difficulty is presented. This highest point (fig. 3), which is about 250 feet above the level of Lake Superior, is a roughly circular mass of diabase protruding through the surrounding schists and apparently is an old volcanic neck.

From its summit numerous lakes filling depressions which are possibly old craters are to be seen. Many of these, if not all, are surrounded by rock rims (figs. 7, 8 and 9). This volcanic neck suggests the probability that all the rocks on the island are of igneous origin, and the problem is to differentiate various volcanic flows. This can be done only in a very imperfect manner.

On North island the rocks are similar in type to those on South island, including grayish diorites and tuffs, but little if any schistosity has developed. In appearance these rocks are similar to the Keewatin greenstones and tuffs, and probably represent an older volcanic series than the mottled tuffs of South island. On the south side of the island some of the rock is schistose and is probably to be correlated with the schists of South island.

Exact correlation of these rocks with formations elsewhere is impossible, but from resemblances to other rocks and stratigraphic relations observed the following general order of formation is given:

Keweenawan: Diabase—volcanic necks and dikes.
Tuffs.
Pre-Keweenawan: Greenstones.
Tuffs.
Sericite Schists.

Keweenawan

Keweenawan Tuffs.—Near the shore of South island, but more particularly on the east, south and west sides, there are numerous outcrops of tuffs which are usually of mottled red and green colours. In some instances the fragments composing these tuffs are of enormous size (fig. 10) and the rock appears to be a conglomerate. Several of the pebbles were extracted from a decomposed mass of this type of rock, and in no case did they show signs of either water or glacial action, moreover, the fragments were all of one type of rock and although roughly angular showed a certain rounding of the corners that eliminated the possibility of the rock being a breccia. In most cases, however, the tufaceous character of the

deposits was remarkably distinct. These tuffs in all probability at one time overlay a considerable portion of South island, and at certain places on the west side of the island they are to be seen overlying the older schists on some of the high hills. At present, however, little trace of the later tuffs is visible except near the present shore line. It seems probable that much of the tuff has been removed by wave action at the time when some of the great gravel deposits along the north shore of Lake Superior were formed. This theory is further strengthened by the



Fig. 5—Diabase dike, showing jagged peaks due to weathering.

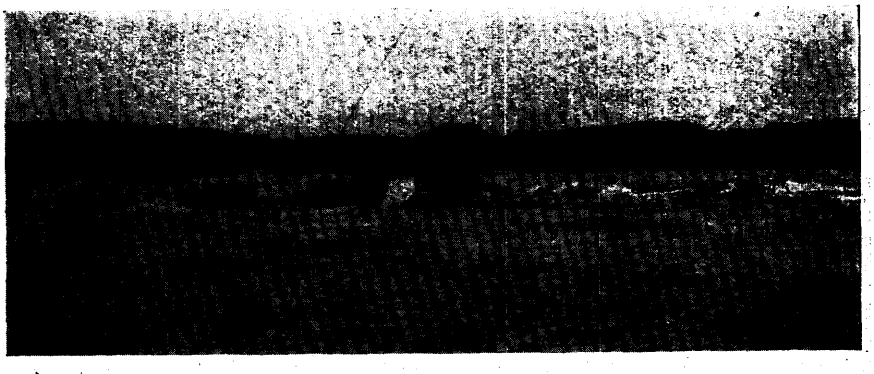


Fig. 6—Reef in front of Slate island lighthouse.

finding of large accumulations of worn pebbles of some of the more resistant rock of the island in some of the valleys above the present lake level.

Keweenawan Diabase.—The latest rock on the island is found in dikes and roughly circular masses which have every evidence of being volcanic necks. Whether these necks represent a molten mass which slowly cooled in the volcano or was extruded in a solid condition is a problem that is difficult to solve. In modern times the only recorded example of the latter type of volcanic eruption is the remarkable spine of Mt. Pelee, and in that case it is probably too soon to observe

certain phenomena that have an important bearing in the case under consideration. In certain instances the older rocks at some distance from the diabase are only slightly altered, and are principally granodiorites and diorites of a red or grey colour. These unaltered portions are, however, of very limited extent and near the shore where the less resistant altered material has been removed. In contact with the diabase the older rock is highly schistose, and nearly the whole mass of the older formation on South island is of this schistose character. Apparently

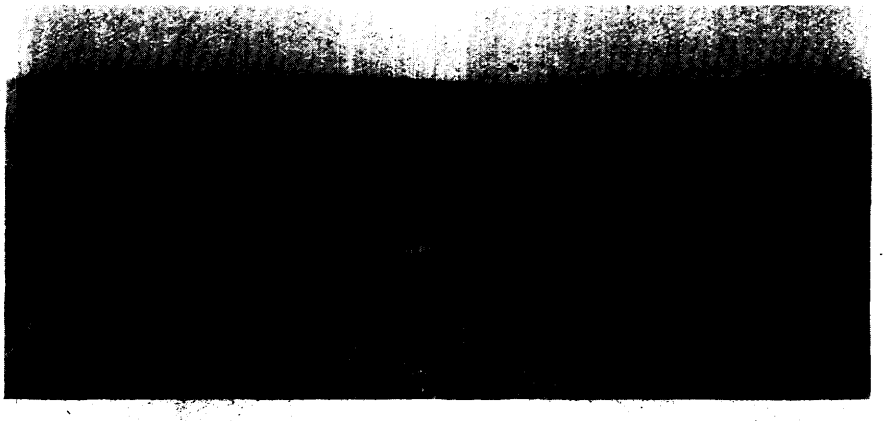


Fig. 7—View from Beacon, showing two lakes and bay.

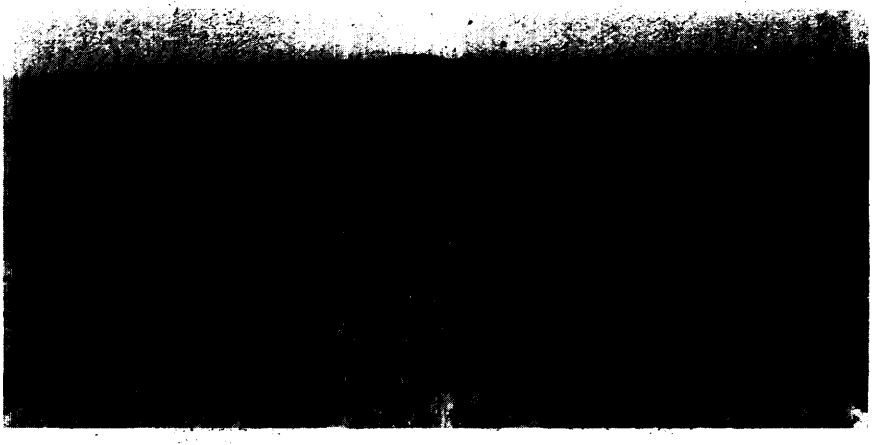


Fig. 8—View from Beacon, showing four lakes.

this schistosity has been developed by the volcanic necks and dikes either from the pressure exerted by a mass of rock in cooling or by the pressure of a mass that was extruded in the solid condition. Where contacts were seen there is no particular evidence of thermal metamorphism such as is found in connection with the great dikes in the Lake of the Woods. The absence of the evidence of thermal metamorphism must be looked upon as presumptive evidence that the diabase was extruded at a temperature near the point at which it would solidify, so that

little heat was transferred to the adjoining rocks. The extraordinary shattering of the older rocks bespeaks a source of pressure not shown in the vicinity of dikes that have come under the writer's observation. In similar manner the same evidence of pressure is lacking in the few comparatively modern volcanoes which it has been his privilege to see.

In composition the diabase is of a normal type consisting of labradorite and augite, with a small quantity of ilmenite and possibly magnetite.

Pre-Keweenawan

Pre-Keweenawan Schists.—The main portion of South island and a part of the south shore of North island is composed of a schist which varies from a grey to cream-coloured sericite schist. In only a very few places is any trace of the original rock evident, but where seen, it is a diorite or a quartz diorite. Undoubtedly these schists gave the name to the islands, for although the rock is unlike slate in most respects, it has one of the most striking features of a slate in its easy separation into thin sheets. These schists are cut by the Keweenawan dikes and volcanic necks, but underlie all the other rocks.

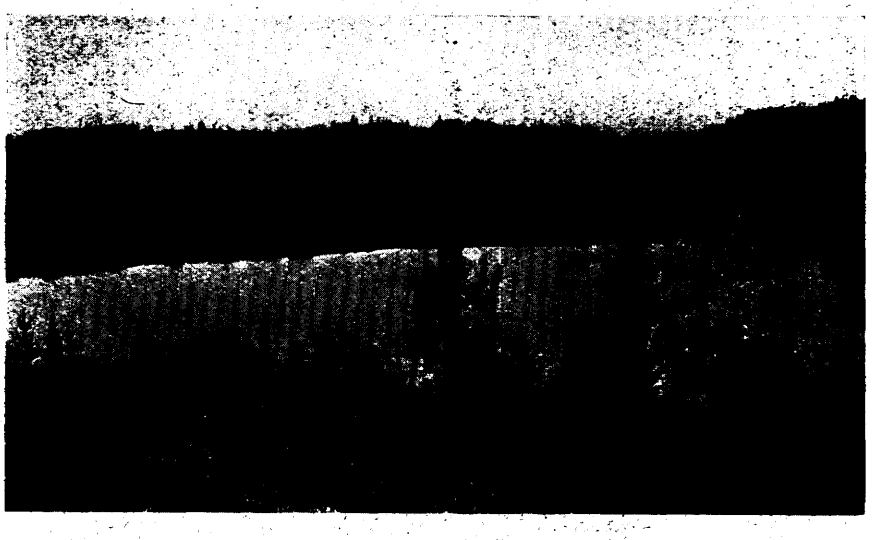


Fig. 9—Crater lake, west side of South Slate island.

Pre-Keweenawan Greenstones.—North island consists for the greater part of a greenish grey diorite, which in places exhibits pillow structure but more commonly is massive. In appearance and character of occurrence this rock resembles the Keewatin greenstones. In general the shore line is precipitous, and, unlike the shore of the south island, deep water is found even close to the shore. From a stratigraphic point of view it is not possible to assign a definite age to this rock, though it overlies the pre-Keweenawan schists which are so prominent on South island.

Pre-Keweenawan Tuffs.—Associated with the greenstones of North island is a considerable area covered by tuffs and breccias, which are petrologically similar to the greenstones. Near Copper Harbour on the south side of the island, these tuffs are cut by a diabase dike so that they are older than the latest rocks of the islands.

Iron Formation

Iron Formation.—On the northwest point of South island is a brecciated banded quartz rock (fig. 11) which resembles banded Iron formation. This is on the shore near the old tunnels which were driven on two veins for gold. In the more northerly of these veins a small quantity of jaspilyte was found accompanying the vein quartz, but a definite connection between this and the brecciated



Fig. 10—Tuff on east side of South Slate island.

rock was not established. In the case of the jaspilyte it was undoubtedly introduced after the development of schistosity in the rock, and is similar to the jaspilyte associated with crystallized hematite and vein quartz in small veins near Maimanse. A second outcrop of Iron formation is found south of the large volcanic neck near the south shore of South island. Neither of these outcrops, however, is of economic importance.

Age of Veins.—With but two exceptions, the quartz veins observed are situated either in the pre-Keweenawan schists or in the Keweenawan diabase. So far as those in the diabase are concerned, they must of necessity be referred to the Keweenawan or to a later period. Those in the schist are in most if not all cases to be referred to the period when schistosity was developed at the time of the

formation of the volcanic necks and dikes, the age of these veins in the schist being the same as that of the veins in the dikes. On North island two small veins were observed in the pre-Keweenawan greenstones and tuffs. For these it is not possible to definitely assign the same age, but as they are not far from outcrops of the older schist it seems reasonable to suppose that they belong to the same series of veins.

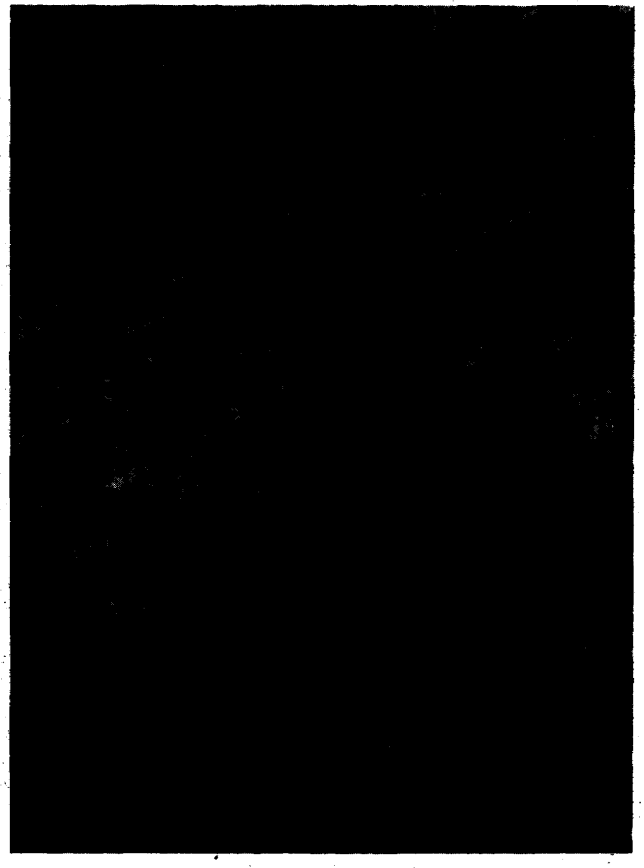


Fig. 11—Brecciated iron formation, South Slate island.

Economic Geology

Copper

On North island some years ago a prospecting tunnel was opened up on the shore of Copper Harbour, evidently with the idea of developing a copper prospect. No information concerning operations is available, and no trace of copper-bearing rock was observed by the writer. The rock through which the tunnel was driven is a volcanic tuff which might possibly carry copper, and it is probable that specks of copper were found to justify the development work, but as the property has been abandoned it would appear that no deposit of economic promise was encountered.

Iron

In former reports mention has been made of Iron formation and iron ore as float. Iron formation was observed in two places, but under conditions that appear to be connected with vein formation. No trace of workable deposits is evident.

Gold

On both the large islands, but more particularly on South island, there is a remarkable development of quartz veins which contain a greater or less quantity

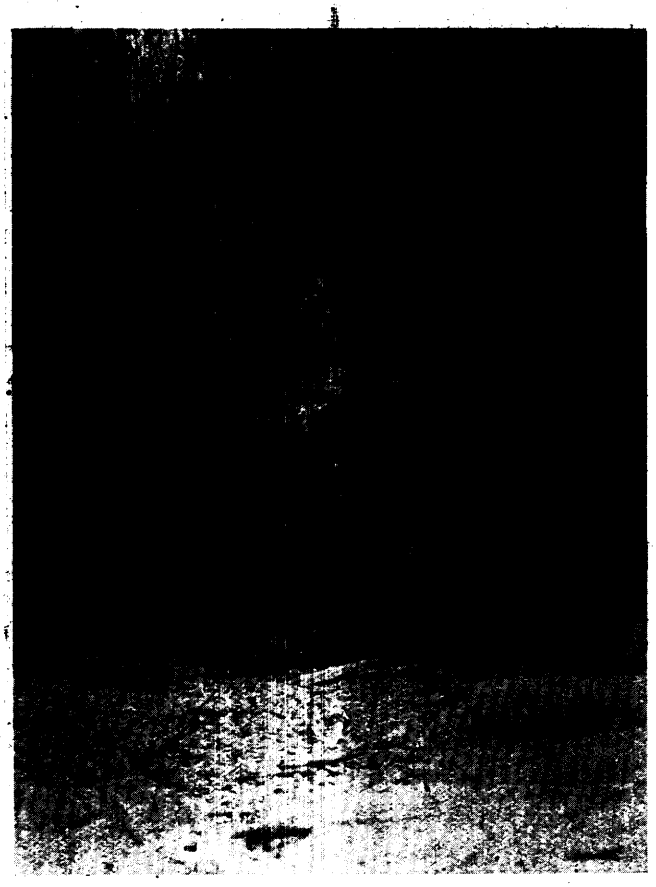


Fig. 12—Old tunnel, northwest point of South Slate island.

of gold. Prospecting work has been done on several of these. In some of the veins rich specimens have been obtained, but so far nothing that would warrant the expenditure of any large sum of money has been found. Probably the richest vein on South island is located on the west side of St. Mary's bay. The various veins are indicated on the accompanying map by letters, and the description of the individual veins follows. All the assays were made by W. K. McNeill, Provincial Assayer.

A veins.—At the point marked A are two small veins just to the west of the high diabase knoll. These are about 8 feet apart, and are 8 inches and 5 inches wide respectively. They strike nearly north-south, and are therefore distinct from veins E and B which have been supposed to be continuous. No trace of a vein was found that would warrant such a supposition. Neither of these veins yielded either gold or silver.

B vein.—At the point marked B are two tunnels, the more northerly of which (fig. 12) is of interest, though the assays of the samples were disappointing. The vein is about 8 feet wide, and consists of white quartz on the south side, red jaspilyte on the north side, and rusty quartz in the centre. The vein is consider-



Fig. 13—E vein, South Slate island.

ably brecciated and is between schist walls. The principal interest in this vein lies in the jaspilyte associated with the vein quartz, which is suggestive in connection with the origin of certain iron deposits.

About 400 feet south of this tunnel is a second one beside a vein about 4 feet wide. In the roof of the tunnel several quartz stringers were visible, but none of these were an inch in width. The samples taken for assay from these veins carried no gold or silver, though the brecciated rock shown in fig. 11 yielded 40 cents in gold per ton.

D vein.—At D is a vein which varies from 4 to 8 feet in width. The quartz is well mineralized and shows some rusty weathering. The sample for assay was taken from a section 4 feet wide and included one foot of wall rock. On assay no gold was found.

E vein.—The largest vein observed is at the point marked E. It consists of white quartz in diabase, and is about eighteen feet wide (fig. 13). This was sampled twice the full width of the vein, but the results of the assays were negative.

F vein.—On the west side of St. Mary's bay is a vein with a width varying from 4 inches to 8 inches. In this vein visible gold was found, and samples the entire width of the vein were taken for assay. It is believed that these samples represent the maximum value that can be expected from any quantity of ore that might be mined from this vein. Selected samples might be taken which would yield much greater values. The quartz is white and milky, and the length as shown by numerous test pits is not less than 400 feet. Three samples were taken for assay, yielding $15.40, $0.00 and $3.20 per ton.

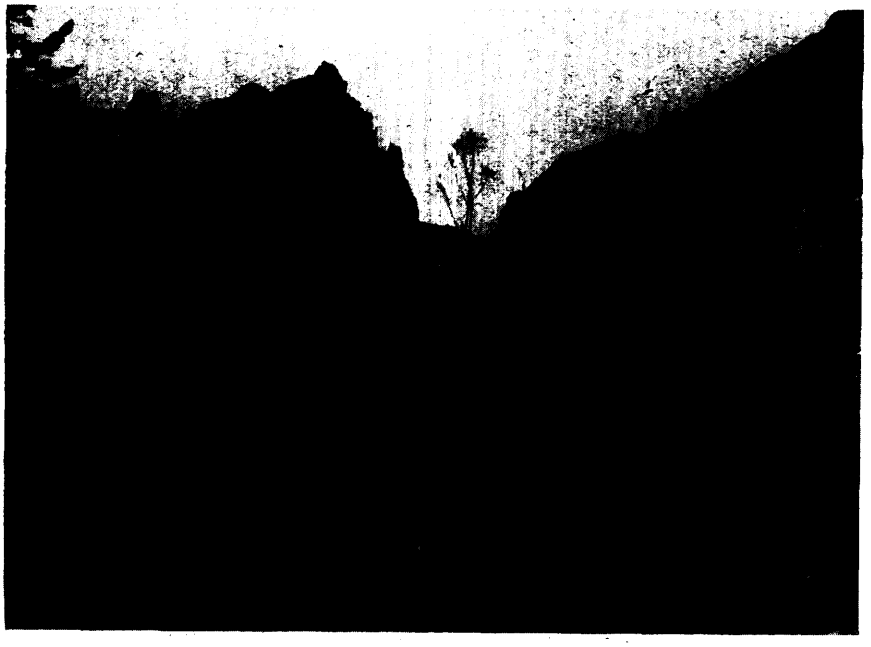


Fig. 14—Lighthouse veins, South Slate island.

G veins.—At the point marked G are two veins about 50 feet apart, the easterly one being 15 inches wide, the westerly one 2 inches. These were exposed on the rocky shore, but were not traced inland. No traces of old workings were found, though there is a record of work having been done. The larger vein gave on assay $1.60 and $2.40 per ton, while the smaller one yielded $2.60 per ton.

K vein.—At the point marked K on South island is a vein about 6 feet wide of rather bluish quartz, upon which several test pits had been sunk. In only one of these was it possible to see the vein material, but in this one the entire width of the vein was exposed. Private reports made to the former owner of the property indicate that this vein extends under water to North island. There is, how-

ever, at present no vein visible on North island that is of sufficient size to warrant the expenditure of much time or money in its development. Two samples were taken for assay, neither of which contained gold or silver. Samples were also taken from small veins on North island near this point, but in no case was gold or silver found.

Lighthouse veins.—Probably the most striking exposure of quartz veins on the islands is on the face of the cliff just below the lighthouse (fig. 14). At this point the vein system appears to consist of at least six distinct veins, though at a point possibly 600 feet east there is only one visible. The greatest width measured is 7 feet. Five samples were taken from various points for assay. One of these showed a trace of gold, the others nil.

N vein.—At N is a vein about 12 feet wide, though the walls are not well defined on the surface. This vein is nearly parallel with the southeast shore of the bay, and strikes approximately northeast-southwest. The sample yielded no gold.

O vein.—At the point marked O are some old test pits from which considerable quartz had been removed. The width of the vein could not be seen in these pits, but from the size of the material on the dumps it is at least a foot wide. One vein 4 inches wide was observed at this place. Two samples were taken, both of which were free from gold or silver.

MINERAL DEVELOPMENTS IN N.W. ONTARIO

By Arthur L. Parsons

Introduction

In accordance with instructions from T. W. Gibson, Deputy Minister of Mines, the writer devoted the greater part of the past summer to the examination of mineral deposits in western Ontario which were reported to be of prospective value in furnishing materials important for munitions.

The materials which received particular attention were copper, iron and pyrite. With few exceptions, deposits upon which development work was not in progress were not visited, though in certain cases where it was thought that valuable information could be secured such examination as was feasible was made. In addition to the above mentioned materials, samples were taken from two places on the Lake of the Woods for platinum assay with negative results.

On account of the nature of the work and the scarcity of help, it was necessary to depend largely on assistance that was cheerfully given by those interested in the properties examined. In particular the writer wishes to express his appreciation to Dr. W. L. Goodwin, Principal of the Kingston School of Mining, Col. S. W. Ray, of Port Arthur, and Dr. Warren Smith, Mokomon, Ontario, for assistance rendered not only by themselves but by those in their employ.

Copper Deposits

Owing to the high price of nearly every metallic product, the attention of prospectors and investors has been turned to the consideration of deposits which under ordinary conditions would not be considered of economic value. In several instances extensive low-grade bodies have been discovered, some of which will probably be worked long after the present stress is relieved. Among these products copper is most eagerly sought, and on account of the probability of the ore carrying values in gold and platinum, the probability of a stable foundation for the copper mining industry seems better than for most other metals. An important factor tending to retard the development of all but high-grade deposits, is the lack of a smelter or matting plant conveniently located with respect to known deposits in western Ontario, the consequence of which is that an unreasonable proportion of the returns for ore must be paid for freight charges.

During the past year copper ores have been shipped from two mines in western Ontario; the Tip Top near Kashaboiwe, and the Port Arthur Mining Company's at Mine Centre. In addition, considerable prospecting and development work has been done on properties near Lake Shebandowan and Mine Centre with more or less success.

The most extensive development is at the Tip Top mine, where a narrow gauge railway six miles in length has been built to haul the ore to the Canadian Northern railway two miles west of Kashaboiwe station.

Though the properties have many points in common, there is not sufficient information available at present to give a general description, hence each deposit is described separately. From the character of certain rocks at the Tip Top mine and from the geological relations of some of the copper-bearing rocks near Mine Centre, it would appear that there is an intimate relation between the copper ores and the Iron formation.



Fig. 1—Shaft house and sorting platform, Tip Top mine.



Fig. 2—Round house, Tip Top mine.

Tip Top Copper Mine

This mine is located near Round lake, and is sunk on a deposit of chalcopyrite and pyrite at the contact of Keewatin greenstone and sericite schist. Associated with the ore body and forming part of the sericite schist, is a large quantity of quartzose rock containing bluish quartz very similar to the quartz associated with the gold ores of the Laurentian, Ophir and St. Anthony mines. The main shaft has been sunk about 200 feet, and four levels have been opened. Only the first two were pumped out at the time of the writer's visit. On each of these levels two stopes have been opened, making 4,000 tons of ore available for mining. The principal vein is about 12 feet wide. The assay plan of the mine shows an ore chute about 150 feet long extending below the third level, but not yet proven on the fourth level. An examination of the drifts and stopes that could be inspected shows at least the quantity of ore above mentioned, but it does not appear to be definitely proven that the ore values cut off as indicated in the assay plan, since the main drift appears to leave the ore body to one side.



Fig. 3—Ore trestle, Tip Top mine.

A second vein about eight feet wide is found near the east end of the second level. This consists principally of pyrite, and is probably to be correlated with a rusty outcrop on the surface near the blacksmith shop.

Shipping was suspended at the time of the first visit in June, owing to the necessity of ballasting the narrow gauge railroad which connects the mine with the Canadian Northern railway. This railroad was constructed in the winter, and with the advent of spring a large force of men was employed in putting the track in shape so that shipments could be continued.

Since Dr. E. S. Moore's report[1] on this property there has been little change in the buildings and equipment except in connection with this railway. A new loading and sorting platform (fig. 1) has been erected at the mine to facilitate handling the ore and waste rock. This is of sufficient size to permit six 10-ton

[1] 20th Rep. Bur. Min., 1911, Pt. 1, pp. 210-13.

cars to be loaded before shifting. A building for storing the two small locomotives (fig. 2) has been erected near by. At the Canadian Northern railway a loading platform has been erected to facilitate the transfer of the ore from the narrow gauge cars to those of standard gauge (fig. 3).

Hoisting operations were recommenced on June 22, and continued during the summer, though much of the ore shipped was obtained from the old stock pile.



Fig. 4—Boarding camp, Tip Top mine.

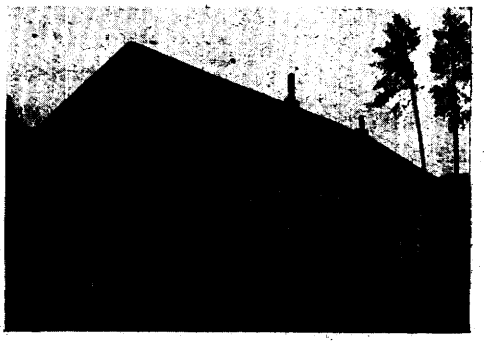


Fig. 5—Manager's house, Tip Top mine.

In addition to the main shaft, three other shafts have been sunk to prospect the property, and considerable trenching has been done. The best showing obtained in this way is near No. 3 shaft. Good ore was taken from this shaft, which is at the side of a valley about 50 feet wide. Several trenches have been opened up in this valley, and in nearly every case gossan and chalcopyrite were found. In one trench considerable ore was taken out, possibly three or four tons, and

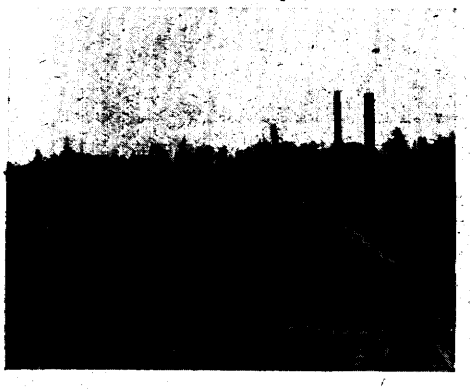


Fig. 6—Assay office and hoist house, Tip Top mine.

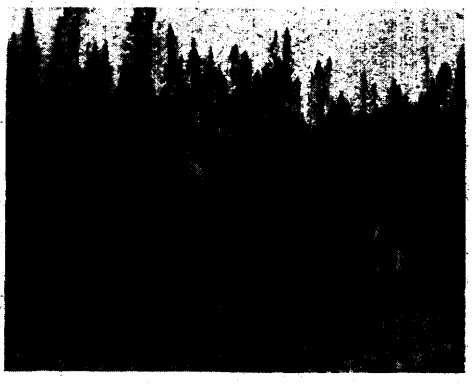


Fig. 7—Transporting men and provisions to Tip Top mine.

the indications point to a second ore body even larger than that upon which the most work has been done. This has been further confirmed by diamond drilling, and the writer was informed by the manager, Mr. Stewart, that about 25 feet of good ore was found in this way. So far as the writer could judge, this body of ore is distinct from the one upon which mining operations have been carried on.

Little can be added from a geological point of view to Mr. Moore's map, though the greenstone was found to have a slightly greater extent than was indicated by his work.

The boarding camp (fig. 4) is located about a mile from the mine on the shore of Round lake, and is unusually clean and well kept. From the point of view of convenience it would be preferable to have it located nearer the mine, but a supply of good water is a factor that offsets to a great degree the inconvenience due to the greater distance.

Prospects near Mine Centre

The copper deposits in the vicinity of Mine Centre are principally associated with schistose rocks which are for the most part altered representatives of the greenstones and anorthosites of the region. These are discussed in greater detail



Fig. 8—Open pit and shaft opening, Port Arthur Copper Co., Mine Centre.

in connection with the description of the Mine Centre iron deposits. The location of the various properties upon which prospecting was carried on is shown in the map accompanying this report.

Port Arthur Copper Company, Limited.—On H. P. 187 a rather remarkable deposit of copper ore was opened in the winter of 1916-17, and several carloads of ore were shipped for treatment to the smelter at Trail, B.C. From information given by W. H. Connell, manager of the company, the copper content of the shipments ranged from 3 to 3.5 per cent. The early work at this property consisted of open-cut mining entirely, the nature of which is indicated in the accompanying view of part of the workings. When the writer reached Mine Centre, work had been discontinued during a reorganization of the company, but before leaving the work was again resumed, and a shaft which shows at the right of the bucket in the picture (fig. 8) had been sunk to a depth of 10 feet with a few days'

work. It was the intention to sink this shaft to a depth of 200 feet before resuming the shipment of ore.

In some respects the deposit is remarkable, as there are scarcely any surface indications of a deposit containing iron or copper. The rock appears for the most part to be a sericite schist which preserves to some extent the traces of an amygdaloidal structure in the rock from which the schist was derived (fig. 9). Little if any gossan or copper stain was observed, but a trench which had been cut across the deposit showed that this schist is highly mineralized with sulphides including pyrite, pyrrhotite and chalcopyrite. This mineralization extends almost to the surface of the rock, so that the absence of weathering products is decidedly remarkable.

The mineralized zone is about 75 feet wide, with the greatest concentration in a width of about 15 feet.



Fig. 9—Schistose amygdaloid, Port Arthur Copper Co's. mine.

The impregnation of this rock appears to have been coincident with or slightly later than the quartz which lines some of the amygdules. Many of the amygdules contain both quartz and sulphides, and in this respect are analogous to the black schist in Ptarmigan bay of Lake of the Woods, which was described by the writer in an earlier report.

During the winter of 1917-18 the shaft was sunk to a depth of 100 feet, and the first level was opened up by a drift which is reported to be about 200 feet long. It is reported that the ore is fully as good at this depth as on the surface, and it is expected that the shaft will be sunk another hundred feet to prove up a further reserve of ore.

This company also holds the following claims: H. P. 181; H. P. 295; G. 207; G. 209 and the N. W. ¼ of H. P. 99.

J. A. Mathieu's Property.—About two miles southwest of Mine Centre, overlooking Bad Vermilion lake, J. A. Mathieu, M.P.P., of Fort Frances erected camps and sank two test shafts during the winter and spring of 1917. Work

was discontinued about the first of July, and no one was on the property when the writer made his visit. The rock is similar to that on the property of the Port Arthur Copper Mining Company, being a sericite schist which is somewhat mineralized with pyrite and chalcopyrite. Some traces of malachite and azurite were observed on the dump, but the copper-bearing minerals were not particularly abundant. The accompanying view (fig. 10) shows the camps and one of the shafts.

Samson Walker's Claims.—About three-fourths of a mile east of Mine Centre, Samson Walker had a few men employed in sinking test pits in a somewhat

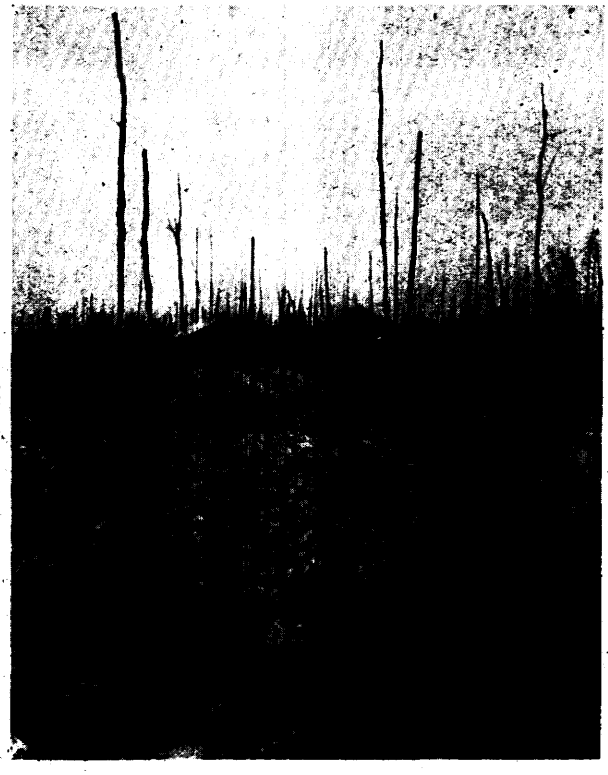


Fig. 10—Shaft and camps, Mathieu's claim.

brecciated schist. Although slightly mineralized, the deposits so far as developed do not appear to be valuable for copper.

Golden Star.—On the old Golden Star mining property two openings were made prior to the writer's visit on bodies of copper ore. In both cases the ore consisted of a mixture of chalcopyrite and pyrrhotite, and in many respects resembles the Sudbury nickel ore. The deposits are located in the greenstone and schists of Keewatin age, and in some portions exhibit a banding similar to that shown by the Keewatin Iron formation. In fact, it is probable that we have here a phase of the Iron formation similar to that shown on the west shore

of the lake, where it grades into a banded rock containing a greater or less quantity of chalcopyrite and other sulphides.

H. H. Wood was engaged in getting out a carload of copper ore, and later in the year made a shipment. At the time of the writer's visit the work was all confined to two open cuts, from 6 to 10 feet wide, the larger of which was about 30 feet long and 10 feet deep at the face of the working.

Laurence Hedburg's Claims.—About two miles east of Mine Centre, Laurence Hedburg was developing copper deposits on two claims, K 308 and H. P. 129.

On the first of these claims the ore consists of chalcopyrite associated with quartz interbanded with schist, forming a great fahlband. Some of the quartz bands are as much as 10 feet wide, and contain some siderite in addition to chalcopyrite and pyrite. The samples taken from this property are some of the

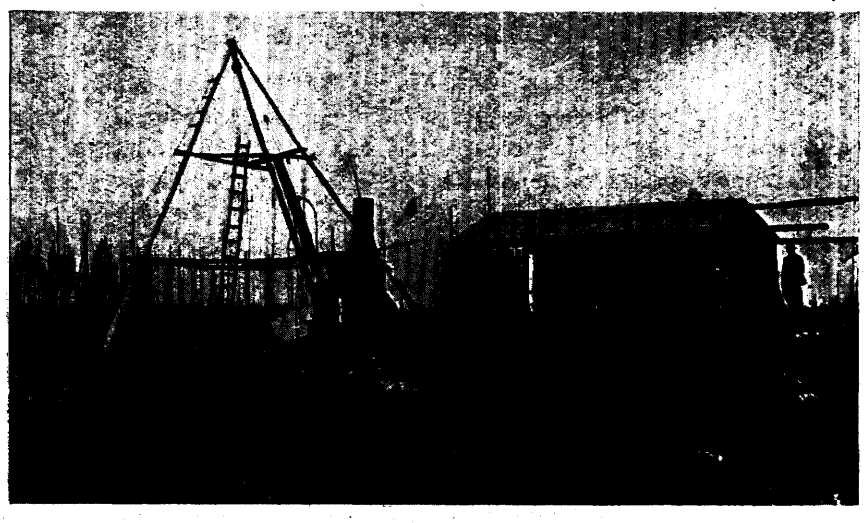


Fig. 11—Drill on H. P. 105, Mine Centre.

most attractive seen by the writer. These high-grade samples come principally from a band about a foot wide which would probably average more than 20 per cent. chalcopyrite in bulk. The claim should be further prospected.

On H. P. 129 Mr. Hedburg had just started work on a schistose amygdaloid which carries some chalcopyrite and some free gold. The writer found some visible gold in a small quartz vein about one inch wide which crosses the schist. At the time of the writer's visit the deposit was not sufficiently developed to enable an estimate of its economic possibilities to be formed. The ordinary rusty outcrop which is so common on deposits of sulphide ores is not prominent here. In this respect it is analogous to the deposits of the Port Arthur Mining Co. which were remarkably free from gossan.

Before an estimate of the value of the property can be made further development will be necessary. The almost complete absence of gossan makes prospecting exceedingly difficult, but it will be well to investigate the amygdaloidal rocks of this vicinity for further deposits of copper-bearing minerals.

International Copper Mining Co.—Under the name of the International Copper Mining Company, Messrs. Kennedy, Riley, Osborn and other gentlemen from Beaudette, Minnesota, were engaged in the development of a copper property on H. P. 105. This claim has been re-surveyed, and is now known as F. F. 387 and 388. A test pit had been sunk in a sericite schist which carried some chalcopyrite, and in some of the fissures erythrite or cobalt bloom was present. At the time of the writer's visit a diamond drill (fig. 11) was being used in the attempt to locate a body of richer ore than was found on the surface. The presence of erythrite gives encouragement to prospect further, since this is so commonly associated with silver ores. It is, however, an unusual mineral in association with copper ores, though in some of the Cobalt mines sulphides of copper have been found. Although considerable work had been done, a deposit that could be worked profitably had not been developed at the time of the writer's visit.

Lake Shebandowan Deposits

Having been informed that work had been done in developing copper and nickel deposits on lake Shebandowan, the writer attempted to find the workings, but as the nickel property was not on the lake shore and the boatman did not know where it was, it was impossible to locate it in the time at the writer's disposal. A small deposit of pyrrhotite not far from the location was seen, but the owner who was met later in Port Arthur confirmed the writer's opinion that this particular outcrop was not of economic importance.

About a mile east of the old Dawson road on the north shore of the lake, is an open cut partially filled with water, from which attractive specimens of azurite and malachite were taken. The work had apparently been abandoned for some time, and an examination of the dump failed to show any quantity of ore.

Mine Centre Iron Deposits

The principal deposits of iron in the vicinity of Mine Centre consist of titaniferous magnetite in which a certain percentage of vanadium is found. It was suggested by Dr. W. L. Goodwin, who was supervising the drilling of a considerable portion of the range, that it should be called the Fetiva range, thus indicating by the name the three prominent elements in the ore, iron (Fe) titanium (Ti) and vanadium (V).

Location

Extending along the northwestern shore of Bad Vermilion lake from a point about two miles from Mine Centre station on the Canadian Northern railway, is a precipitous cliff in which are located two or more parallel deposits of iron ore. By the use of the dip needle and magnetometer, as well as by the finding of outcrops, these deposits have been traced across the rolling country intervening between Bad Vermilion lake and Seine bay of Rainy lake, and thence along the north shore of Seine bay. The limit of the deposit on Seine bay was not observed by the writer, but he was credibly informed that at least one of the deposits outcrops near the mouth of the bay, giving a body of ore from 12 to 15 miles long.

Transportation

These iron deposits are at present reached in the summer by canoe or by a trip through the woods from Mine Centre. Part of the distance can be covered by a wagon road, and in conveying heavy supplies it would be necessary to extend this road. For actual mining operations, however, it would be necessary to put in a siding either from Mine Centre or Olive siding, so as to provide for the shipment of ore. Such a siding would involve the construction of four to six miles of track to reach the deposits that with present development appear to be the most promising. With further development, this could be extended parallel with the strike of the deposit so as to permit of working the deposit in several places.



Fig. 12—Outcrop of iron ore near Bad Vermilion lake.

Geology

The geology of the area covered by these iron deposits as well as the greater part of the Mine Centre copper deposits has been studied on two occasions by A. C. Lawson.[1] Unfortunately, that portion of the country to the northwest of Bad Vermilion lake was completely burned over a year or so ago, destroying large quantities of valuable timber. While this fire was a calamity so far as the loss of timber is concerned, it has given an opportunity of studying the geology that was not available when Dr. Lawson examined the region. The new information is incorporated in the accompanying map, which is based principally on Lawson's second one.

[1] G. S. C. Vol. III. N.S., 1887-8, Pt. I. Sec. F., Report on the Geology of the Rainy Lake Region; also G. S. C., memoir No. 40, The Archean Geology of Rainy Lake Re-studied, 1913.

The most important alteration in the mapping is in connection with the granite, practically all of which is referred by the writer to the Algoman rather than to the Laurentian. This change is due to the contact relations shown at the Golden Star mine between the granite and the Seine conglomerate. At this place the conglomerate has been metamorphosed by the granite, so that there is a narrow band of schist at the contact of the two retaining the outlines of the pebbles of the conglomerate, though in other respects similar to the sericite schists in this and other pre-Cambrian regions. Another feature connected with this metamorphism, is an apparent impregnation of the conglomerate with a certain amount of the granite. This feature is discussed at greater length in the description of the Seine conglomerate. A similar feature was noted near the contact of the granite and the anorthosite areas. In certain cases the anorthosite was impregnated with quartz near the contact with the granite, so that it was not always easy to find the contact between the two.

The geological succession of the formations found in the area covered in this report and the descriptions of the copper deposits is as follows:

Granite and Granite Gneiss		Algoman.
Quartzite and Slate Conglomerate	}	Seine Series—Huronian.
Anorthosite Greenstones	}	Keewatin.

Algoman

Algoman Granite.—The Algoman granites have been most excellently described by Lawson, so that only a brief description will be necessary in this report. Formerly these granites were referred to the Laurentian, and it is only by observing the contact relationships that it is possible to assign a definite age to the great granite masses. Probably the best that can be done in most cases is to say that it is not later than a certain period.

The granites most closely observed were those around Bad Vermilion lake which are light in colour and moderately coarse grained. Dark minerals and sulphides are almost lacking, and the rock consists principally of quartz and plagioclase feldspar. Strictly speaking, therefore, it can hardly be called a granite, but approaches the quartz diorites. In places the feldspar has been partially altered to sericite, and at the contact of this rock with the overlying Seine conglomerate, molybdenite was found to which it is difficult to assign any other origin than the granite. The quartz in the granite has a peculiar bluish tint, but when observed in the rock in the field the mass appears to have a pale cream colour. This is possibly due to the presence of sericite which has resulted from the alteration of the feldspar.

Keewatin

Keewatin.—The Keewatin rocks of the area are of two general types, both of which have suffered alteration in certain places, giving rise to schists and para-gneisses whose origin is sometimes difficult to trace. These two principal types are anorthosite and greenstone, the latter being in some instances a more basic marginal phase of the former.

The main anorthosite mass is somewhat elliptical in form, and is roughly bounded by later granite masses. Along the southern border of the anorthosite no trace of a basic margin was observed, but occasionally quartz was found. At first it was thought that this indicated a crystallization of quartz from the molten anorthosite, but the impregnation of the Seine conglomerate at the Golden Star mine by granite, and the consequent enrichment of this rock in quartz, leads to the conclusion that the quartz present in the marginal phase of the anorthosite is due to the action of the later granite. On the northern edge of the anorthosite the rock becomes more basic and finally grades into an iron ore, but there is a less basic band as the northern granite is approached, and an enrichment with quartz similar to that seen on the southern edge. In the midst of the anorthosite

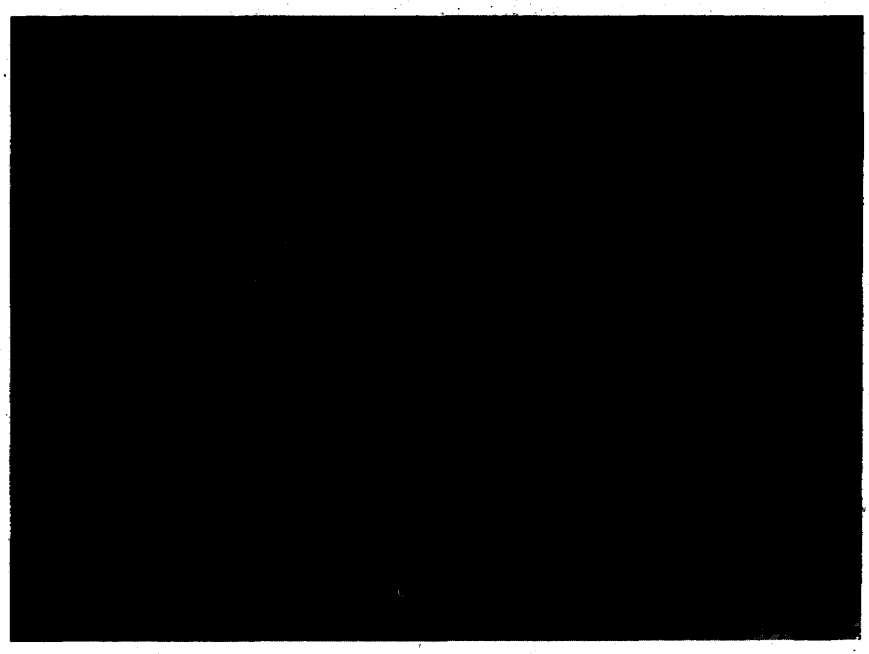


Fig. 13—Anorthosite enclosing diabase and granite fragments.

area is another mass of granite of the same petrological character as the outcrops to the north and south. The only other exposure of anorthosite observed was about a quarter of a mile west of Mud lake, where it assumes a peculiar mottled appearance. A feature of interest was observed at several places, more particularly on the west side of Outlet bay, where the surface of the anorthosite was covered by an igneous breccia, the fragments of which are principally diabase with an occasional fragment of granite (see fig. 13).

The essential difference between the anorthosite and the more common Keewatin greenstone lies in the presence of such minerals as hornblende, augite and biotite in the greenstone, thus giving rise to diorites and gabbros. These greenstones may be considered a more basic phase of the anorthosite.

By earth movements involving pressure and heat, both these rocks may be materially altered in structure and appearance. Schists of various types may be developed which, on account of the ease with which they permit the passage of solutions, are favourable to the formation of secondary ore deposits in veins and fahlbands. Large areas of these schists are developed near Mine Centre. In some cases they have been much crumpled after the original schistosity was developed. When such crumpling is found between comparatively straight bands, it is not always easy to comprehend the processes involved. A good example of this type of deformation is found just north of the Canadian Northern railway about a mile and a half west of Mine Centre. Here the pressure apparently has been applied from about N. 20°W., if we assume that the slaty cleavage is at right angles to the direction of pressure (see fig. 14).

Limestone.—In the Keewatin rocks near the Golden Star mine is a small outcrop of limestone which has been described in considerable detail by Dr. Lawson.[1] In certain portions there is crystallized magnetite and a rough banding suggestive of Iron formation. In many respects it is similar to the limestone associated with the Goudreau pyrite deposits, part of which has been shown by the writer to be a vein formation. In the present case it appears to be a tilted sediment, though bounded above and below by igneous rocks.

The Seine Series

Seine Series.—Inasmuch as the quartzites and slates of this series are not known in this region to be carriers of either iron or copper ores, the writer did not attempt to study them, but has accepted the former mapping.

In the case of the Seine conglomerate certain interesting features were observed, though the time devoted to examining this series was brief, seeing no deposits of immediate economic importance were reported from the region covered by it. In the conglomerate the pebbles are fairly representative of the older rocks and include granites, schists, greenstones and banded Iron formation. In the vicinity of Grassy lake the conglomerate has been squeezed so that it appears as a schist with "eyes" of harder rock, and it is not always clear that it is a squeezed conglomerate. A careful search, however, resulted in the finding of less altered material in which the rounded nature of the pebbles was still visible. The best exposure seen by the writer was about a half mile east of the Golden Star mine, where little if any metamorphism has occurred. The character of the rock is shown by the accompanying photograph (fig. 15). At the contact between the conglomerate and underlying granite at the Golden Star mine, there is an interesting phase which has been discussed by Lawson, and as one result of his interpretation of the phenomena observed the granite has been referred to the Laurentian. This contact phase consists of rounded pebbles more or less metamorphosed, with a matrix consisting largely of quartz, and other material derived from the underlying granite. To this type of material he has given the name "fanglomerate."

[1] G. S. C. Memoir 40, p. 44.

When the writer saw the rock in the field, it appeared to him to be a conglomerate that had been impregnated for several feet with molten granite; under such conditions the granite would be referred to the Algoman series of Lawson. A study of thin sections, both of the granite and the contact phase of the conglomerate, gives evidence that is strongly confirmatory of this interpretation, though in many respects the material is very unsatisfactory. The granite is composed of quartz and feldspars, principally plagioclase, with very little of the common dark minerals. In places the feldspar has been partially altered to sericite, which is possibly the cause of some of the creamy colour seen on a weathered surface.

The conglomerate in this contact zone presents several points of interest. It consists of pebbles from half an inch to four inches in diameter, that for the most part have been water-worn. Between the pebbles there is an abundance of

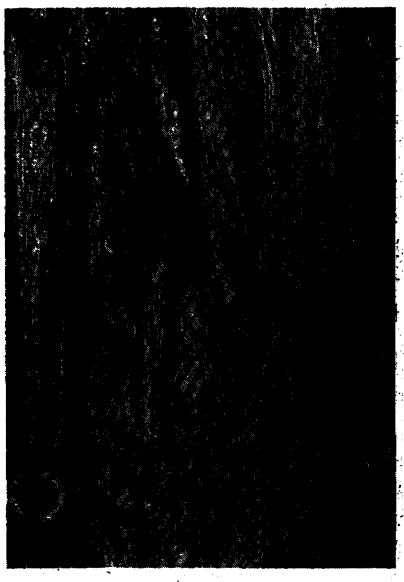


Fig. 14—Sericite schist, showing secondary crumpling and development of secondary slaty cleavage, Mine Centre.

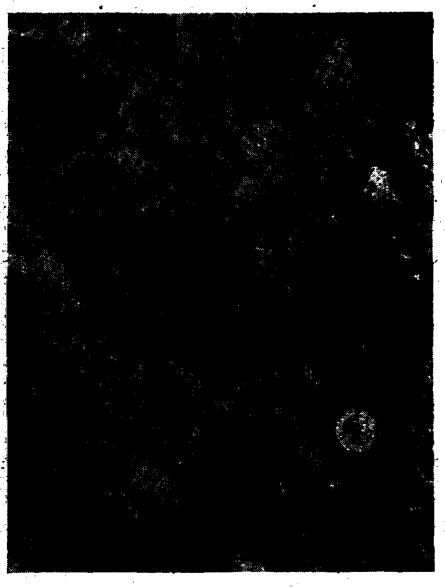


Fig. 15—Seine conglomerate near Mine Centre.

quartz which has been more or less corroded, and is enclosed in a ground mass that appears to be sericitic. No feldspars were recognizable. Associated with this interstitial material pyrite and molybdenite were recognized, not only in the thin sections but with the naked eye. These sulphides are present only in the interstitial material and not in the pebbles. If this deposit were formed in the manner suggested by Lawson, it is difficult to conceive of conditions that would preserve the molybdenite without visible alteration. Molybdenite is one of the minerals that is seldom if ever found except as a result of igneous intrusion, though frequently it is in rocks that have been metamorphosed by such intrusion. As a result of the presence of this mineral, and in spite of the otherwise unsatisfactory character of the thin sections, the writer is referring the Bad Vermilion granites to the Algoman series rather than to the Laurentian.

Iron Ores

The iron deposits are intimately connected with the anorthosite and gabbro, and are located not far from the granite area which parallels the northwest shore of Bad Vermilion lake and Seine bay of Rainy lake. Near Bad Vermilion lake two workable bodies of ore are present, and occasionally a smaller third one is found; but in the covered region near Seine bay it has not been definitely shown that there is more than one. The ore appeared to be magnetite, though a portion of it was stated by Dr. Goodwin, who was developing the properties, to contain a considerable percentage of titanium and some vanadium. Through Dr. Goodwin's courtesy the writer was enabled to make a microscopic examination of one of the drill cores with a view to determining the relations existing between the ore and the adjoining rock. Several schistose bands were cut by the drill, and it was thought desirable to ascertain whether these represented different types of original rock, or were merely shear zones in the anorthosite-gabbro. Unfortunately, none of the drill holes started in the pure anorthosite, but the relationships are such that there is little doubt that the gabbro is merely a more basic marginal phase of this rock. With the exception of two slides in which the minerals could not be definitely identified by the microscope, the core appears to be divided mineralogically into three distinct portions which are still genetically related, and with the exception of the richer ores all the rock showed plagioclase feldspar or some of its alteration products. A further exception is made of the afore-mentioned two samples where the minerals could not be identified.

The first 67 feet appears to be normal gabbro, and schist derived from gabbro, and is characterized by the presence of plagioclase, calcite and hornblende or biotite, with minor quantities of pyrite and magnetite.[1] In the next 173 feet the character of the rock differed in two respects: augite was the predominant dark mineral, and ilmenite with its decomposition product leucoxene was present as a rock-forming mineral. Pyrite and biotite were present rather uniformly. From this point to the bottom of the hole at 384 feet, augite was lacking, though biotite or chlorite was present in nearly every section. Magnetite[1] was present in every section but one, and ilmenite and leucoxene were not found. A mineral which came as a surprise in connection with the ore bodies was apatite, which was in well formed crystals surrounded by magnetite. The microscopic examination would tend to the supposition that the ore would be rather high in phosphorus. It is also possible that when more material for examination can be secured, the apatite may prove to be the source of the vanadium that has been reported from these ores. This seems probable, as there is no other source indicated by the minerals present in the sections, and vanadium and phosphorus have similar chemical relations.

[1]The analyses made later and given in the text indicate that the mineral recognized as magnetite is in nearly every case ilmenite. In the ore body leucoxene was absent, so that it was not possible to make a distinction between the two minerals, magnetite and ilmenite. The analyses strengthen the supposition that the ore is due to magmatic segregation. On account of the lack of definite chemical formulae for the minerals hornblende, augite, biotite, and chlorite, it has been impossible to make a calculation showing the percentages of these minerals in the rocks.

The ore is in many respects similar to the celebrated Kiruna ores in Sweden, but the associated rocks are very different; the Kiruna ores being immediately associated with syenite porphyry and quartz porphyry. Another more nearly related series is found in Nelson county, Virginia, where ilmenite and apatite form a rock or ore mass which appears much the same in hand specimens as the Kiruna ores.

Origin of Iron Ores

The iron ores of this range have a peculiar interest among Canadian ores, as they furnish a type of deposit which is important in other regions but has not been noted before in Canada. Being associated with great masses of anorthosite, and containing neither siderite, hematite nor limonite, it appears to owe its origin to igneous causes. The one feature favouring a sedimentary origin is the great length of a comparatively narrow band of iron ore. So far as microscopic examination has shown, there is no accompanying rock to which a sedimentary origin could reasonably be assigned. When other similar deposits are recalled—magnetite and titaniferous magnetite containing more or less apatite associated with anorthosite—it seems reasonable to look upon the ore as a magmatic segregation.

Representative samples were taken from the drill core for analysis to show not only the quality of the ores, but to get further light on the genesis of the rocks and ores. The analyses have been made by W. K. McNeill, Provincial Assayer with the following results.

Analyses of Samples from Drill Core, W. L. Goodwin Property, Bad Vermilion Lake

No.	Depth feet	SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	Na_2O	K_2O	H_2O	CO_2	TiO_2	P_2O_5	V_2O_5	S FeS_2	Total.
1.....	2	44.14	12.47	5.07	6.72	10.30	1.98	3.50	0.27	2.03	7.20	0.00	.....	.....	FeS_2 6.67	100.35
6.....	64	36.66	14.14	3.93	11.63	11.13	7.84	1.52	0.22	5.41	5.51	Tr	.....	.....	S 2.12	100.13
9.....	79	45.34	21.26	5.39	5.23	7.72	4.06	4.24	0.29	3.34	2.68	.....	0.08	.....	S 0.73	100.36
12.....	93	37.92	18.75	10.56	12.61	4.96	3.78	0.75	Tr	5.02	2.33	2.10	.....	.....	S 1.37	100.15
19.....	130	45.32	20.77	3.23	8.73	7.10	6.72	0.99	Tr	4.89	1.91	.....	.....	.....	.....	100.17
29.....	180	40.34	22.89	2.15	16.16	3.15	4.01	2.02	Tr	6.77	2.19	0.20	0.07	.....	.....	99.95
36.....	253	37.68	21.25	0.65	15.27	8.65	3.14	1.01	Tr	5.66	4.85	0.35	1.78	.....	.....	100.29
37.....	260	4.28	43.67	3.35	22.38	6.15	0.43	0.64	Tr	2.58	0.81	14.40	1.35	Tr	.....	100.04
38.....	276	10.10	21.46	2.73	34.88	1.85	2.20	0.42	Tr	2.14	1.60	23.44	0.06	0.11	.....	100.39
42.....	299	29.80	27.46	1.80	15.28	4.50	3.63	3.58	0.09	4.52	4.50	5.06	Tr	.....	.....	100.22
45.....	356	6.74	5.34	16.08	39.13	0.50	0.75	0.41	Tr	1.84	0.79	27.52	1.10	0.09	.....	100.29
46.....	358	7.60	13.92	9.77	35.80	1.90	3.01	0.67	0.27	2.12	0.88	24.88	.....	0.08	.....	100.90
48.....	371	11.67	36.44	5.77	24.47	5.50	3.18	0.64	Tr	2.51	0.38	4.92	1.70	Tr	.....	100.18
49.....	377	12.08	33.30	6.37	28.09	5.25	3.18	0.70	0.20	3.15	0.36	5.78	1.69	Tr	.....	100.35
50.....	384	14.00	25.18	3.29	27.25	6.20	1.53	0.80	0.62	3.11	5.37	5.80	1.51	Tr	FeS_2 5.06	99.72

Pyrite Deposits at Mokomon

About a mile from Mokomon station on the Canadian Northern railway extensive development work was in progress during the past season in proving the extent of some pyrite deposits on lot B, concession V, Conmee township. The work consisted principally of trenching and diamond drilling. Over a large portion of the property there is a very deep overburden, so that geological boundaries could not be readily seen, and the writer was informed by the former owner of the property that he traced these deposits by means of a dip needle where they were not in evidence on the surface. This use of the dip needle at first seems surprising, as pyrite is one of the minerals which does not affect the dip needle to any extent. It is, however, worthy of note that in most places where pyrite is present



Fig. 16—Pyrite deposit near Mokomon.

there is also some pyrrhotite and possibly magnetite, both of which are magnetic, so that it may be desirable to give more attention to dip needle reading in prospecting even for sulphide ores.

In trenching it was found necessary in many places to sink to a depth of forty feet through a hard boulder clay which required very little timbering. By means of the trenches and the diamond drilling five deposits were proven, and as a result the property was taken over by the Nichols Chemical Company during the winter.

The rocks on the property appear to be principally Keewatin greenstones with some rhyolitic portions, and in a few places a conglomerate was uncovered which is probably to be correlated with the Seine conglomerate. These rocks containing

the pyrite deposits rise quite abruptly from the Kaministiquia valley, along which may be seen a comparatively level terrace which appears in part to be connected with the flat-lying Animikie deposits that are better exposed a few miles nearer Port Arthur.

Details of the extent of the deposits could not be given at the time of the writer's visit, but the accompanying photograph (fig. 16) of a quarry face on one of the deposits will give some idea of size.

Lake of the Woods

In view of the scarcity of platinum and the consequent extremely high price of this metal, the writer was instructed by the Provincial Geologist to examine any known serpentine deposits in the western part of the Province to ascertain whether there might be a source of platinum in this region. Two deposits of serpentinous rock had been observed by the writer in his earlier work on Lake of the Woods, both of which are easily accessible, one being a copper-bearing rock on Allie island, and the other a serpentinized dike in the Welcome channel. These were both visited the latter part of August and samples of about 100 pounds were taken from each place. The samples were sent to W. K. McNeill, Provincial Assayer, but both yielded negative results.

OGAHALLA TO COLLINS

On the National Transcontinental Railway, Ontario

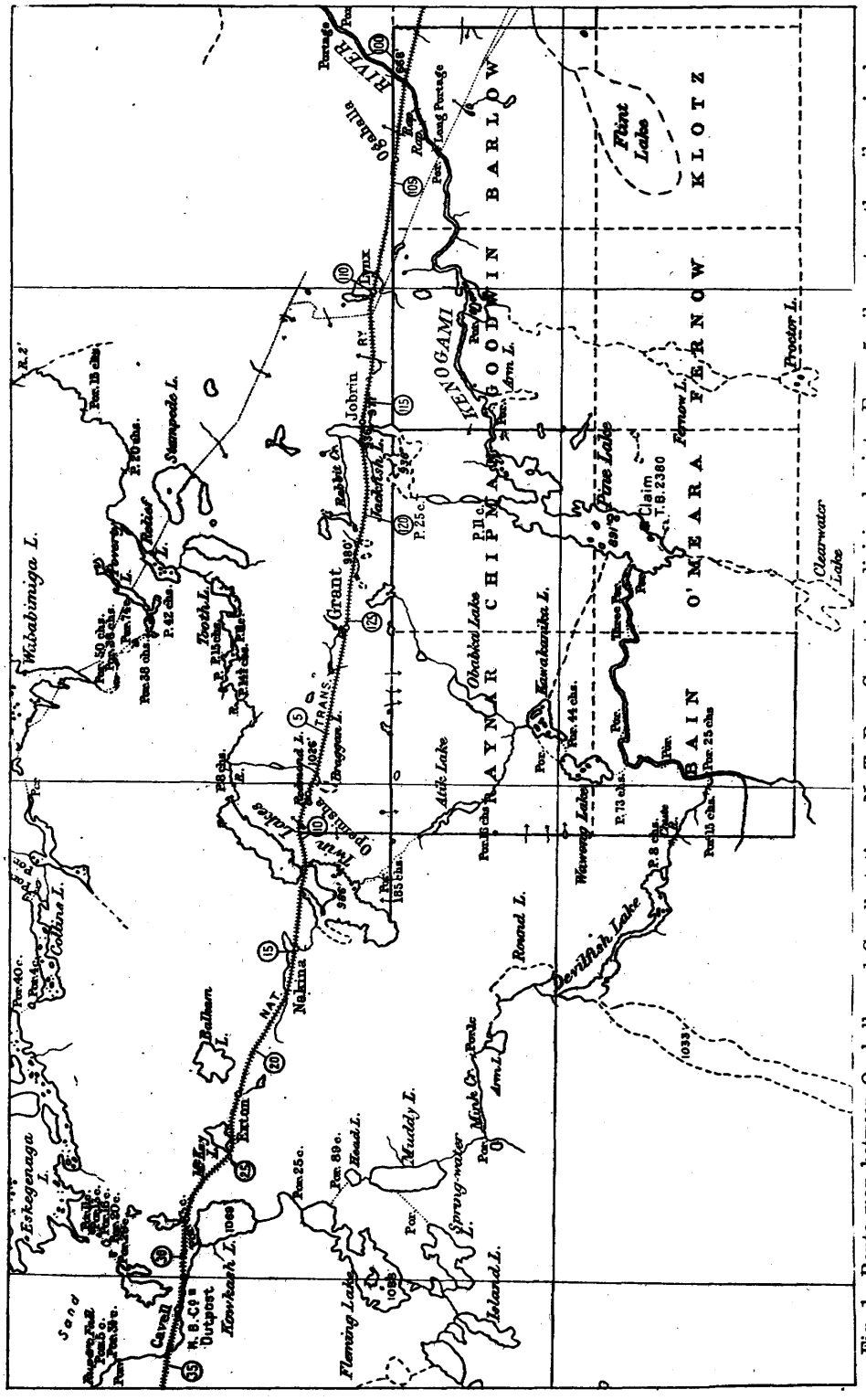
By Percy E. Hopkins

Introduction

The following report gives the results of an examination made during June and July, 1917, along the line of the National Transcontinental railway for a distance of 175 miles between Ogahalla station, at the crossing of the Kenogami river, and Collins station, which is located on Trout lake some 30 miles northwest of Lake Nipigon. The route over this railway from Winnipeg to Cochrane is described in Guide Book No. 9 of the International Geological Congress, 1913, by Messrs. A. G. Burrows, W. H. Collins and M. E. Wilson. In that report the central portion of the route is described only in a general way owing to the line of railway not being finished at that time; hence these notes will add to the information contained in the guide book. In addition, some exploratory canoe trips were made inland for the purpose of inquiring into the mineral possibilities of the areas. A pyrrhotite deposit on Pine lake was examined, and water routes not previously mapped between Smooth Rock, Caribou and Round lakes were investigated. The sketch maps accompanying the report were prepared by Messrs. W. J. Bell and P. A. Jackson of the Bureau of Mines staff. The assays mentioned in the report were made by Messrs. W. K. McNeill and T. E. Rothwell of the Provincial Assay Office.

Ogahalla to Cavell

A. G. Burrows when examining the line of railway in 1912 was able to get as far west as the Kenogami river, a large picturesque river famed for its speckled trout and sturgeon. From Kenogami river to Cavell and on to Kowkash station, (fig. 1) may be spoken of as the western part of the northern Ontario clay belt, These clays were probably deposited in lake Ojibway. Associated with the stratified clays are varying amounts of boulder clay, sand, gravel, peat, erratics and frequent exposures of hornblende and biotite granite and granite gneiss, which make the area on the whole unsuitable for agricultural purposes. It is, therefore, considerably rougher than the vast clay belt which extends from the Kenogami river easterly into the Province of Quebec. Cutting the Laurentian gneiss at mileage 111.7 (fig. 1) is a narrow Keweenawan (?) diabase dike. Grant, a divisional point on the railway, is surrounded by grey granite gneiss which is cut by red granite. South of Grant on Pine lake is a large pyrrhotite deposit carrying low values in copper, nickel and gold. The deposit is referred to in more detail in a following paragraph. From Opemisha to Paska station, a distance of 40 miles, there are extensive sand and gravel deposits with numerous kettle lakes, representing probably a pause in the front of the great ice sheet which at one time covered this whole area.


Ogahalla
Jobrin
Grant
Wababimiga L.
Stampede L.
Tooth L.
Obonga L.
Kenogami R.
Kawakamika L.
Waweig Lake
Pine Lake
Claim T.S. 2380
Flint Lakes
Proctor L.
Clearwater Lake
Fenow L.
Devilfish Lake
Round L.
Muddy L.
Island L.
Flaming Lake
Cavell
Kowkash L.
Esnagami L.
Colins L.
Nakina
Beaton L.
McKay L.
Eaton
Obonga Lakes
Arch Lake
Obakbiki Lake
Jackfish L.
Rabbit Cr.
Long Portage
Portage
Tunnel
Bridge
Trestle
Fm.
Pt.
Ch.
Lk.
Cr.
R.
Arm
Island
Sand
N. B. C. R. Outpost
TRANS.
NAT.
1033
1068
1098
1026
966
1000
1048
1100
1050
1075
1125
1150
1175
1200
1225
1250
1275
1300
1325
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1500
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1575
1600
1625
1650
1675
1700
1725
1750
1775
1800
1825
1850
1875
1900
1925
1950
1975
2000
2025
2050
2075
2100

Cavell to Ombabika

For the route between Cavell and Ombabika the reader is referred to the report and map of the Kowkash Gold Area.[1] The rocks here belong largely to the Keewatin complex, consisting dominantly of basalt, quartz porphyry, slate and Iron formation. There has been considerable work done on gold prospects at Howard falls, 9 miles north of Kowkash and in the vicinity of Tashota. At the present time (April, 1918) this work seems to have been discontinued. Iron deposits were also investigated in 1906 and 1907 on the Onaman iron range, near where Paska station is now situated. Some promising-looking iron pyrites deposits also occur in the area. The railway crosses the height of land, altitude 1,118 feet, one-half mile to the east of Redmond. To the east of this watershed, the waters drain northward into James bay while to the westward they drain into Lake Superior.

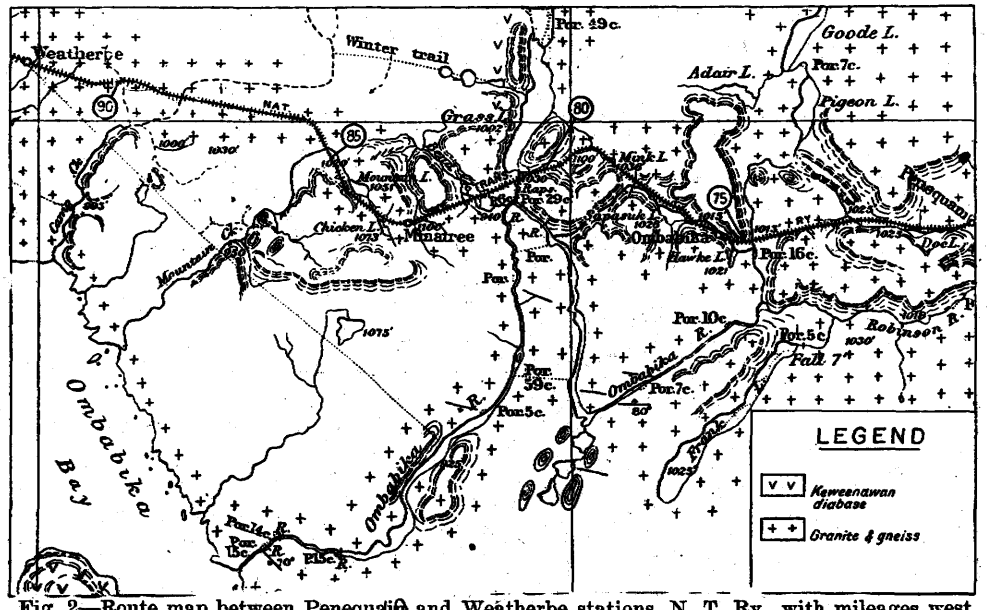


Fig. 2—Route map between Penequain and Weatherbe stations, N. T. Ry., with mileages west of Grant. Base from Map No. 8A, Geol. Sur. Canada. Scale, 4 miles to the inch.

Ombabika to Collins

The Ombabika river is a well-travelled route which is used in going from Lake Nipigon to the Albany river, and thence to James bay. Practically the whole distance from Ombabika to Collins, as shown by figs. 2, 3 and 4, is underlain by Laurentian hornblende, biotite granite gneiss and some younger granites, and overlain with small remnants of Keweenawan conglomerate and sandstone, which are in turn capped by diabase. The area on the whole has been burned, giving it a bleak appearance. Considerble drift, consisting chiefly of stratified sand and clay, occurs between mileages 104 and 127. The deposits, which are at least

[1] Ont. Bur. Mines Report, 1917, Vol. XXVI, pp. 190-226.

100 feet in thickness as seen in some of the stream beds, were probably laid down in glacial Lake Warren that formerly occupied the Lake Nipigon basin. Near Weatherbe, at mileages 91.3 and 93.3, narrow dikes of diabase cut the grey hornblende gneiss. Lake Nipigon can be seen from the railway only at a few intervals in the vicinity of Ferland. Mileage 102, immediately west of Ferland, is spoken of as "the summit." At this point the railway passes through

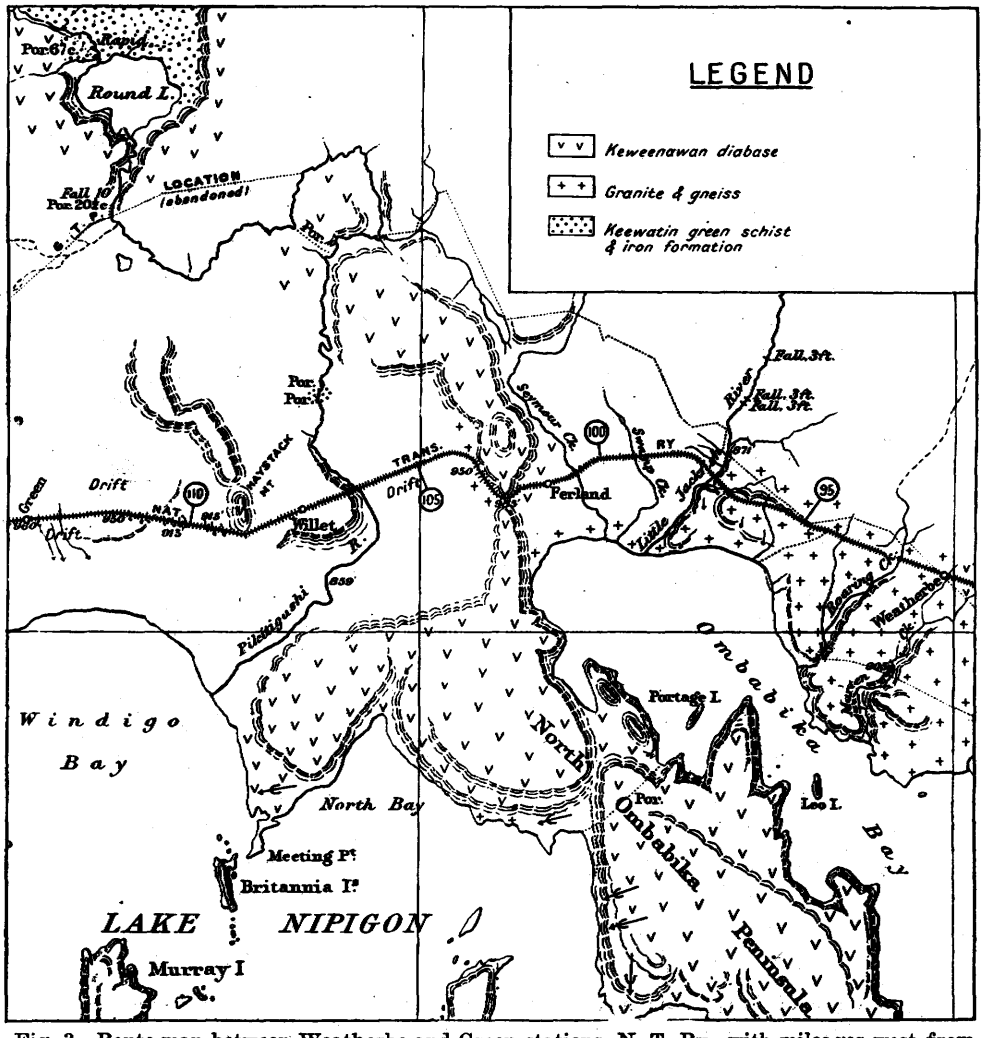


Fig. 3—Route map between Weatherbe and Green stations, N. T. Ry., with mileages west from Grant. Scale, 4 miles to the inch. Base from Map No. 8A, Geol. Sur. Canada.

a gap in a prominent north and south ridge of Keweenawan diabase whose southerly extension forms the prominent North Ombabika peninsula, on Lake Nipigon. Immediately west of the ridge can be seen the underlying gneiss. The railway crosses the Pikitigushi or Mud river near Willet at mileage 106, this point being 7 miles by river from Windigo bay, the northwestern part of Lake Nipigon. The fact that this is the only stream navigable for launches between

the railway and Lake Nipigon will tend to make Willet an important place for tourists or anyone wishing to communicate with Lake Nipigon. About the only rock exposure in this vicinity is a conspicuous, conical-shaped hill of Keweenawan diabase known as Haystack mountain, which is situated one mile west of Willet north of the railway. The hill has an altitude of 1,266 feet by aneroid, and may be seen from many parts of Lake Nipigon, 30 to 40 miles distant. It is the intention of the Ontario Government to build a look-out tower on this hill for use in connection with its forest protection system.

The Whitesand river is crossed at mileage 123.3. Speckled trout may be caught in this river, as in most streams between Ombabika and Collins.

Armstrong is a divisional point surrounded by granite, gneiss, conglomerate, sand and boulders. The massive, fresh-looking granite, at a point on the railway five miles west of Armstrong, contains large inclusions of hornblende granite gneiss, showing that the granites are of two ages. A knoll of reddish Keweenawan conglomerate may be seen lying on the gneiss about 100 yards south of the town. Molybdenite is reported to occur in patches in the granite on some of the islands in Tunnel lake about two miles south of the railway, while float containing molybdenite was also reported to have been found on Trout lake near Collins. A thin sheet of diabase, only a few feet thick in places, lies on the granite gneiss in the vicinity of Pascopee station between mileages 13 and 15. This diabase can be traced southeasterly for 25 miles to Lake Nipigon, the sill increasing to 400 or more feet in thickness as Lake Nipigon is reached. From Pascopee to Collins and for many miles to the west granite gneiss is the prevailing rock.

Armstrong and Vicinity

The geology in the vicinity of Armstrong was examined while making a track survey of several lakes, viz.: McLaurin, Mackenzie, Mattice, Castle and Pillar. Brook trout are plentiful in many streams connecting these lakes. Much drift, especially sand, occurs in the area. The underlying rock is Laurentian granite and gneiss, as may be seen at numerous places along the railway. Lying on the gneisses are occasional thin horizontal beds of conglomerate and sandstone. (See fig. 4.) A few hundred feet south of Armstrong the conglomerate is at least 20 feet thick, and contains numerous round and angular crystalline fragments. The conglomerate and red sandstone on the shores of Pillar lake lie under and adjacent to a diabase sheet which is at least 250 feet thick. The diabase overlies all the other rocks in the immediate vicinity, and is the prevailing rock. It is 200 or more feet in thickness, and has a characteristic, vertical, columnar structure. This jointing is most beautifully shown on the shores of Castle lake, 7 miles southwest of Armstrong, where many of the vertical columns have fallen over. Frequently isolated columns present castle-like effects, as shown in the accompanying photographs (figs. 5, 6, 7 and 8). Numerous calcite stringers carrying considerable pyrite occur on the east and west shores and near the extreme south end of McLaurin lake. These narrow veins range up to three inches in width and cut the massive diabase at various angles. Samples from several of the veins, however, were found on analysis by W. K. McNeill to contain no silver.

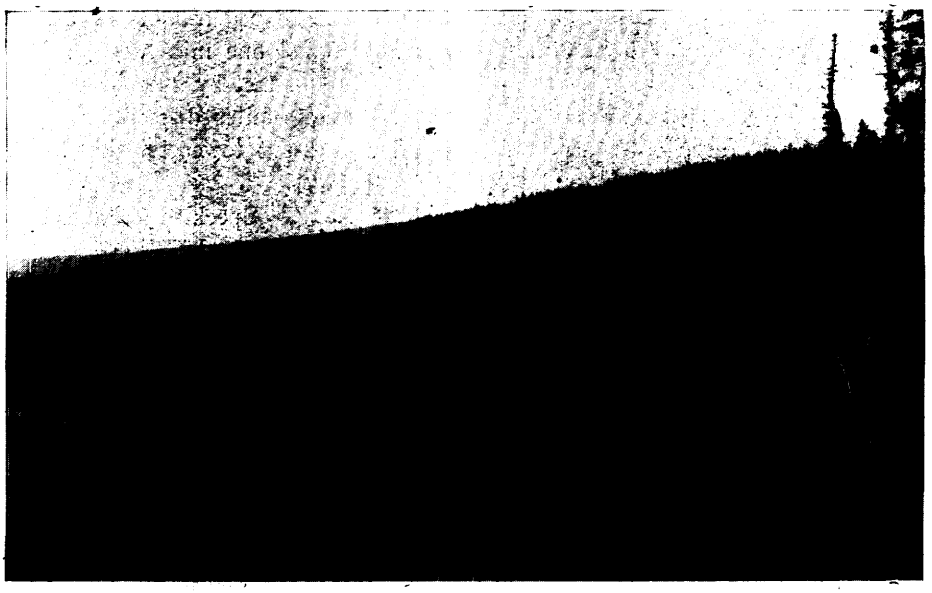


Fig. 5—General view of Castle lake and vicinity.

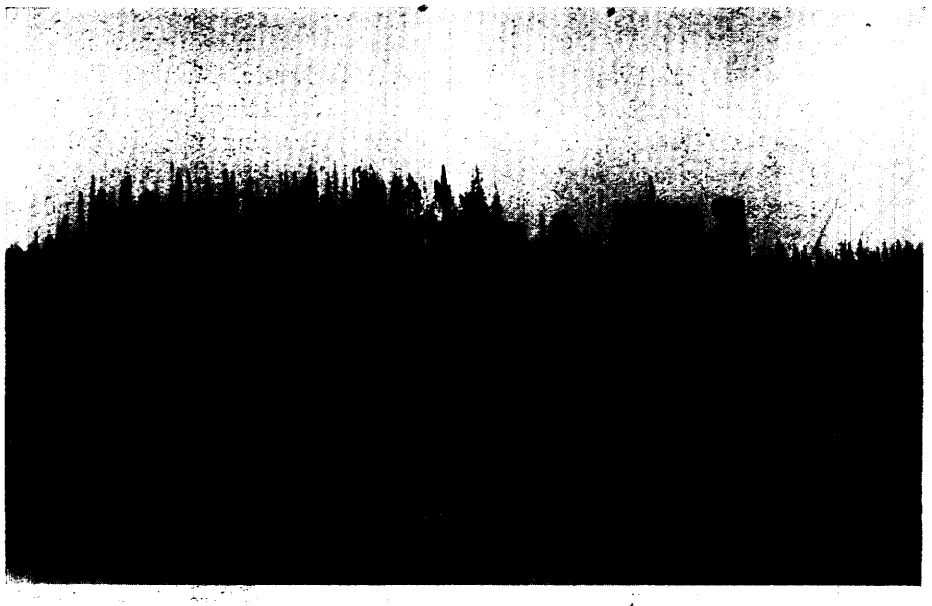


Fig. 6—Columnar diabase rising about 200 feet above Castle lake.

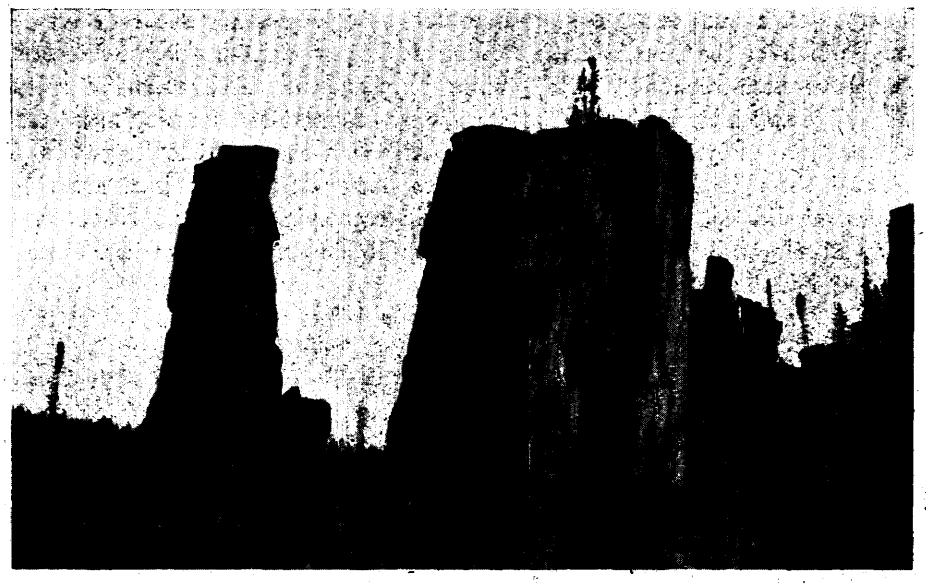


Fig. 7—View at close range of some of the diabase pillars on "Castle Hill," Castle lake.

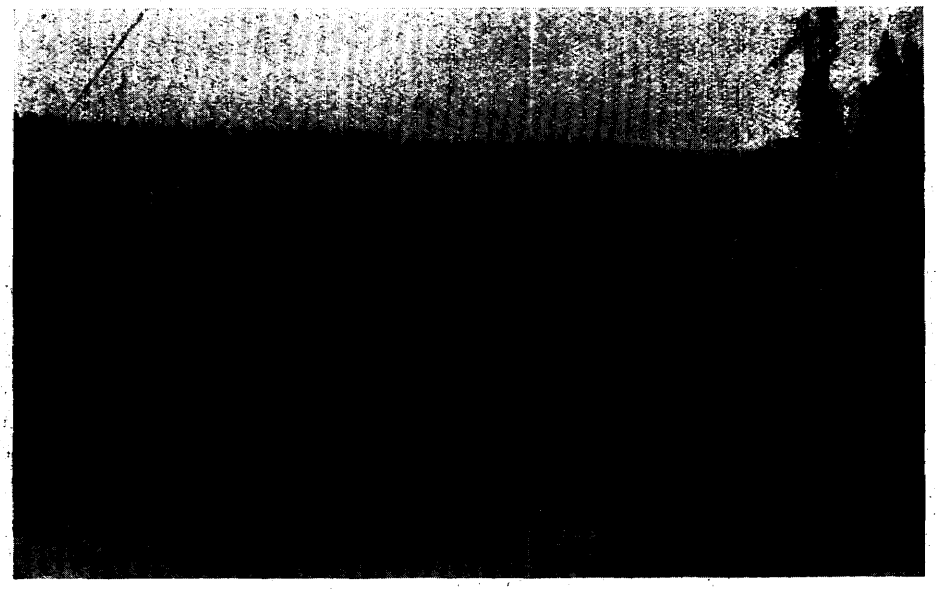


Fig. 8—Columnar diabase on Castle lake, eight miles southwest of Armstrong station.

Molybdenite on Tamarack Lake

Six miles north of Collins station on the northeast shore of Tamarack lake, and less than a quarter of a mile from the portage which runs from the lake around a falls at the mouth of the Boiling-sand river (fig. 4) molybdenite occurs in a coarse flesh-coloured biotite granite or pegmatite dike, which is at least 20 feet wide and intrudes biotite granite gneiss. A sample containing molybdenite was found on analysis to carry no gold. Although the molybdenite occurs disseminated through the rock in flakes up to one-quarter of an inch across, yet the mineral did not appear to be present in economic quantity. However, the locality might be a favourable one in which to do some prospecting, since no trenching had been done.

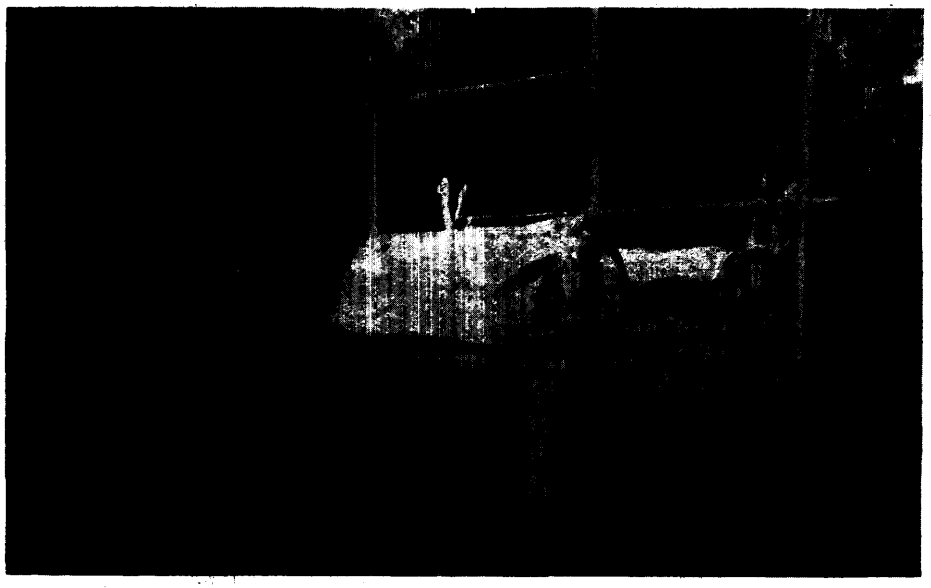


Fig. 9—Indian graves on Smooth Rock lake. The coffins are placed above ground and are covered frequently with canvas. July, 1917.

Smooth Rock Lake

Smooth Rock lake, shaped like a huge devilfish, is some 25 miles across and contains many islands. The general character of the shores and islands is low, almost continuous rock with little soil covering, and the timber recently burned, consequently, there are few black flies or mosquitoes in the area. Exploration party No. 7 of the Ontario Department of Crown Lands, in charge of H. P. Proudfoot, O.L.S., with F. J. Snelgrove as geologist, passed through Smooth Rock lake in 1900, made a micrometer-log-compass survey of part of the lake and found the geology to consist of Laurentian hornblende granite gneiss.[1]

Lying on or cutting the gneiss on the north shore and halfway down Lone Breast bay is an olivine diabase, probably a sill remnant, 200 feet in height. Under the microscope the labradorite laths are set in a groundmass of augite containing

[1] Report on Exploration of Northern Ontario, 1900.

numerous grains of olivine and much magnetite. Some miles farther west at the narrows of the same bay is another outcrop of Keweenawan (?) diabase. Between these outcrops of diabase there is hornblende schist cut by a massive grey biotite granite. An island in Lone Breast bay to the south of the olivine diabase hill consists of banded "sugary" quartz, and pyrite striking nearly east and west and dipping vertically. The rock resembles portions of the altered Iron formations on Caribou, Round and Marshall lakes. The guide, Alfonso D'Alton, stated that similar rock occurs on the first small lake northeast of the outlet of Lone Breast bay, and on the west side of Outlet bay, Smooth Rock lake. The writer was also informed that Lone Breast bay drains by a large river and three lakes with three portages on the route, northeasterly into Whitewater lake. This being the case, Smooth Rock lake has at least three outlets. Smooth Rock lake is 20 feet lower than Caribou lake, as determined by the drop in the falls and rapids on Caribou river which connects the two lakes. The writer made a track survey of the east bay of Smooth Rock lake, Caribou river and Outlet bay of Caribou lake. The four short portages on Caribou river are over Keweenawan diabase, the remainder of the route being through Laurentian granite gneiss and pegmatite.

Caribou Lake

A micrometer-compass survey of Caribou lake and a geological examination of its shores and islands were made by W. H. Collins[1] in 1906. The writer spent two or three days on the lake before examining the area to the east between Caribou and Round lakes. The outlet bay or commencement of Caribou river which had not been previously mapped is surrounded by granite and gneiss (fig. 4).

A portion of the northeast end of the lake was examined. Here two small lakes, one of which is called Fletcher lake, drain from the north into a long bay on the northeast end of Caribou lake. The rocks in the vicinity, as shown in fig. 4, consist dominantly of Keewatin pillow lavas, with some narrow bands of Iron formation, quartz porphyry, hornblende schist and rusty carbonate, striking a little north of east. The Iron formation consists of alternate bands of magnetite, usually an inch or two in width, and sugary quartz. Collins refers to a band of magnetite 12 inches wide from this vicinity. In places much iron pyrites occurs in the formation, but neither iron nor iron pyrites were seen in economic quantity. The quartz porphyry contains numerous quartz and some feldspar phenocrysts, and resembles the quartz porphyries accompanying the Iron formation in Deloro township and in the Onaman and other iron ranges. Capping these older rocks in places are Keweenawan diabases, the conspicuous outcrop being known as Kellar's peak, which is at least 400 feet high. Four miles southwest of Kellar's peak and on the northeast end of an island which is at least one mile long is a quartz vein, six inches wide, containing copper pyrites. A sample from this vein yielded on assay 80 cents of gold to the ton. At the extreme northeast end of Caribou lake is a portage 25 chains long which passes over a water divide. The rocks on this portage are hornblende gneiss and quartz-porhyry schists, which strike east and west and dip 70 deg. to the south, and may represent a recurrence of the Laurentian.

[1] A Geological Reconnaissance of the Region traversed by the National Transcontinental railway between Lake Nipigon and Clay lake. Can. Geol. Surv. Report No. 1059.

Caribou Lake to Pikitigushi River

For some time rocks belonging to the Keewatin complex have been known to occur on Caribou lake and 18 miles to the southeast in the vicinity of Round lake, but little has been known of the intervening area. A. W. G. Wilson, however, found these schist rocks to continue across the interval between the northeast end of Caribou lake and Pikitigushi river.[1] The writer made a track survey and geological examination along a chain of lakes and streams through this area, which resulted in the delimiting of a portion of the south boundary of the Keewatin area as shown in fig. 4. This route commences by a small portage which leaves Caribou lake at a point approximately six miles from its northeast end. The portage passes over the height of land into a small pond which drains by means of streams and lakes easterly into the Pikitigushi river at a point about ten miles above Round lake.

The Keewatin rocks in this area consist of massive and schistose diabase and greenstone rocks which frequently show the ellipsoidal structure. In addition to green schists there are hornblende, chlorite and talc schists, rusty carbonates and Iron formation. These rocks strike from northeast-southwest to east and west, and usually have a vertical dip. The Iron formation, which consists of sugary quartz and magnetite, occurs in bands up to 50 feet in width, at frequent intervals from the west side of Caribou lake to Round lake. One of the richest outcrops seen occurs on the south central shore of Moon lake, but nowhere did the iron appear to be in commercial quantity. In places, viz.: on Fletcher, Michell and D'Alton lakes, the Iron formation is accompanied with varying quantities of iron pyrites, as is frequently the case in other parts of the Province. The outcrop of sugary quartz on the southeast shore of Michell lake is at least 500 feet long, 3 feet wide and contains about 50 per cent. of disseminated iron pyrites. Fuchsite, a chromium-muscovite, occurs in bands up to a foot in width near the same locality.

Quartzose schists, resembling Lawson's Couchiching series and the Marshall lake series, occur at the 25-foot falls on the west end of Pawshowconk lake, also near the northeast end of Caribou lake and on Lone Breast bay, Smooth Rock lake. Moore[2] describes similar rocks with the Iron formation at Round lake.

Cutting the old rocks at the east end of Michell lake and in the vicinity of Fuchsite and Cumaway lakes are numerous, narrow quartz porphyry intrusions post-Keewatin in age. Under the microscope the white-weathering porphyries are seen to contain numerous quartz, feldspar and biotite phenocrysts in a micro-crystalline groundmass of the same composition. Quartz veins, varying from a few inches to two feet in width and carrying iron pyrites and copper pyrites, were seen in the area. A sample from a vein near the rapids between Michell and Fuchsite lakes gave on assay 40 cents of gold to the ton. It would appear that this particular area is worthy of prospecting for gold, since gold-bearing veins are frequently found in a similar association of rocks throughout many parts of central Canada.

[1] Memoir No. 1, Geology of the Nipigon Basin, Can. Geol. Surv., p. 51.
[2] Ont. Bur. Mines Report, Vol. XVIII, 1909, Pt. 1, p. 158.

Three small areas of hornblende granite and gneiss occur in the area, viz.: at the first portage between Caribou lake and the stream running into Michell lake, and on the southwest and southeast shores of D'Alton lake.

Lying unconformably on the old Keewatin on Moon lake is a small area of nearly flat-lying conglomerate and grey sandstone at least 10 feet in thickness. The conglomerate contains well-rounded pebbles consisting of white quartz, Iron formation, granite gneiss, etc., embedded in a greywacké groundmass. The sediments are probably Keweenawan in age, since they resemble the isolated patches to the south in the vicinity of Lake Nipigon. The exposures on Moon lake are the most northerly known Keweenawan sediments in the Lake Nipigon basin.

Capping all the rocks referred to above is the diabase of the Nipigon sill. A prominent ridge or sill remnant passes all the way from the Pikitigushi river across the south sides of Reef and D'Alton lakes, and probably joins up with the diabase on the southeast shore of Caribou lake, fig. 4. Much of this ridge was burned over in the summer of 1917.

A few calcite veins up to one foot or more in width were seen conforming with the strike of the Keewatin schist on the islands and shores of Reef lake. No metallics were noticed in the veins, and samples from three different veins show the absence of silver on assay; nevertheless, the presence of such veins in a formation quite similar to that at Cobalt might warrant some of these calcite veins being prospected for silver. According to an old Indian report, silver was obtained from a calcite vein projecting out of the water on Reef lake at a point near where the river enters from Moon lake.

Pyrrhotite on Pine Lake

Pine lake, an expansion of the Kenogami river, lies about eight miles southeast of Grant station. The rocks surrounding the lake consist chiefly of Laurentian (?) hornblende granite and gneiss. These are cut by massive red biotite granite and a few narrow dikes of diabase, probably of Keweenawan age. On the southeast shore of the lake on claim T. B. 2390, (fig. 1), are three parallel bands of pyrrhotite which have been referred to by E. V. Neelands.[1] The deposits occur in a hornblende gneiss, strike slightly north of west for 100 feet and dip vertically. The south vein, which is at least 10 feet wide, consists of massive, granular pyrrhotite with a little pyrite and disseminated grains of quartz or chalcedony. A chipped sample across 10 feet yielded on assay[2] the following: Nickel 0.14 per cent.; gold 40 cents per ton; copper, none, and platinum, none. The middle band, which lies 50 feet to the north, is approximately six feet wide, and consists dominantly of pyrrhotite with some pyrite and a little disseminated molybdenite. The northerly deposit, 100 feet from the middle one, is about 10 feet wide and contains some pyrite and chalcopyrite. A few samples from the latter body yielded on assay[3] the following: Copper 0.40 per cent.; nickel 0.26 per cent.; gold, none, and platinum, none.

[1] Survey and Exploration of Northern Ontario, Department of Crown Lands, Ontario, 1900, p. 149.
[2] Assay by W. K. McNeill.
[3] Assay by W. K. McNeill.

The rocks on Little Pine lake are almost horizontal, and are similar to those on Pine lake, namely, Laurentian (?), hornblende-chlorite gneiss. These are cut by massive, flesh-coloured biotite granite. No mineral deposits of any value were seen on the lake. Little Pine river, the outlet, flows with a swift current through an excellent agricultural area.

Economic Notes

No minerals in economic quantities have been found in the area, yet one would infer from the geology and mineralogy that certain localities are favourable for gold, molybdenite, iron pyrites and probably for iron and silver.

Gold.—In the Kowkash and Tashota area there are several gold prospects which are described by the writer in the report on that area. The Wells property near Tashota is the one on which most work has been done. Here a shaft 140

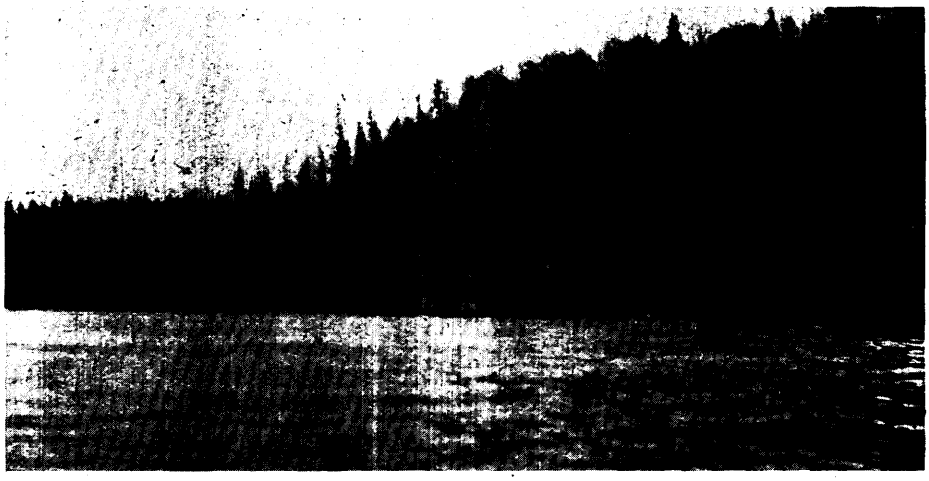


Fig. 10—Workings on pyrrhotite deposits, mining claim T B 2390, Pine lake, June, 1917.

feet deep and some lateral work on the 90-foot level show that there is an auriferous quartz deposit reported to average $5.00 in gold to the ton across five feet. Apart from the Kowkash-Tashota area which has been prospected only in a few parts, there is an unexplored area of similar rocks, extending at least from Caribou to Round lake, which might be worthy of prospecting for gold. Samples yielding 40 cents and 80 cents of gold per ton were obtained from veins on Caribou and Fuchsite lakes. In the vicinity of the latter lake the rocks consist of green schists intruded by numerous quartz porphyry dikes, an assemblage of rocks in which gold-bearing veins are frequently found.

Molybdenite.—The presence of molybdenite in granite and pegmatite on Tunnel and Tamarack lakes and in float on Trout lake, shows that molybdenite occurs over a wide area, and warrants a further search for the mineral in the vicinity.

Iron Pyrites.—Several deposits of iron pyrites occur in the Kowkash-Tashota area which would justify further exploration. Most of these deposits are described

in the report on the Kowkash area, the more important locations being marked on the map accompanying that report. On account of the present scarcity of sulphur the iron pyrites might be used in the making of sulphite pulp at the pulp-mills in northern Ontario. Deposits of little or no importance were seen on an island in Lone Breast bay, Smooth Rock lake, on Fletcher and Michell lakes, and with the iron formation at Round lake.

Iron.—Two iron ranges occur in the area, viz.: the Onaman range, consisting of a north and a south band in the vicinity of Paska station, and the Round lake range, which extends intermittently in a westerly direction to Caribou lake. The Onaman range, apparently the richer of the two, has on the whole too much rock interbanded with the narrow magnetite layers to make the deposits of economic importance; however, E. S. Moore who examined the deposits in detail in 1907 [1] and 1908 [2] regards the eastern end of the southern range, which lies two and three-quarters miles south of Paska station, to be worthy of further prospecting.

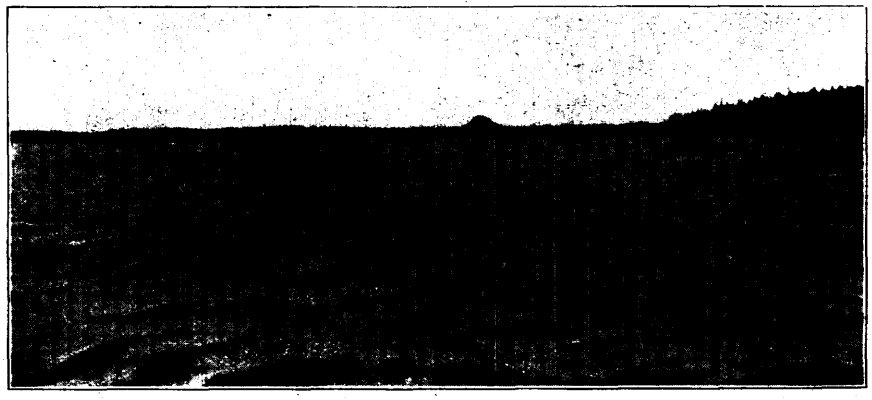


Photo by E. S. Moore.

Fig. 11—"Haystack" mountain, N. shore of Lake Nipigon.

Silver.—Silver was obtained in only one sample in the area, viz.: on the McKinnon claim which lies one and three-quarter miles north of Tashota. On this claim there is a large quartz vein, 25 feet wide in places, which contains a dark streak a few inches wide, rich in galena, zinc blende and chalcopyrite. Samples of the sulphides from this vein gave on analysis $1.00 of gold and 11 ounces of silver per ton. Numerous narrow calcite veins were seen cutting the diabase sill on McLaurin lake, to the southwest of Armstrong, but no silver values were obtained in the several samples which were assayed. Several calcite veins up to one foot in width occur in the Keewatin, which is capped by conglomerate and sandstone, and in turn by diabase, in the vicinity of Moon and Reef lakes. No silver values were obtained from these veins, but one would infer from the geology that such calcite veins are worthy of further investigation.

[1] Ont. Bur. Mines Report, Vol. XVII, 1908, pp. 170-189.
[2] Idem, Vol. XVIII, 1909, pp. 196-253.

NOTES ON LAKE ABITIBI AREA

By Percy E. Hopkins

Introduction

During September and part of October, 1917, a part of the Lake Abitibi Area was explored. This included a geological examination of a large portion of the shores and many islands of the Abitibi lakes. Examinations were also made of part of the Ghost river and a recent gold discovery in Rickard township. In addition, a track survey was made of the Okikodosik and Patten[1] rivers, and a trip made over a trail 15 miles north of Hughes station where silver was reported to have been found. Sketch maps of the various parts examined are embodied in the report. These were drawn by P. A. Jackson. The analyses of samples collected were made by W. K. McNeill, Provincial Assayer.

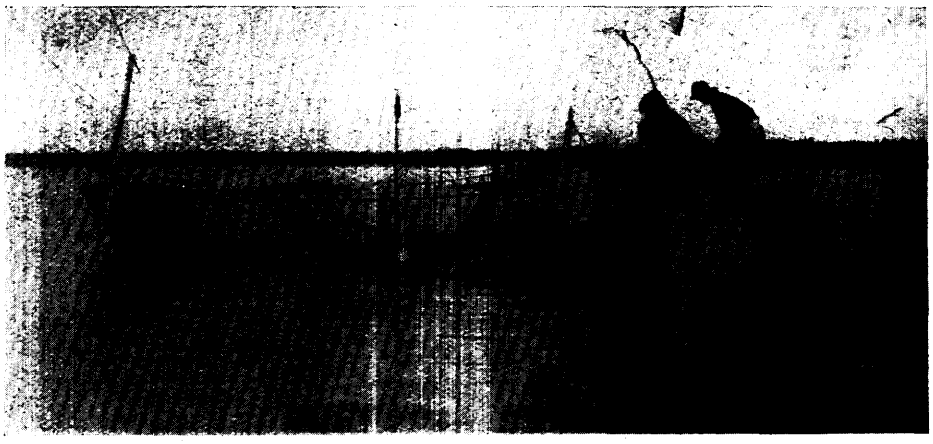


Fig. 1—Lifting pound nets, Lower Abitibi lake, September, 1917.

Only cursory examinations of the Abitibi area had been made by various explorers previous to M. B. Baker's[2] more detailed examination in 1908. Since that time the area has been made easily accessible by the construction of the National Transcontinental railway which touches the northern part of Lower Abitibi lake in places, and crosses several streams flowing into Upper Abitibi lake. Low Bush and Mace stations are within a few hundred feet of the lower lake, while La Reine and La Sarre stations in Quebec are on the Okikodosik and Whitefish rivers, 5 and 8 miles respectively from the upper lake. The excellent transportation facilities afforded by the railway and large waterways have attracted tourists and greatly aided the farming, fishing and pulp industries of the area. The Abitibi Pulp and Power Company are obtaining large quantities of pulpwood

[1] The name "Patten river," approved by the Geographic Board of Canada, has been substituted for that of "Woman river," there being several rivers in Ontario to which the name Woman has been given.

[2] Ont. Bur. Mines Report, Vol. XVIII, Pt. 1, pp. 263-283.

from their limits around the lakes. Owing to the lands not having been opened for settlement, no farming is being carried on at present in this part of Ontario, but on the Quebec side numerous farms have been located and large clearings made in the vicinity of the railway. A fishing industry has been established, the fish consisting of whitefish, pickerel, pike and suckers. Prospecting is hindered in part of the area by the scarcity of rock outcrops, but gold discoveries were made in 1917 in Rickard township, and also near the source of the Lightning river.

Topography

The country as a whole is low, flat and largely drift-covered, being part of what is generally known as the Great Clay belt. The long railway tangents suggest that the country is level and free from much rock. No rock was seen



Fig. 2—Hudson's Bay Company post, Upper Abitibi lake, Quebec, established in 1755. The two buildings in the foreground, over 50 years old, have been flooded recently by the raising of the level of Abitibi lake. The new buildings are in the background.

along the railway from Cochrane easterly to the crossing of the Low Bush river, a distance of 42 miles. The roughest part of the area is immediately south of Upper Abitibi lake, where numerous hills rise 300 to 600 feet above the lake.

Lake Abitibi, consisting of Upper and Lower lakes connected by a narrow channel, is a large but shallow lake, with an area of 350 square miles and a watershed of 3,735 square miles. The lake level was raised in 1913 by the building of a temporary regulating dam at Couchiching falls on the Abitibi river, five miles from the lake, by the Abitibi Pulp and Power Company. At this dam and at Low Bush water gauges are read daily, the datum being that of the National Transcontinental railway. The company endeavours to maintain a normal high water level not exceeding an altitude of 878.5 feet. For the year 1917, however, the average level of the lake equalled the above figure, due to the excessive precipitation during the months of June, July and August. Wind tides also have a very perceptible effect in changing the elevation at different parts of the lake.

There is a projected development by the Abitibi Company of Twin Falls on the Abitibi river, the power house to have four units operating under a head of 55 feet and using 4,500 cubic feet per second. This development will maintain the river above the dam at lake level and drown out Couchiching Falls entirely. Construction work was suspended temporarily early in 1917, the foundations of the dam being well under way at the time. At present the company derives power from Iroquois Falls, farther down the river. Twin Falls will supplement this.

General Geology

The geology of the area has been described by Mr. Baker; hence only a brief summary and a few additional notes will be given. The accompanying sketch maps (figures 8 and 9) serve to show the actual rock outcrops in certain areas.



Fig. 3—National Transcontinental railway crossing of the Lowbush and Circle rivers, September, 1917.

Keewatin

The Keewatin consists dominantly of pillow lava and altered diabase, with subordinate amounts of agglomerate, conglomerate (?), slate, Iron formation, dolomite, and hornblende and chlorite schist.[1] The large volume of these volcanic rocks is a striking feature of the south shore of Upper Abitibi lake. Despite glaciation, the surface is rough and much broken, from the uneven weathering of the rocks, due to their ellipsoidal structure and the abundance of calcite. The principal area of slate and greywacké lies in the vicinity of Mace station. These fine-grained grey rocks may be composed partly of volcanic fragmental material which has been water-sorted. They strike about N. 80° E. and dip vertically, and may be continuous with the sediments on the west shore of the lake.

[1] These rocks are called Abitibi Volcanics by M. E. Wilson. Geol. Surv. Can., Mem. No. 39, Kewagama Lake Map-Area.

Intrusives

These older rocks are intruded by serpentine, granite, and diabase, the latter two being described by Baker as Laurentian and post-Middle Huronian, respectively. Their ages have not been definitely determined, since sediments of Timiskaming age have not been found in association with them.

On the east shore of Lower Abitibi lake is a massive dike-like mass of serpentine or altered peridotite clearly cutting Keewatin graphitic schists. A definite age has not been established. However, the serpentine resembles some of the serpentine deposits of the Porcupine area and those in Dundonald and Reaume townships, which are considered to be pre-Algoman in age.

Much of the quartz diabase and gabbro of the area appears to be younger than the Keewatin in the field, and yet has a slightly older look than the Nipissing diabase at Cobalt, and may also be pre-Algoman in age. Such rocks may be seen on the Ghost hills, (fig. 8), south of Upper Abitibi lake, in the new township of Lamplugh, and also on the Okikodôsik and Patten rivers. Microscopic examination of these rocks confirms the field evidence. A sample from a point on the west shore of Upper Abitibi lake and one and a half miles south of the narrows, shows the feldspars altered to kaolin and sericite, and the augite to hornblende and chlorite, there being many graphic intergrowths of quartz and altered feldspars. Gold-bearing quartz veins are reported to occur in the altered quartz gabbro near the mouth of Patten river, (fig. 9). This rock resembles the diabase-gabbro intrusions of Robb township,[1] and Beatty and Munro townships,[2] where gold is also found. The diabase on Shaft or Gold island in Lower Abitibi lake contains a quartz vein carrying visible gold, and may be of pre-Algoman age also.[3]

The hornblende and biotite granites and syenites occur as batholiths, stocks and dike-like masses. The rocks are usually quite massive and fresh, thus resembling Algoman granites in other areas. The fact that gold occurs in a pegmatitic vein on lot 4, concession C, Steele township, and in a quartz vein cutting the granite in South bay, Lower Abitibi lake (see fig. 9), suggests that some of the gold deposits of Lake Abitibi are genetically connected with the granites.

Many of the quartz diabases cut the rocks described above and resemble, both megascopically and microscopically, the quartz diabases of the Cobalt area. Even if some of the diabases are Keweenawan in age, it will be difficult to separate them from the pre-Algoman (?) diabases. Silver appears to have accompanied the diabase intrusion at one place, viz.: north of Hughes station, to which further reference is made below. Should the Shaft or Gold island gold deposit belong to the Keweenawan epoch, then this is another example of gold deposition in the latter. The only other known similar gold-bearing deposits in Ontario which have been assigned to this age are those at the Crystal gold mine on Wanapitei lake and the Havilah mine north of Thessalon.[4]

[1] Ont. Bur. Mines Report, Vol. XXIV, Pt. 3, 1915, pp. 58-60.
[2] Ont. Bur. Mines Report, Vol. XXIV, Pt. 1, 1915, p. 180.
[3] Ont. Bur. Mines Report, Vol. XXIV, Pt. 1, 1915, pp. 243-248.
[4] Geol. Surv. of Can., Memoir No. 95, pp. 114-116.



Fig. 4—Collection of moose antlers by Indians, north of Ghost river, Abitibi lake. The large set has a spread of over five feet.

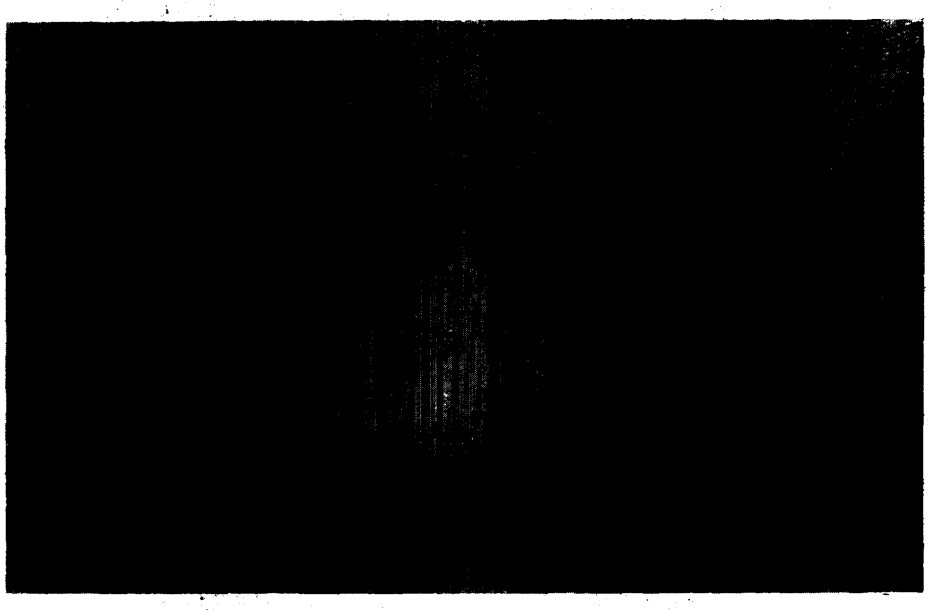


Fig. 5—Rounded greenstone boulder in stratified clay at cabin near mouth of Mattawasagi (Teddy Bear) river, Upper Abitibi lake, September, 1917.

Pleistocene

The drift deposits consist largely of stratified clay or clay and sand, which were deposited in a huge glacial lake named Lake Ojibway by A. P. Coleman. A beautiful section of the stratified clay, 15 feet thick, may be seen at the Indian cabin near the mouth of Teddy Bear or Mattawasagi river, township of Stoughton, (fig. 8). There are from 10 to 15 double layers in a foot-section of the clay. Near the bottom of the section the layers are slightly wrinkled and contain an occasional large, smooth boulder, probably representing glacial till. The rocks which rise through the clay have been glaciated, the striæ striking from 10° to 20° to the east or west of south, astronomic.



Fig. 6—Stratified clay at Indian cabin, near mouth of Mattawasagi (Teddy Bear) river, Upper Abitibi lake, September, 1917.

Economic Geology

Chromiferous Serpentine

On the east shore of Lower Abitibi lake, on lots 3 and 4, concession C, Steele township, is an occurrence of chromiferous serpentine which was discovered in 1909 by M. B. Baker. Mr. Baker was unaware of the presence of chromium until a laboratory examination was made of the serpentine collected. Since he did not return to the area, and owing to the importance of chromium in the steel-making industry in the form of chrome-steel for guns, armour-plate and tool-steel, it seemed advisable that a further examination should be made of the occurrence.

The massive serpentine, or altered peridotite, occurs as a dike-like mass cutting Keewatin graphitic schists, and is classed as pre-Algoman in age since it resembles the pre-Algoman serpentine in other parts of northern Ontario. The rock outcrop is larger than stated by Baker, having an area of at least five acres. The serpentine contains much finely disseminated magnetite and minute veinlets

of the same mineral. The rock is cut by narrow calcite veins carrying some talc. No reddish-brown streak, suggesting the presence of chromite, could be obtained from the black mineral. Baker, who describes the petrography and chemistry of the serpentine, obtained 6.72 per cent. of Cr_2O_3. This percentage is rather high for the rock as a whole, since a composite sample consisting of numerous pieces of serpentine from various parts of the outcrop, yielded on analysis[1] 2.75 per cent. of Cr_2O_3 and no platinum. This percentage of chromium

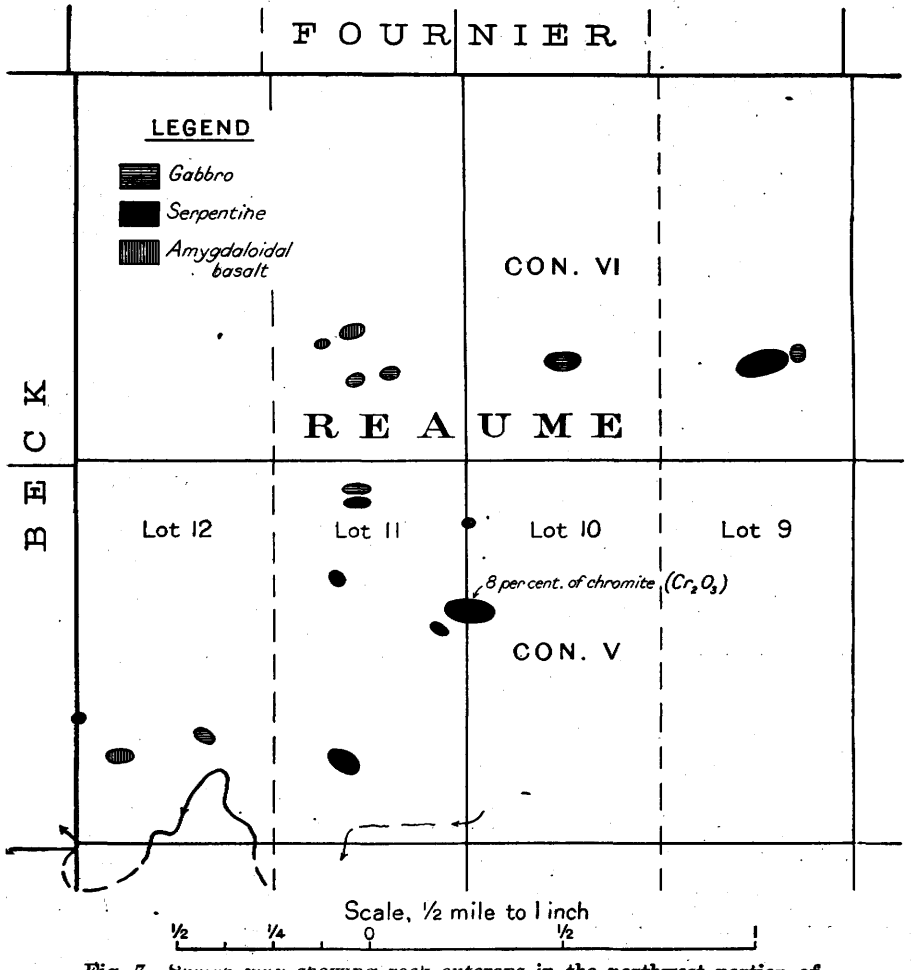


Fig. 7—Sketch map showing rock outcrops in the northwest portion of Reaume township.

is much too low to be of economic value. However, it might be advisable to trench along the borders of the serpentine mass in the hope of locating lenses of ore, as chromite often occurs at the contact.

Chromium was also detected in a sample of serpentine which was sent to the Bureau of Mines by William Campbell of Low Bush from a point on Lower Abitibi lake about four miles southeast of the outlet of Abitibi river. The sample

[1] Analysis by W. K. McNeill, Provincial Assayer.

resembled the serpentine previously described, and was found to contain[1] 0.82 per cent. of Cr_2O_3, no platinum and no nickel.

Serpentine occurs in various parts of northeastern Ontario,[2] some outcrops of which contain economic deposits of nickel-copper ore,[3] and asbestos,[4] while others contain chromium, platinum, and microscopic diamonds,[5] but not in commercial quantity. Certain of these outcrops are worthy of further prospecting for these minerals, especially for chromite, since practically all the chromite deposits of the world occur in serpentine and sands resulting from the disintegration of this rock. It is not likely that a large body of disintegrated serpentine will be found in Ontario owing to the country having been glaciated. Reaume township is one of the best known places in Ontario to prospect for chrome ore. The mineral occurrences have already been described; the accompanying sketch map, (fig. 7), may be of value to anyone wishing to prospect this locality. A small body of chromiferous serpentine carrying about 8 per cent. of Cr_2O_3 occurs on the line between lots 10 and 11, concession V, and approximately 33 chains south from the south boundary of concession VI, Reaume township. Much drift[6] occurs in the area, but by further trenching workable deposits of chromite might be found.

Early in 1918 D. O'Connor discovered chromite in the north part of lot 2, concession I, Dundonald township. The chromite occurs finely disseminated through serpentine. A sample assayed 1.34 per cent. of chromium.

The chief sources of chromite in the world and the most recent returns of production[7] are:—

	Year.	Production.
British Empire:		
India	1915	3,767 tons.
Rhodesia	1916	88,871 "
Canada[8]	1916	27,030 short tons.
Australia (N.S.W.)	1916	450 tons.
Other Countries:		
Asiatic Turkey	1909	11,364 metric tons.
New Caledonia	1916	74,115 " "
Bosnia-Herzegovina	1913	305 " "
Greece	1914	7,059 " "
Russia	1912	21,277 " "
United States	1916	40,000 tons (gross).
Japan	1911	1,527 metric tons.

The demand and prices for chromite have advanced in late years. The prevailing prices are very satisfactory, and in the latter part of 1916 the scale in force for Quebec chromite[9] f.o.b. Quebec Central Railway's stations was: 50

[1] Analysis by W. K. McNeill, Provincial Assayer.

[2] Some of these exposures are referred to by M. B. Baker, Ont. Bur. Mines Report, 1917, Vol. XXVI, pp. 270-2.

[3] Since 1912 the Alexo mine has been shipping ore which will average 4.90 per cent. of nickel and 0.60 per cent. of copper, according to the Report of the Royal Ontario Nickel Commission.

[4] During parts of 1916 and 1917 asbestos was shipped from the Porcupine area.—Ont. Bur. Mines Report, 1917, Vol. XXVI, pp. 108 and 273-4.

[5] Ont. Bur. Mines Report, 1914, Vol. XXIII, pp. 47-8.

[6] E. D. Bolton surveyed Reaume township in 1907 and reported seeing no rock in place; however, he remarked on the great irregularity in the magnetic variation of the compass, especially crossing lots 8 and 9, concessions V and VI.

[7] Department of Scientific and Industrial Research, Advisory Council, London, Eng., 1918.

[8] Canada's chrome ore comes from the Coleraine and Black Lake districts, Quebec, which produced 35,726 short tons, valued at $495,981 in 1917.

[9] Canadian Mining Journal, Mar. 15th, 1917, p. 121.

per cent. ore, $45 a ton; 40 per cent. ore, $38.75; 30 per cent. ore, $22.50; 25 per cent. ore, $18. For special purposes ore higher than 50 per cent. can be marketed at $1.00 a unit. Ore containing as low as 12 per cent. of Cr_2O_3 is being concentrated by two mills at Black Lake, Quebec.

In April, 1918, California chromite was offered at $1.40 to $1.60 per unit f.o.b. shipping points, this being for ore running 45 per cent. chromic oxide.

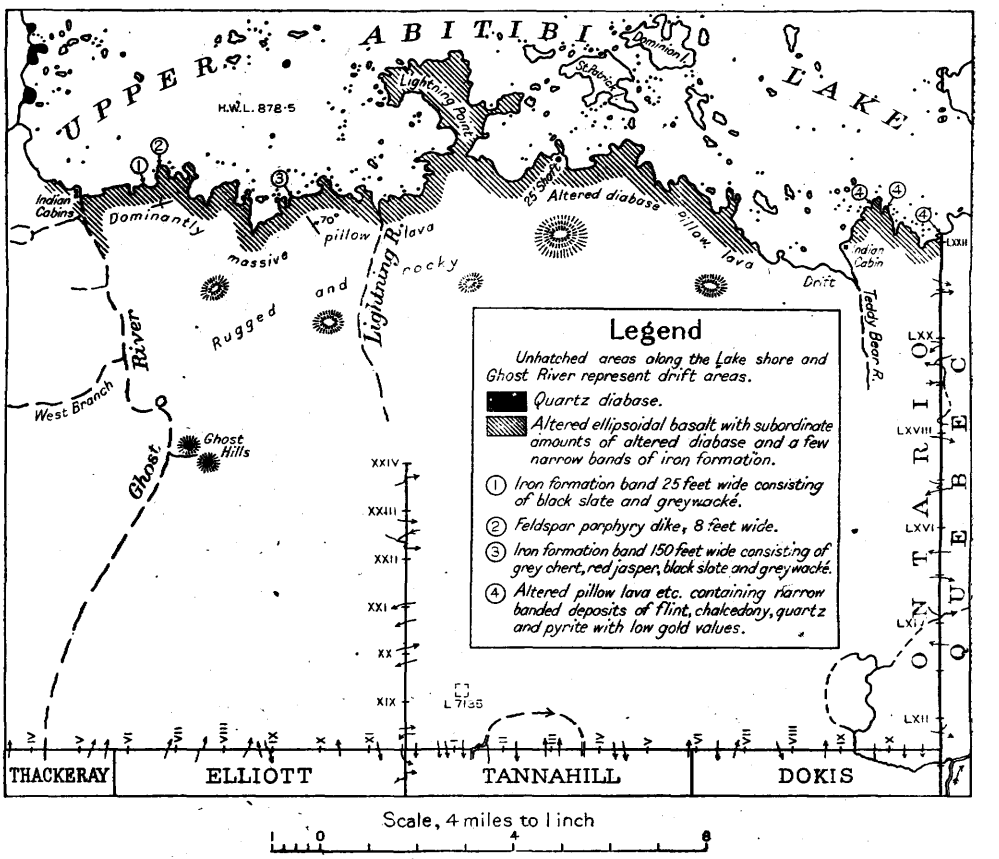


Fig. 8—**Map of a portion of the south shore of Upper Lake Abitibi, showing approximate location of the original gold discovery claim, L 7135, north of the township of Tannahill.**

Pyrite

On the southwestern edge of the serpentine mass referred to in lot 4, concession C, Steele township, is an iron pyrites deposit upon which some work has been done. The richest portion of the deposit is reported to be covered by water at present, Abitibi lake having been raised 9 feet by the building of a temporary dam at Couchiching falls. Mr. William Campbell, Low Bush P.O., Ont., who is a part owner, stated that the pyrites is practically pure over a width of 8 feet and for a considerable length. On the shore can be seen much gossan and considerable pyrite disseminated through a graphitic schist, the occurrences being almost identical with a pyrite deposit in lot 7, concession VI, McCart township.[1]

[1] Ont. Bur. Mines Report, 1917, Vol. XXVI, pp. 271-272.

Gold

On Abitibi Lake

During 1906 and 1907 numerous claims were staked for gold on the shore and islands of the Upper and Lower Abitibi lakes and considerable work done on some of them. The deposits are described by W. G. Miller[1] and M. B. Baker.[2] Four types of auriferous quartz veins may be mentioned, namely: (1) veins in the Keewatin greenstones; (2) veins in the Keewatin rusty-weathering dolomites; (3) veins in Algoman (?) granite, and (4) veins in quartz diabase, probably of pre-Algoman or Keweenawan age. The last type, which is the most promising, is represented by the Shaft or Gold island deposit (fig. 9). No work has been done on the property, however, since 1907, when a shaft 75 feet in depth was sunk on a narrow vein carrying considerable visible gold. The deposits on the shores of Upper Abitibi lake between Teddy Bear or Mattawasagi river and the interprovincial boundary (see fig. 8) are narrow, and consist of banded chert, chalcedony, red jasper and quartz, thus somewhat resembling a banded Iron formation. Much pyrite and some limonite are present, and low values in gold may be obtained on assaying.

On Patten River

In 1913 gold was reported to have been found at the 30-foot falls near the mouth of Patten[3] river which is about two miles west of mileage 126 on the interprovincial boundary. Several claims were staked and some surface prospecting done. The rock in the vicinity is an altered quartz gabbro, which looks fresher than the Keewatin and older than the Keweenawan. The quartz veins are narrow, usually under six inches in width, and contain pyrite, calcite and occasionally low gold values. The vein on the last portage at the 30-foot falls was reported to contain some visible gold. The deposits appear to be of no economic importance. However, they are of interest in that they represent another locality in Ontario where gold has been found.

The locality is reached from La Reine station, Quebec, by the Okikodosik and Patten rivers. A track survey was made of these waters by T. J. Patten, O.L.S., in 1906 in conjunction with his survey of the interprovincial boundary. The writer on his trip last autumn found only slight alterations were necessary in the plan of Patten's track survey, and has shown the rock outcrops on the accompanying map.

No pillow lavas were seen on the route; however, some of the hornblende and chlorite schist may represent altered volcanic flows, while others may be the basic parts of the Laurentian. Some of the granite gneisses appear to be typical Laurentian rocks, while the massive, fresh-looking granites resemble the Algoman granites.

[1] Ont. Bur. Mines Report, 1907, Vol. XVI, pp. 219-220.
[2] Ont. Bur. Mines Report, 1909, Vol. XVIII, pp. 268-271.
[3] Previously known as Woman river.

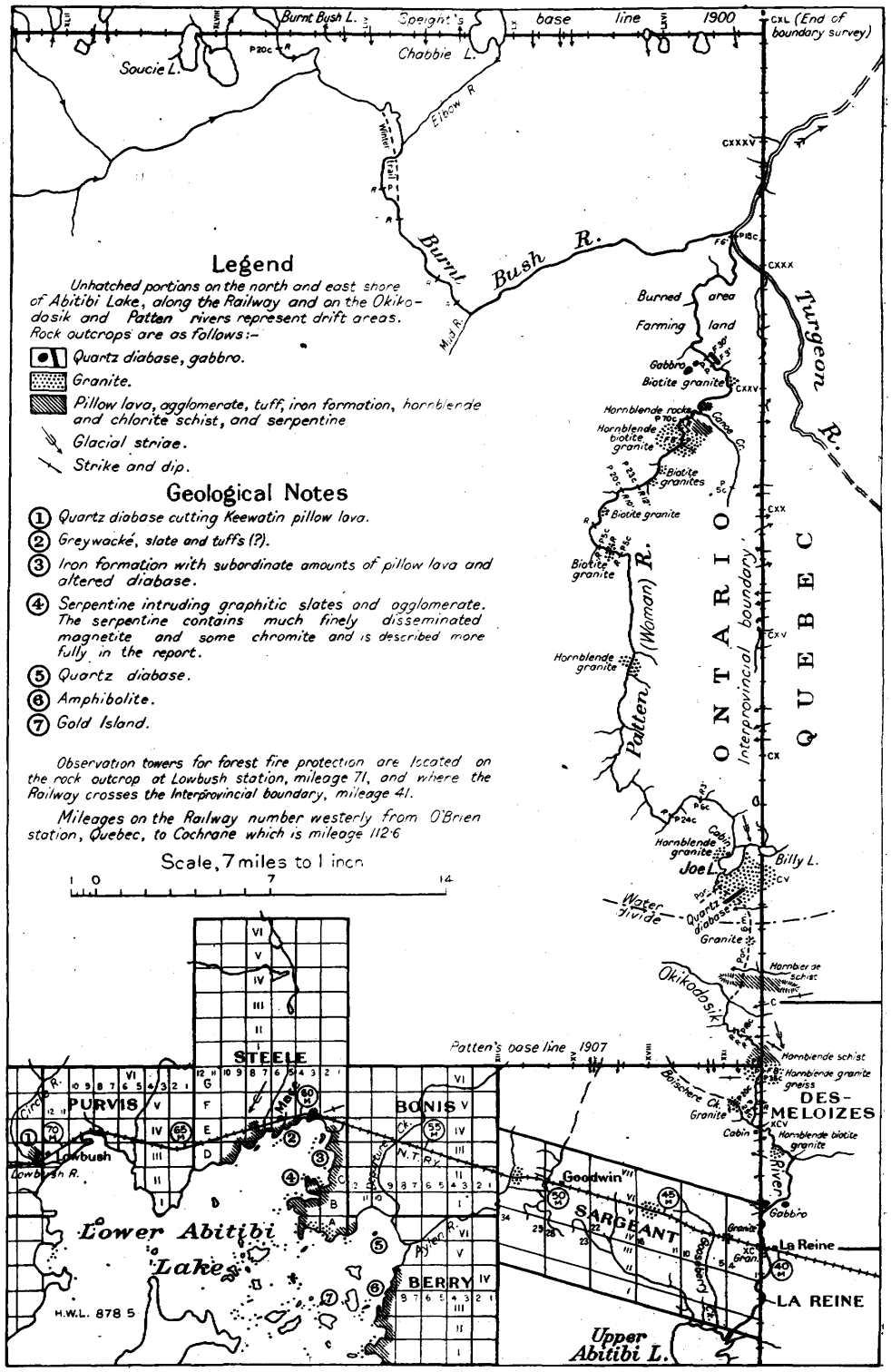


Fig. 9—Geological sketch map of part of the Abitibi Lake area.

In Rickard Township

Rickard township is situated 10 miles west of Abitibi lake and can be reached by the Abitibi river as shown on Fig. 10. The banks of the river from Abitibi lake to Couchiching falls, a distance of 5 miles, are low and free from rock exposures, but from Couchiching falls to Twin falls (which is situated to the west of Rickard township), a distance of 20 miles, the river has eroded the channel to a depth of 50 to 100 feet below the general land level, and occasionally rock outcrops may be seen. The rocks at Couchiching falls are pillow lavas intruded by numerous narrow quartz diabase dikes. One and one-half miles below, at Little Couchiching falls, in lot 2, concession IV, Knox township, is a greyish-green carbonate schist with large grains of quartz, representing probably an altered quartz porphyry. Seven or eight outcrops of altered ellipsoidal basalt may be seen between Little Couchiching and the west side of Rickard township. On account of the proposed development of Twin falls which will maintain the

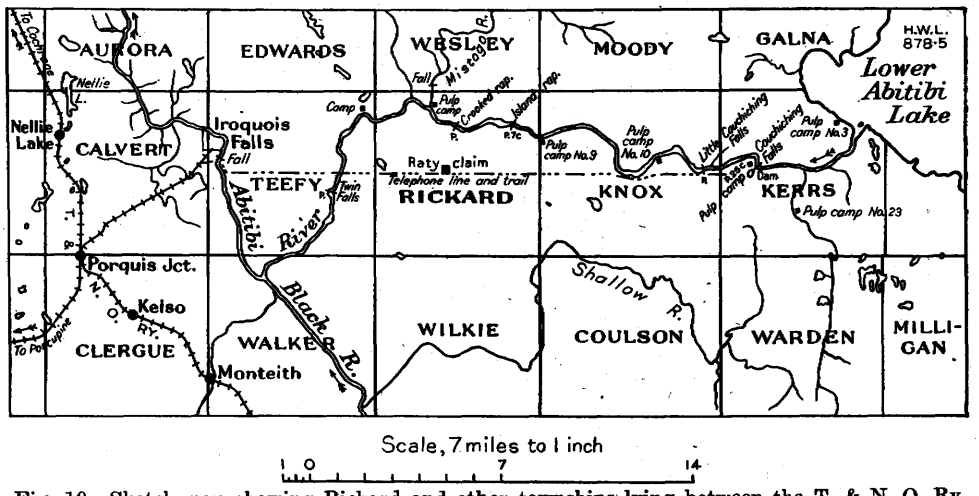


Fig. 10—Sketch map showing Rickard and other townships lying between the T. & N. O. Ry. and Lake Abitibi.

river above the dam at the level of Lake Abitibi, thus drowning out Couchiching falls, the timber along the river has been cleared away on each side, to make a wider water channel for the towing down of pulpwood. Much of Rickard township will be flooded, as shown by fig. 11.

In July, 1917, gold was found on the southwest quarter of the south half of lot 7, concession IV of the township. The discovery was made by a Finn named John Raty at a point 200 yards from a telephone line which runs from Iroquois falls to Couchiching falls on the Abitibi river and had been travelled for some years by the officials of the Abitibi Pulp and Power Company. Shortly after the discovery, representatives of two mining companies sampled the vein, but obtained low values. Later, in sinking, the prospector found a rich gold showing at a depth of five feet, which resulted in the Mining Corporation of Canada securing a working option. At present, April 1918, the shaft is 100 feet in depth at which level some drifting has been done. Some very rich samples have been obtained.

The country is undulating, and superficial deposits consist of stratified clay, through which occasional rocks rise as high as 100 feet above the stream valleys. Much of the forest in this area was destroyed by the big fire in 1916.

Only a cursory examination has been made by explorers of the geology along the canoe routes, with the exception of J. G. McMillan's exploratory trips across Rickard and surrounding townships in 1904.[1] The rocks are pre-Cambrian, consisting of Keewatin pillow-lava schist (meta-basalt), with subordinate areas of altered diabase and cherty Iron formation, all of which have been intruded by narrow dikes of feldspar porphyry and quartz-diabase, probably of Algoman

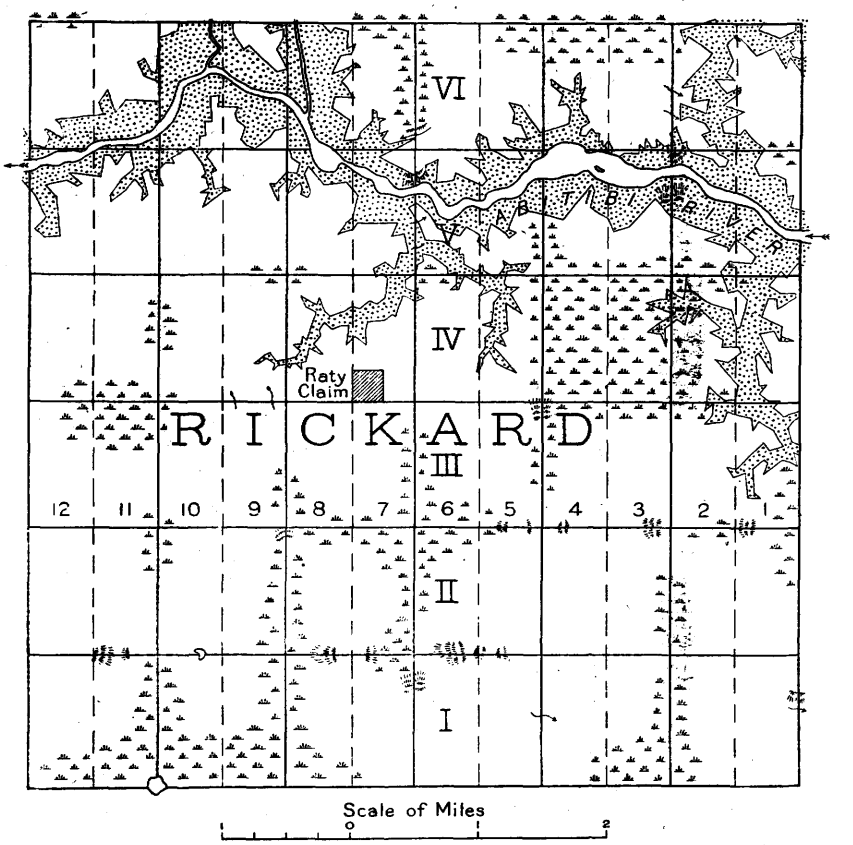


Fig. 11—Rickard township, showing location of the Raty gold discovery. The stippled area will be flooded as a result of the power development at Twin Falls.

and Keweenawan age respectively. The greenstones are in places altered to carbonate schists. The quartz-diabase appears to be similar, both megascopically and microscopically, to the Nipissing diabase at Cobalt, but its age cannot be definitely stated. A few narrow dikes of porphyry from two to ten feet in width intrude the greenstones on the Raty claim. About one-half the rock is composed of somewhat rounded phenocrysts of pinkish feldspars with some hornblende and quartz. Under the microscope many of the feldspars are seen to have a zonal struc-

[1] Ont. Bur. Mines Report, 1905, Vol. XIV, pp. 184-212.

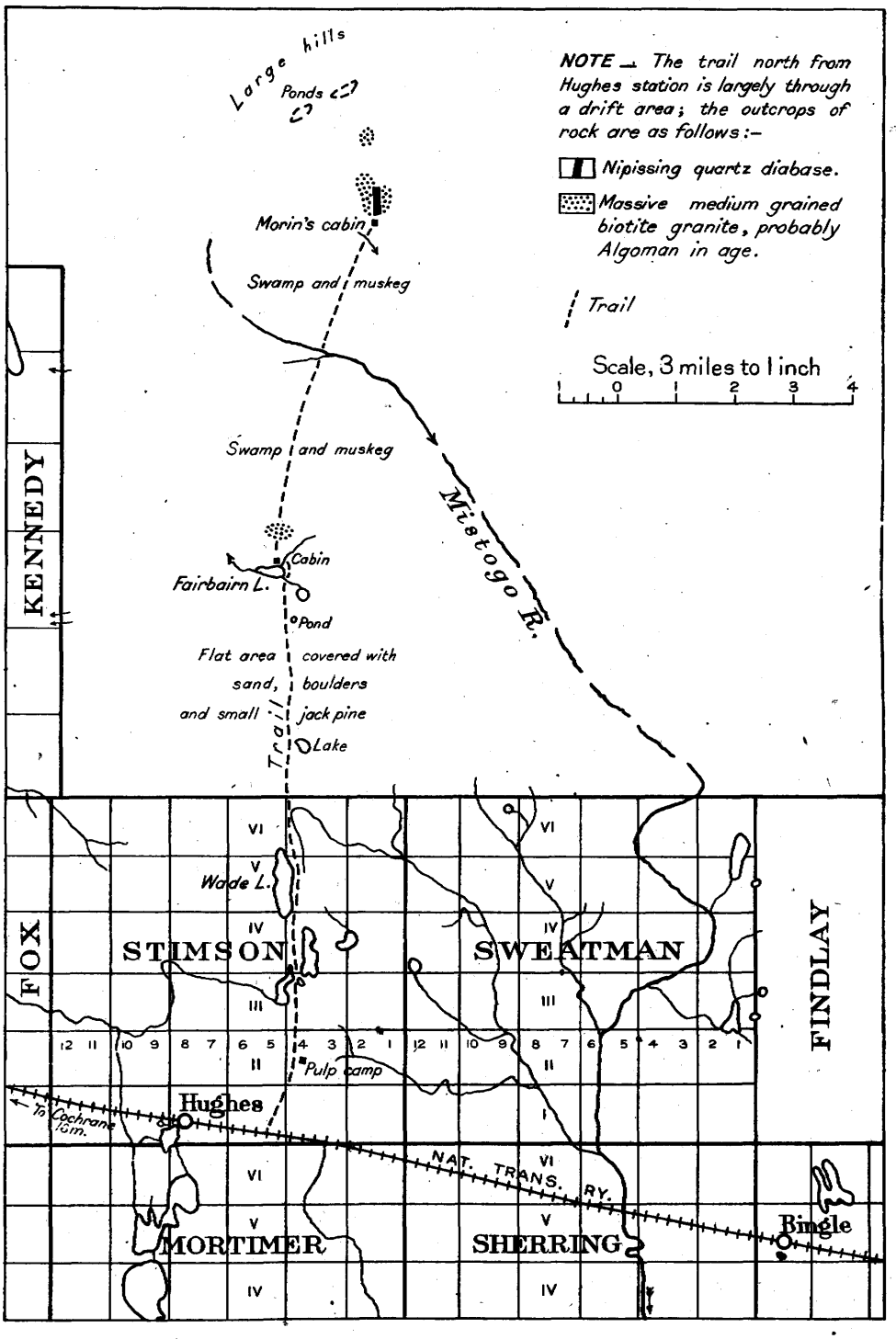


Fig. 12—Sketch map of a portion of the unsurveyed area north of Hughes Station, N. T. C. Ry.

ture, there being an occasional albite phenocryst. The hornblende phenocrysts are partly altered to chlorite. The groundmass is microcrystalline, and consists of hornblende, chlorite, plagioclase feldspar, quartz and apatite.

Gold was first found near the centre of the claim in a three-inch quartz vein striking east and west in a rusty weathered carbonate schist. The main deposit, however, is on the north part of the claim, and strikes east and west for at least 600 feet. The vein averages about six feet in width and dips almost vertically. Quartz, the chief gangue mineral, has a milky appearance. Calcite occurs as a replacement mineral in the wall rock rather than in the vein itself. Talc and sericite are frequently met with, while feldspar is not so prominent. Next to quartz pyrite is the most abundant vein mineral, there being also small quantities of copper pyrites, galena, and molybdenite. Molybdic oxide and native copper are secondary minerals near the surface. The gold, which is extremely coarse in places and varies in colour from light to dark yellow, occurs in crushed dark portions of the quartz with tellurides and other minerals, the gold usually crystallizing out after the tellurides. In the samples examined two tellurides have been identified, viz.: tetradymite (bismuth telluride) and altaite (lead telluride). A silver telluride may be present, as considerable silver was found on analysis. The values disappeared at a vertical depth of 40 feet. The magmatic waters connected with the porphyry intrusions may have had much to do with the ore deposition. The wall rock of the main vein is now a carbonate schist originating probably from a diabase. A small steam plant is in operation and diamond-drilling is being done.

Near Lightning River

A gold find was made by L. B. Howey, M. R. Howey, and W. M. Cochenour south of the Lightning river in the autumn of 1917, which resulted in a considerable number of mining claims being staked. The discovery claim, L. 7135, in the recently-named township of Holloway, which is shown in fig. 8, lies approximately one and three-quarter miles northeast of the northeast corner of Elliot township. Messrs. G. Young and S. Cragg, who have optioned the claim, state that gold values up to $40 to the ton were obtained from samples, and that the vein is about one foot in width, 200 feet long and dips about 25° from the horizontal.

Silver

A trip was made from Hughes station, N. T. C. railway, into the unsurveyed territory 16 miles to the north, where silver was reported to have been found by J. Morin. The trail is over sand plains, swamp and muskeg as shown on fig. 12. On the trail to the north of Fairbairn lake is a small outcrop of massive, pink, medium-grained, biotite granite. Similar rock occurs on Morin's claim, which in addition is cut by a quartz-diabase dike, 60 feet wide and probably of Keweenawan age. In the diabase and running in the direction of the dike for about 200 feet, is a quartz-calcite vein from a few inches to one foot in width, which contains small quantities of chlorite, pyrite, galena and copper pyrites. A few samples from the vein yielded on assay 3 ounces of silver to the ton and no gold.

THE MATACHEWAN GOLD AREA

By A. G. Burrows

Introduction

In the fall of 1916 a discovery of gold was made on the Davidson claims in Powell township, which is on the Montreal river, in the District of Timiskaming. Powell township is near Fort Matachewan, a Hudson's Bay Company post, consequently the area has become known as the "Matachewan Gold Area." Prospecting had been carried on from time to time since the discovery, in 1906, of silver in James township, at Elk Lake. Gold was found at several places in the southeast part of Alma township and in the north central part of Cairo township, in an area of syenite, a few years previous to the discovery in Powell.

At the Davidson claims in Powell township the original discovery was native gold in an irregular mass of quartz and rusty weathered schist. In 1917 gold was

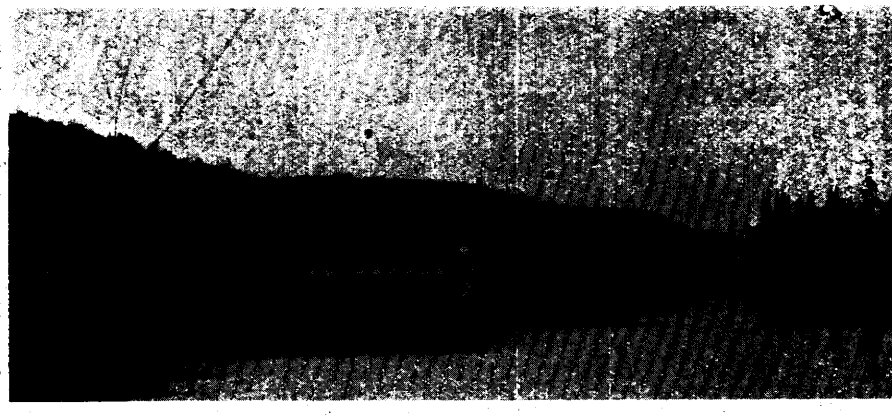


Fig. 1.—Scene on the Montreal river, north of the mouth of the East Branch (looking north).

found in a reddish porphyry by Sam Otisse on his own claims to the northeast of the Davidson. This prospector also discovered gold in a band of grey pyritous schist which lies to the south of the porphyry. Further work on the Davidson claims resulted in gold being found in the red porphyry which outcrops on these claims.

Since there was no detailed geological map of this area, the writer was instructed by Dr. W. G. Miller, Provincial Geologist, to make an examination of the country in the vicinity of the "finds." It was found that while a number of claims had been staked the previous winter, work was being done on only a few of these, consequently only a very small part of the new staking has been well prospected.

A geological knowledge of the area was obtained by travelling the township boundaries, traversing most of the water routes, and making sections away from

the water routes. Only a few of the claim lines in the vicinity of the Davidson find were travelled, since most of the claims were very irregularly staked in the winter and diffieult to follow in the thick bush in summer. However, a general examination was made of Powell, Cairo, Baden and Alma and the Matachewan Indian Reserve, while portions of the north parts of Yarrow and Kimberley also received attention.

During the season of 1917, Dr. H. C. Cooke, of the Dominion Geological Survey, examined an extensive area to the west of the Matachewan area, and his map of this country, showing the geology and canoe routes, will be of great assistance to the prospectors working westerly from the Montreal river.

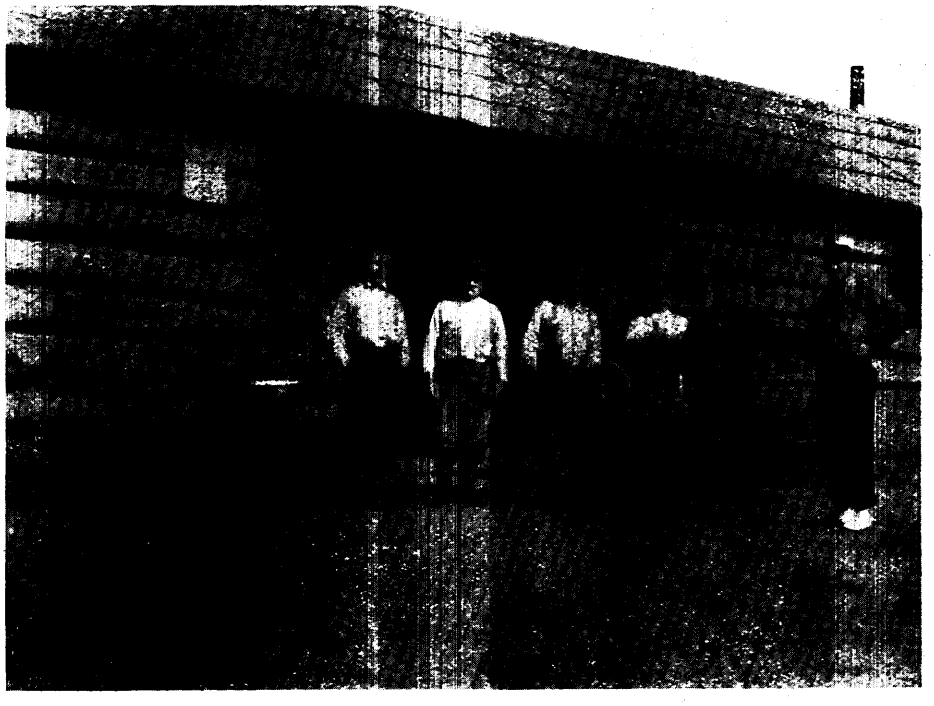


Fig. 2.—Davidson camp. The discoverer of gold on the Davidson, Jake Davidson, is the second figure from the left.

Ingress to the Area

The nearest railway station is Elk Lake, the terminus of a branch line of the Timiskaming and Northern Ontario railway that leaves the main line at Earlton station.

From Elk Lake there is a canoe route up the Montreal river a distance of about 30 miles to the Davidson landing. In high water in spring a gasoline boat has been utilized as far as the foot of the Long portage, with a short portage around Indian Chute. The trip by canoe alone is very arduous, owing to the swift current in the Montreal river above Indian Chute. In this trip three portages are necessary. In low water during the summer all the stiff rapids above Indian Chute are usually poled or tracked.

A route from Elk lake, by way of Long Point lake, was used by various parties in 1917. This requires transportation of supplies and canoes over the Gowganda wagon road to Long Point lake, from which there is a water route down stream by way of the East Branch of the Montreal river to the Matachewan area. Supplies for operations in 1918 were taken in (from Elk Lake railway station) over a winter road that roughly follows the Montreal river.

Early References to the Area

In 1875 Robt. Bell, of the Canadian Geological Survey, made an exploration survey of a route from Lake Huron to James Bay.[1] In his report he describes the east and west branches of the Montreal river, which flow through the Matachewan area. The geology is of necessity very briefly described, but reference is made to the conglomerate and other rocks along the route. The igneous rocks are for the most part called diorite, a general term for the basalt, diabases and other rocks in the complex of basic igneous rocks. Bell describes a quartz vein containing specular iron ore, along the east branch, about ten miles south of the junction with the main Montreal river.

In the Report of Survey and Exploration of Northern Ontario, 1900, J. L. R. Parsons,[2] geologist with Exploration Survey Party No. 3, gives a brief description of the geology along the Montreal river where it traverses the Matachewan area. He obtained low values in gold from two samples of quartz and pyrite in veins near the first rapid below Fort Matachewan.

In 1903 G. F. Kay made an examination of an area to the southwest of Lake Abitibi. His report has a description of a canoe route from the Black river to Fort Matachewan. Part of this route is shown in the northeast portion of the accompanying geological map of the Matachewan gold area. Microscopical descriptions of rocks occurring on Turtle, Separation and other lakes in the Indian Reserve or in Alma township, are given in Mr. Kay's report.[3]

In 1911, the Bureau of Mines, Ontario, published a sketch map, by W. M. Goodwin, showing part of the geology of the area between Porcupine and Gowganda. On this map the geology of part of the west portions of Powell and Baden townships is given.

In 1914, P. E. Hopkins, of the staff of the Bureau of Mines, examined claims in Yarrow township, on which iron ore was reported, and also some fluorite and barite veins in Cairo township. His notes on these occurrences are referred to later in the report.

Topography

The country described in the report is near the height of land separating the waters flowing to James Bay from those flowing to the St. Lawrence river. A portage at the north end of Matachewan lake crosses the divide between these waters. The area is of the rocky lake type, but much of the rock is concealed by a

[1] Geological Survey of Canada, 1875-6; Report of an Exploration in 1875 between James Bay and Lakes Superior and Huron, p. 301.
[2] Report of Survey and Exploration of Northern Ontario, p. 111.
[3] The Abitibi Region. Ont. Bur. Min., 1904, Vol. XIII, p. 112.

thin covering of soil. Where not recently burned over, there is a very heavy growth of medium sized timber. The topography is quite rugged in parts, some hills reaching 200 feet above the plain. Changes of elevation of 50 to 100 feet are frequent. Conspicuous hills can be observed near the north end of Matachewan lake. These are of greyish andesitic rock intruded by fresh-looking diabase. On the west side of Mistinigon lake there are high ridges of quartzite and conglomerate of the Cobalt series. Matachewan lake from its north end to Fort Matachewan is simply a long narrow sheet of water with precipitous shores on either side. The portion of the Montreal river above the Long Rapids in Kimberley township consists of a series of lake expansions with high shores and connected by short flat rapids.



Fig. 3.—One of several large pot-holes at the mouth of Davidson creek.

An interesting feature relating to the physiographic history of the area has been the diversion of the west branch of the Montreal river from its former to its present course. At one time the river flowed easterly from a point one and a half miles north of the south boundary of Powell, through what are now the Davidson claims, and emptied into the Montreal river a mile north of the junction with the East branch. The ancient channel followed for three-quarters of the distance the course of Davidson creek shown on the map. From a small pond at the end of the small stream flowing to Davidson creek there is a depression for three-quarters of a mile to the present West branch. The divide between this pond and the West branch is seventeen feet above the latter, in low water, as determined by Sutcliffe and Neelands in their hydro-electric survey of Matachewan or Big Bend falls. At

the west end of the pond there is a large dry pot-hole in the greywacké slate formation, and also a large cavern-like basin in the pond itself which had been formed by the cutting action of a strong eddy in the old river. For a half mile along Davidson creek, near Davidson camp, there is an accumulation of huge boulders along the bed of the old stream, while near Davidson's landing, at the mouth of the creek, there are numerous large pot-holes in the Keewatin rocks. Some of these pot-holes are shown in the accompanying illustrations. The West branch empties into Lake Matachewan at Matachewan falls, where there is a drop of 41 feet in 600 feet. The diversion of the river from its former course has been quite recent, geologically speaking, since the falls have been carried back only a short distance from the lake, with practically no gorge. There are two small rapids above the falls and below Mistinigon lake, and it is probable that formerly this

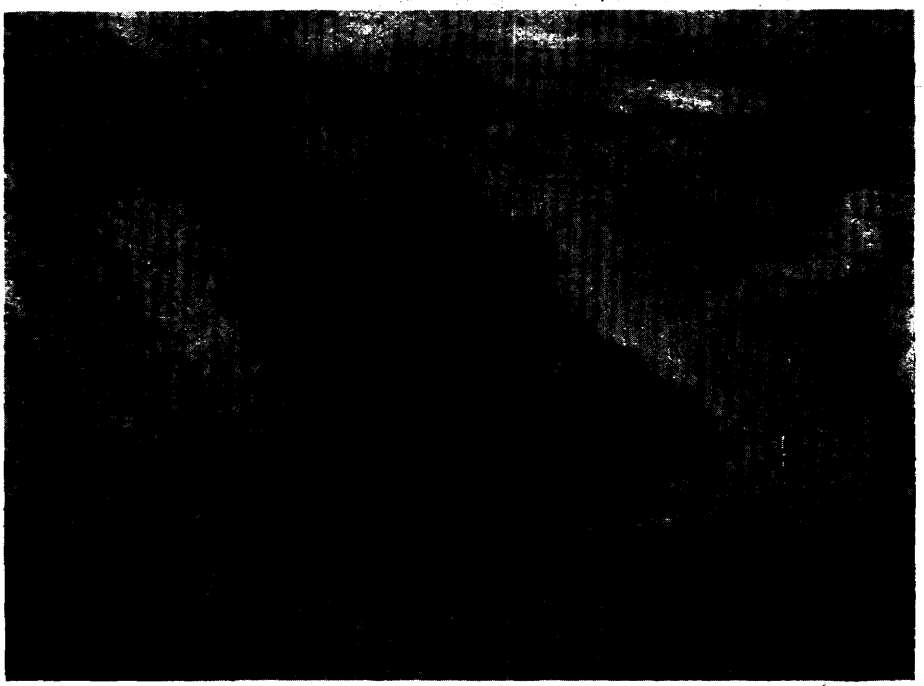


Fig. 4.—Cavern-like basin at the head of the north branch of Davidson creek. At one time this was probably part of the old course of the west branch of the Montreal river.

lake was a long narrow body of water closed at its north end, and discharging easterly from opposite the big island.

The old course of the West branch followed a depression between the older Keewatin series and the later sedimentary rocks of the Cobalt series, as shown on the accompanying geological map.

Timber

This area has been burned over several times in the history of the Hudson's Bay Company at Fort Matachewan. Charred stubs of large pine trees are frequently observed throughout the green forest. The present timber is suitable for

pulpwood, railway ties and local building purposes. It consists of the common trees of northern Ontario, spruce, jackpine, balsam, birch, poplar and cedar. Along the east shore of the Montreal river, from the East branch to the north end of Matachewan lake, there are small groves of red and white pine, which represent the northerly limit in northern Ontario for these trees.

The greater part of Cairo township has been burned over recently, exposing rolling sand plains and areas of rocky ridges burned off clean. A stretch across the southerly part of Powell township was burned over in 1916.

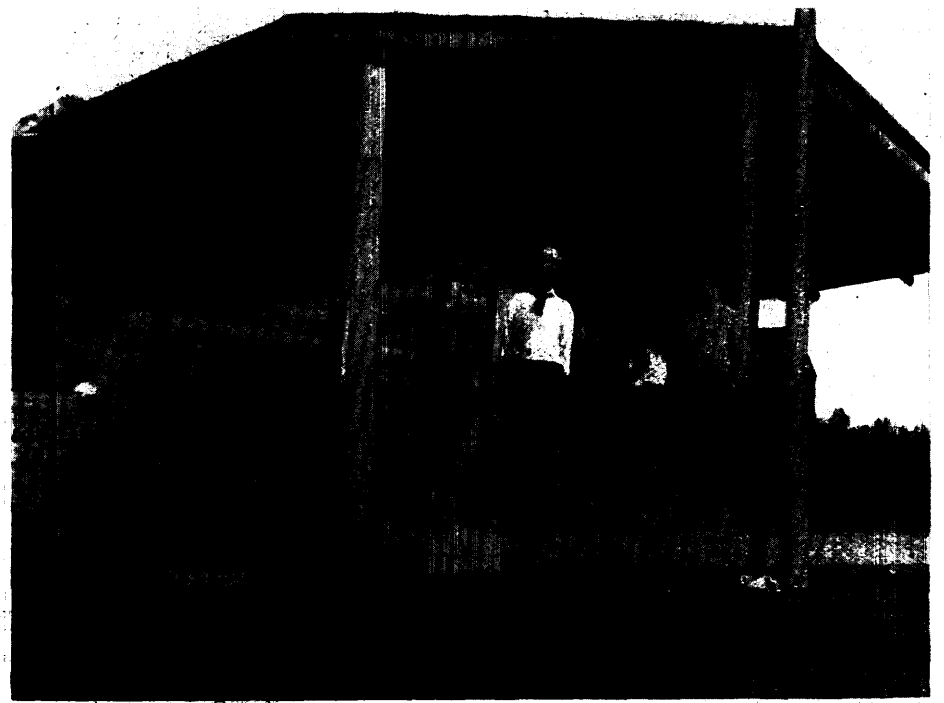


Fig 5.—Fort Matachewan. Steve Lafricain, for many years in charge of the Hudson's Bay Co. post at Fort Matachewan, is the second figure from the left.

Agriculture

The area is not suitable for agricultural purposes, except in small patches. Most of the soil is gravelly and sandy, and there are wide stretches of clean sand with small jackpine. Small areas have been cleared by the Indians in the Indian Reserve, and there is a vegetable garden at Fort Matachewan. Fine potatoes, turnips and cabbages are grown at these places.

Geology

The compact rocks are all referred to the pre-Cambrian. The following legend shows a classification of the rocks in the probable order of geological succession, from the Pleistocene to the Keewatin.

PLEISTOCENE—	
GLACIAL AND RECENT	Sand and gravel.
PRE-CAMBRIAN—	
ANIMIKIAN (Cobalt series)	Conglomerate, quartzite, slate-like greywacké.
	(Unconformity)
ALGOMAN?	Granite, syenite, porphyry, diorite, diabase.
	(Intrusive contact)
LAURENTIAN?	Granite, gneiss.
	(Intrusive contact)
KEEWATIN	Greenstone (pillow lava), meta-basalt, andesite, old diabases, serpentine, felsite, volcanic fragmental, Iron formation, conglomerate.
INTRUSIVE ROCKS	Diabase.

The oldest rocks of the area are of Keewatin age and consist mostly of basic to intermediate volcanics, accompanied by chert (Iron formation) and schistose sedimentary rocks like quartzite and conglomerate. These have been intruded by numerous diabase and porphyrytic dikes, whose age, beyond that they are younger than the Keewatin schists, is difficult to determine.

The older rocks have also been intruded by acid rocks like granite, syenite, gneiss and porphyry, which are probably of Laurentian or Algoman age. These acid rocks have also been intruded by numerous dikes of diabase, some quite fresh-looking.

A series of flat-lying sediments of the Cobalt series has been deposited on the eroded surface of the older greenstones, granites, syenite, porphyry, and some of the diabase dikes.

At only one place was a diabase dike observed intruding the Cobalt series, but a few others have been reported. This is in marked contrast to the older rocks, which are everywhere intruded by numerous dikes of diabase, consequently most of these dikes would appear to be older than the Cobalt series. In addition, at several points unconformities between the Cobalt series of sediments and diabase dikes have been noted. It would therefore seem that the conglomerate in the area would not be worth prospecting for silver, owing to the scarcity of sills and dikes of diabase of Keweenawan age.

Keewatin

The Keewatin is represented by altered lavas, meta-basalt, andesite, porphyry, diabase, serpentine, carbonate rocks, Iron formation, quartzite, conglomerate, etc. These rocks are for the greater part much altered, and many are now schists. Where schistose the general strike is approximately northeast and southwest.

Both amygdaloidal and ellipsoidal lavas occur in parts of the area, but most of the greenstone type of rock is fine-grained, dark-coloured meta-basalt. Fine-grained blackish rock can be well observed in the Keewatin area east of Whiskey Jack creek, in Cairo township. Here the ferromagnesian mineral has been altered to chlorite, but laths of plagioclase are well preserved, with extension angles near oligoclase-andesine. Secondary feldspar, mica and quartz are present, also numerous grains of magnetite, altering to leucoxene.

Excellent exposures of pillow lava occur to the south of St. Paul lake and on mining claim HF 13, west of Fox rapids. In the latter place there are also numerous amygdules in the altered lava. The pillow lava, east of the road from Fox rapids, is associated with bands of volcanic fragmental, of fine-grained and agglomeratic character, and some cherty Iron formation.

Light coloured felsite occurs with the pillow lava and Iron formation on claims HF 13 and 12502, west of Fox rapids. In hand specimens the rock is quite fine-grained, but under the microscope occasional small phenocrysts of feldspar are seen. The rock is crushed, and contains numerous minute veinlets of secondary quartz. The siliceous iron formation is in bands, and several pits have been sunk on it where there is an oxidized surface from the weathering of iron pyrites. These different rocks are intruded by dikes of diabase, and thin remnants of basal conglomerate of the Cobalt series overlie unconformably this complex.

Rocks north of Davidson Creek.—The Keewatin rocks in Powell township that are exposed to the north of Davidson creek are greatly altered to schists. Some of the green and grey schists are probably derived from igneous rocks of basic to intermediate composition. Other schists are highly oxidized at the surface and show no indication of their origin. While rusty-weathering, below this oxidation they are light grey in colour, and contain quartz, carbonate, sericite and iron pyrites. On the Otisse claims, 5379 and 5380, this grey rock has been found to be gold-bearing, and it may prove of economic value as a gold deposit.

On mining claims 5387 and 5390, and adjacent claims, extremely altered volcanic rocks, some of which are fragmental, are recognized. They are cut by numerous whitish-weathering feldspar-porphyry dikes and diabase. The older rocks and the porphyry dikes contain quartz veinlets in places, and low values in gold are sometimes obtained. One of the porphyry dikes occurs on the trail 30 chains west of the Montreal river; another on the creek south of a small lake on claim 5402. A greyish porphyry dike with quartz veinlets is seen 12 chains northwest of number two post of claim 5385. These dikes belong to an older series than the orthoclase porphyry on the Davidson and Otisse claims, and are probably associated with the Keewatin rocks. Similar dikes occur in other parts of the area, but they do not appear to be of economic importance.

Sedimentary Rocks.—Schistose sedimentary rocks are seen on the east shore of Mistinigon lake about one and a half miles north of the south boundary of Powell and on the north side of the trail leading to the Davidson claims. The rocks are in vertical attitude and strike N. 60° E. They can be traced easterly in the township to beyond Otisse lake, and consist of coarse material resembling conglomerate, and finer material like greywacké. The inclusions in the conglomerate rock are mostly small fragments of rocks of obscure origin, whitish porphyry, felsite, etc. A sample of the greywacké material from 15 chains north of No. 1 post, claim 5375, examined in thin section, contains numerous fragments of feldspar and quartz and bits of rocks, in a fine groundmass. This rock is best preserved on the north shore of Otisse lake. Small porphyry dikes, altered dikes of basic igneous rock, and numerous diabase dikes, interrupt the continuity of these bands across country. No

relationship was observed between these schistose sedimentary rocks and the schistose altered igneous rocks to the south, consequently it is thought advisable to group them with the Keewatin, of which they appear to form a part.

However, the possibility of these sediments being a remnant of the Timiskaming series, folded with the Keewatin, must be considered. This area lies midway between Midlothian township, where J. G. McMillan[1] recognized a wide area of Timiskaming, and the Kirkland Lake area, where this series occurs in large volume.

Light-coloured Porphyritic Rocks.—There are a number of light grey-coloured porphyritic rocks which are associated with the dark, very basic Keewatin greenstones, that are also probably altered volcanics, since these occur in larger volume than is generally seen in the porphyritic dikes. These rocks are prevalent in parts of the Indian reserve, especially on Turtle lake, and around Matachewan lake above Matachewan falls. Feldspar phenocrysts can often be observed in hand specimens. A sample from the east expansion of Turtle lake shows altered plagioclase phenocrysts, in a groundmass of hornblende needles, biotite, zoisite, feldspar, and quartz. There are also rounded areas of fine-grained secondary quartz. Some of the rock is crushed and mashed to resemble a conglomerate, but is an autoclastic. Volcanic fragmental material occurs on the north line of Alma township to the west of the two-mile post, and on part of the shores of Alma lake. Along with the altered igneous rock in the northeast part of Alma there are bands of slate-like rock, greatly metamorphosed, and belonging to the Keewatin complex. Owing to the intermingling of the sedimentary with the igneous metamorphosed rocks, it would be difficult to separate them.

To the south of the narrows at the south end of the upper part of Lake Matachewan there is a greyish porphyritic rock, which under the microscope proves to be an andesite or porphyrite. Phenocrysts of plagioclase (oligoclase or andesine) and hornblende (actinolite) are abundant, while these are surrounded by small rods of feldspar in a dense groundmass in which hornblende can be recognized. Rocks of somewhat similar appearance occur on both sides of the lake inland, so that the volcanic rock is widespread and is probably an old lava flow rather than an intrusive.

An analysis of the grey porphyritic rock by W. K. McNeill, Provincial Assayer, shows the following percentage composition: Silica 59.06, alumina 14.39, ferrous oxide 5.80, ferric oxide, 2.14, lime 6.98, magnesia 5.11, soda 2.75, potash 1.20, water 2.31, carbon dioxide 0.44.

Serpentine.—There is an exposure of serpentine on a small island near the west shore of Mistinigon lake, one-half mile north of Bell island. The rock contains minute veinlets of asbestos. Serpentine also occurs at points on the east shore where there is a large proportion of carbonate, the surface of the rock being altered to a rusty brown colour. The rock also contains a number of white calcite veins.

[1] T. & N. O. Railway map of part of area between Gowganda and Porcupine, 1911.

One mile northeast of Fox rapids, there is a mass of serpentine on the west side of Whiskey Jack creek. Here a pit has been sunk, but no asbestos or chrome ore was observed in the material on the dump. Just south of the pit there is a mixture of serpentine and carbonate rock in bands that are much contorted, with a rough honeycombed surface where the lime rock has been leached out.

Diabase in Keewatin.—In the areas of Keewatin, particularly in Powell and Baden townships, there is an abundance of diabase with the older rocks. This diabase has not been separated on the map from the older rocks. The occurrence is similar to that in other Keewatin areas, as in Maisonville and Munro townships, where diabase occurs in large volume with the greenstones and other rocks. The age of this diabase is unknown, but its freshness under the microscope suggests that it is much younger than the greatly altered Keewatin. Since the Timiskaming series in neighbouring areas, *e.g.*, Kirkland Lake area, is also schistose like the Keewatin, it is probable that the diabase is also younger than this series and consequently post-Timiskaming.

A specimen of quartz diabase from a ridge just south of the 2nd mile post on the north boundary of Powell township is quite fresh under the microscope. It contains laths of plagioclase and augite, some of the latter showing twinning. Quartz is present in numerous grains; a small quantity of magnetite occurs in the specimen.

Granite and Gneiss (Laurentian?)

There are exposures of granite and gneiss along the Montreal river from a short distance below Fox rapids to the foot of the Long Portage. Similar rocks occur along the north boundary of Kimberley between the crossings of the Montreal river. The two rocks, reddish granite and dark grey to black glistening hornblende gneiss, are intermingled, and are similar to rocks that in areas farther south have been referred to the Laurentian.

Granite and Diorite (Algoman?)

There are two small areas of reddish hornblende granite in the north part of Powell township. There is another small area in the northwest part of Baden township, and a larger area of granite and quartz diorite in the northeast part of Baden and the northwest part of the Indian reserve. The granite is pinkish in colour, and the diorite is a grey coarse-grained rock in which the feldspars are mostly plagioclase, the other constituents being orthoclase, quartz, hornblende and biotite.

Very small outcrops of granite occur in the northeast part of Alma township. The exact age of these isolated areas of granite is not known. They are all quite fresh and massive, and intrude the Keewatin. They are probably of Algoman age, like similar rocks in the Kirkland lake and Cobalt areas, that are younger than rocks of the Timiskaming series.

Syenite (Algoman?)

There is a batholith of syenite which extends across parts of Cairo and Alma townships into Holmes and Flavelle townships to the east. It has a width across

Cairo and Alma of five miles. Here and there it is intruded by fine-grained reddish acid dikes and also by dikes of diabase.

The rock is generally of a rich red colour in fresh material, and varies greatly in crystallization, often showing lathlike porphyritic crystals of feldspar one-half an inch in length. There is usually only a very small percentage of hornblende and quartz in the rock.

A specimen from the Brookbank claim, in the southeast part of Alma, is a quartz hornblende syenite, composed largely of red feldspar showing a somewhat perthitic intergrowth in the crystals. Magnetite and apatite are accessory minerals.

A specimen from the Chief claim, also in the southeast part of Alma, is similar in its feldspar, but contains only a little chlorite as the ferromagnesian mineral.

A sample of syenite from the Biederman claim (16042) on Browning lake was analyzed by W. K. McNeill for its alkali content and contains 9.05 per cent. of potash and 2.95 per cent. of soda, showing that most of the feldspar is orthoclase. The high percentage of potash in the syenite is worthy of note, being about three-quarters as much as that contained in the orthoclase feldspar at the well-known Richardson feldspar mine in Frontenac county, on which experimental work has been done for the production of soluble alkalies, in aid of the fertilizer industry. It may be that at some future time this large deposit of syenite will be of value as a source of potash.

The syenite is an important formation, since several gold-bearing veins have been located in it, and while no economic deposits are yet proven, the area is worthy of careful prospecting. In the same rock veins of barite and fluorite have also been discovered.

The syenite is intrusive into the Keewatin, but underlies unconformably the conglomerate of the Cobalt series.

The erosion of the syenite batholith took place largely before the deposition of the rocks of the Cobalt series, since a considerable area of conglomerate lies unconformably on the syenite in Cairo township.

Relationship Between Syenite and Granite-Gneiss.—The relationship of the syenite to the granite and gneiss in the southeast part of Cairo is not known, but the syenite is believed to be the younger rock, since it shows no gneissic structures, and is probably of Algoman age. There are a number of syenites, granites and porphyries in northern Ontario with which gold-bearing quartz veins are associated, and these are considered to be post-Timiskaming intrusives, following the irruption of which there was gold mineralization.

Orthoclase Porphyry (Algoman)

Intruding the schist, on the Davidson, Otisse, and other claims to the northeast, there is a reddish porphyritic rock, that outcrops at various points. Owing to the great amount of drift and the intrusion of diabase dikes it was not determined whether the porphyry occurs as an irregular dike or as a series of stock-like bodies. On the Davidson claims, numbers 5372 and 5374, the porphyry is very irregular, as determined by trenching, and has a somewhat oval shape, with greatest

width of about 300 feet. On the line between the northeast Davidson claim (5375) and the Otisse claim (5379), the porphyry has a width of at least 450 feet, and is probably even wider, since the rocks are drift-covered to the south.

In most of the rock phenocrysts of feldspar can be observed. Under the microscope these prove to be orthoclase. The groundmass is largely feldspar of similar composition. Chlorite is present in small amount. Crystals of iron pyrites are abundant in the rock, and in surface specimens are partly altered to limonite. In addition there are quartz and calcite veinlets and replacements of the same minerals.

On the surface the rock is partly oxidized and discoloured by iron oxide stain. In one trench on the Davidson an excavation over six feet in depth was made with pick and shovel in loose rock. The weathering has also broken down large dome-like masses of porphyry into loose fragments, as seen in the illustration.

There are numerous quartz veinlets in the mass of porphyry. These are seldom over three inches in width, and most of them are fractions of an inch. These

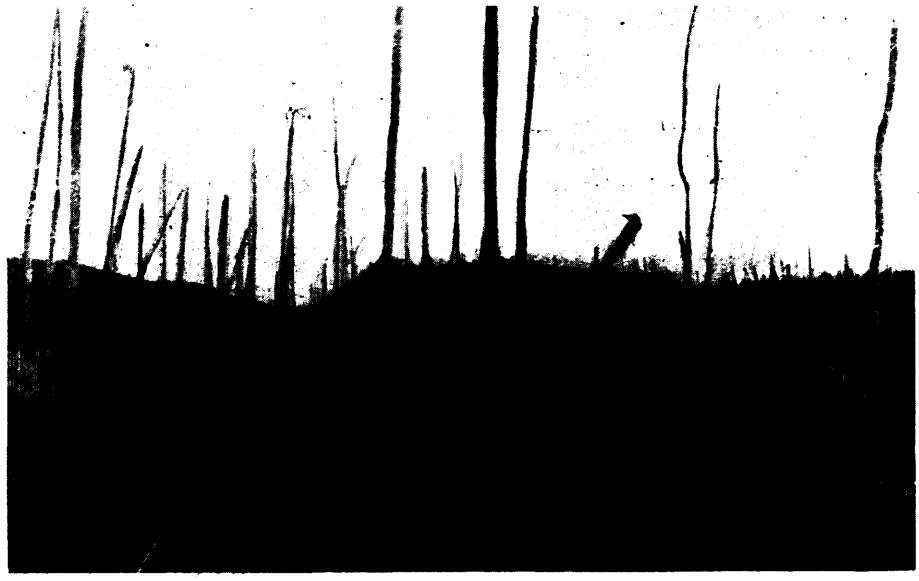


Fig. 6.—A hummock of orthoclase porphyry, weathering to small fragments, on Davidson claim 5372.

irregular veinlets give the porphyry the character of a stockwork. Samples of porphyry with quartz are occasionally encountered on the surface, showing visible gold, and the decomposed earthy surface will usually show gold in panning.

At the west end of the outcrop on the Davidson, near the contact, the porphyry contains quite large crystals of orthoclase, nearly an inch in length, and a similar rock is seen in a dike of porphyry extending northwesterly on the Robb claim, 5399. Any extension of similar porphyritic rocks to the west is concealed by a thick covering of conglomerate of the Cobalt series.

An analysis of the orthoclase porphyry, by W. K. McNeill, Provincial Assayer, shows the following percentage composition: Silica 61.80, alumina 18.86, ferric

oxide 2.95, ferrous oxide 0.32, lime 0.63, magnesia 0.34, potash 8.86, soda 3.19, water 0.54, carbon dioxide 0.84, pyrite 1.45; total 99.78.

The small stock-like masses of orthoclase porphyry on the Davidson and Otisse claims are probably of the same relative age as the syenite of Cairo township.

The high percentages of potash in the two rocks suggest a similar origin, while the different crystallization expressed may be due to the relative size of the intrusive bodies.

Cobalt Series

In the southerly part of the area covered by the accompanying map there is a wide extent of rocks of the Cobalt series, consisting of conglomerate, quartzite and slate-like greywacké, similar to other numerous exposures over a wide extent of



Fig. 7.—Conglomerate hill (Cobalt series) west of Davidson discovery.

country from Cobalt northwesterly to Porcupine, and named by W. G. Miller from the occurrence of these rocks with the silver deposits at Cobalt.

The series is generally in a nearly horizontal attitude of gently undulating rolls, seldom with greater dip than twenty degrees. Along the south boundary of Powell the sediments dip gently to the east at 5° to 15°. East of Davidson creek a section shows in ascending order quartzite, slate, conglomerate, quartzite, greywacké and conglomerate. Twenty chains east of the southwest corner of Powell township a cliff facing west exposes 18 feet of reddish weathering greywacké, overlain by 12 feet of conglomerate, with southeasterly dip of 5 to 10 degrees.

However, along the north shore of the main Montreal river, one and one-half miles west of Fox rapids, the rocks of the Cobalt series, quartzite and conglomerate,

are more highly tilted, to nearly 45 degrees. This may be due to a fault along this part of the river, which shows such a marked dissimilarity between the rocks on the different sides. A conglomerate just west of the mouth of the creek flowing from Knott lake has been rendered somewhat schistose, but contains the usual large fragments of Algoman (?) granite and syenite.

Unconformity at Base of Cobalt Series.—Basal conglomerate is exposed at numerous points extending from the West branch to near Fox rapids. One-quarter of a mile northwest of No. 1 post, claim 5374, there is a striking unconformity between the Cobalt series conglomerate and the Keewatin. Here the old surface



Fig. 8—Flat-lying sediments of Cobalt series in the east part of Yarrow township.

consisted of a banded schistose sediment which had been intruded by a diabase dike about 30 feet wide. Recent erosion has exposed these old rocks to about the original surface on which the Cobalt conglomerate was deposited, as there are thin skins of isolated patches of conglomerate at several places. This conglomerate contains large fragments of the old sediment and also of the diabase, and the line between the old schist and the later conglomerate is very distinct. The material here has been derived from local rock rather than by glacial transportation from a distance, but the old pre-Cobalt series surface, from the present evidence, would indicate a rather smooth rounded outline.

Other similar unconformities can be observed just west of No. 2 post, claim 5383, and on claim HF 13, west of Fox rapids.

On the northeast shore of Moyneur lake, in Cairo township, the conglomerate lies unconformably on the syenite. There is a similar relationship exposed in a cliff on the west side of the beaver meadow that extends southerly from Cameron lake. Here the conglomerate was deposited on a steep surface.

On the east shore of Mistinigon lake, opposite the north end of Bell island, there is a hill of conglomerate which overlies Keewatin. On the north side of the hill the Keewatin consists of chert or Iron formation, that extends along the shore for a quarter of a mile. Fragments of the chert are included in the base of the conglomerate.

Diabase

Diabase occurs abundantly in parts of the area. The Keewatin and the intrusives (granites, syenite and porphyry) are cut by numerous dikes of diabase;

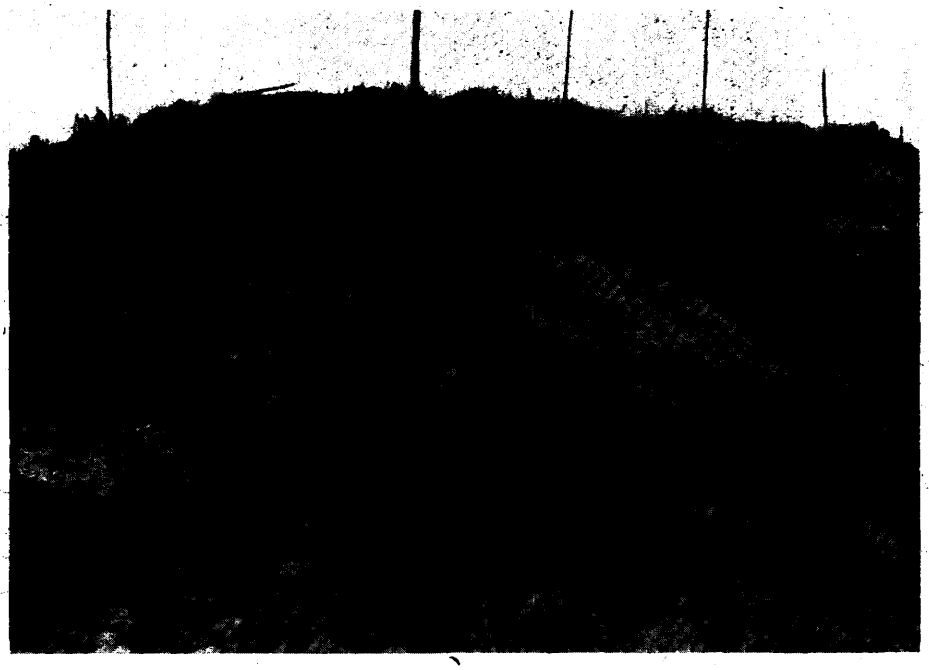


Fig. 9.—Unconformity, claim 5383, between conglomerate of Cobalt series (light-coloured patch), and underlying dark-coloured Keewatin, intruded by diabase.

whereas in the rocks of the Cobalt series these dikes are quite rare. In the vicinity of the Davidson claims there are several dikes of diabase that lie unconformably below the basal conglomerate of the Cobalt series. These dikes intrude the orthoclase porphyry that has been classed with the Algoman intrusives. It is probable that most of the dikes are post-Algoman and pre-Cobalt series in age.

The dikes ordinarily are of the normal type, medium-grained, showing chiefly plagioclase feldspar and augite with some interstitial quartz.

Occasionally porphyritic varieties that contain large phenocrysts of greenish feldspar up to two and three inches in diameter are observed. One of these occurs on

the north line of Alma, 20 chains west of the second mile post. It contains greenish porphyritic feldspar in a coarse matrix of labradorite and augite with magnetite.

There are several narrow dikes of porphyritic diabase intruding Keewatin rocks along the trail north of Davidson creek.

On the east shore of the southwest bay of Squaw lake in the Indian reserve there is a hornblende diabase. Small rods of plagioclase are set in crystals of hornblende and hypersthene. Interstitial quartz is abundant, and magnetite occurs in small grains.



Fig. 10—Dike of porphyritic diabase on trail to Davidson camp from Montreal river.

Pleistocene

Deposits of unconsolidated material cover a great part of the area. These consist largely of sand and gravel accumulations of glacial origin. A wide stretch of sand and gravel in the form of a rolling plain occurs in the southeast part of Cairo and the northeast part of Kimberley. This plain is crossed by the Long portage. There is an esker-like ridge on the south boundary of Cairo, just west of Whiskey Jack creek. The Height of Land portage at the north end of Matachewan lake is over a sand plain, probably an outwash plain from a glacier.

Morainic ridges of boulders are seen two miles up the East branch of the Montreal river, and the trail from the Montreal river to the Davidson claims follows along a similar ridge.

Economic Geology

The chief interest in the area is in its possibilities as a gold producer. For some years gold has been known to occur in Cairo and Alma townships, but it was not until the discovery on the Davidson claim in Powell in 1916 that the area attracted much attention.

Since only a small part of the area has been closely examined by the prospectors, it is possible that other promising finds will be made in the Keewatin areas in Powell and adjoining townships. The Keewatin rocks near the contact with the intrusive syenite in Cairo and Alma townships should be worthy of close examination, and it is possible that other small masses of orthoclase porphyry, similar to the occurrences on the Davidson and Otisse, will be found. Prospecting is, however, rendered difficult by deposits of sand and gravel over much of the area.

Gold in Cairo and Alma Townships

Gold was found by Jake Davidson, a prospector, in the sand-gravel stretches to the north of the Montreal river, near Fox rapids; the writer is informed by him that he frequently obtained colours in the pan, but found no place where there was any placer workable under present conditions.

Gold occurs in quartz veins in some parts of Cairo and Alma townships.

Craig Claims.—The Craig claims are situated about three miles north of Fox rapids. Here a wide quartz vein was discovered with a north and south strike. At one place trenching has shown a width of 150 feet of quartz, and silicified and brecciated syenite which is the wall rock of the vein. Part of the vein material is somewhat felsitic in appearance, suggesting some fine-grained igneous rock related to the syenite.

At one point a shaft has been sunk about 60 feet, with short drifts on the vein, and fine visible gold has been reported in the shaft and drifts, and in samples on the dump. No gold, however, was seen by the writer, but samples of material from the dump showed low values in gold. A little iron pyrites was observed in pieces of quartz and syenite, but generally the sulphide is in very minor quantity. The property is equipped with a small steam hoisting plant and has a good set of mine buildings.

Chief Claim.—The Chief claim (17310) is situated about 20 chains west of the two-mile post on the east boundary of Alma. A discovery of gold in a small hummock of syenite, which outcrops in a beaver meadow, was made some years ago. The vein strikes E. and W. and is quite narrow, varying in width from a mere crack to about six inches where exposed for 30 feet. A few shallow pits were sunk on the vein, and some samples rich in gold are reported to have been taken from the westerly pit, which was filled with water at the time of the visit. A sample of vein material from the dump, consisting of quartz, chalcopyrite, and a little galena, gave an assay of $4.40 in gold. Attempts were made by trenching to pick up the vein on the hill to the east, but only mere stringers were found, a sample of which showed no gold.

Brookbank Claim.—This claim (17801) lies in the southeast corner of Alma township, where the rock is a red syenite. Some work has been done about four chains west of the east boundary of the township and just northeast of the cabin, which is on the boundary. Here there is a N.-S. vein on which two pits had been sunk. The vein is about two inches in width between the pits, showing for 30 feet. The vein filling is chiefly quartz, but contains also some galena, copper pyrites, pyrite, and some barite and fluorite. No gold was observed, but one assay of two inches of vein contained $5.20 in gold and 8 oz. in silver, while another of five inches in width from the north pit gave $7.60 in gold and 8 oz. in silver.

Cooper Claim.—Gold is also reported on the Cooper claim (MR 5645), which lies nearly a mile northwest of the Brookbank.

The above properties were not being worked during the summer of 1917, and there were only a few prospectors in Cairo and none in Alma.



Fig. 11.—Large boulders of auriferous quartz and schist, Davidson claim 5372.

Gold in Powell Township

Davidson Claims.—These claims are situated in Powell township about two miles west of the Montreal river. Gold was found by Jake Davidson in 1916, on the south part of claim 5372, in a mass of quartz and schist. This deposit strikes nearly east and west, and has been traced by trenching for 225 feet. It dips 60°S., is 40 feet wide at the west end, and narrows toward the east. The quartz is very irregularly distributed in the schist, and for the most part the veinlets or quartz masses are transverse to the strike. The deposit very probably is lenticular in form. To the southeast there are a number of huge boulders of material from this deposit. The surface of the schist is weathered to a brown

rust, largely due to the oxidation of the iron in the ankerite, which forms a part of the altered rock. There is also a proportion of bright green serpentinous mineral. Gold in a state of very fine division was noted at a few places in this deposit. The only sulphide observed is a little iron pyrites, but for the most part the deposit is deficient in mineralization. A few chains southeast there is a quartz vein on which a pit had been sunk some years previously by Steve Lafricain, of Fort Matachewan. This quartz vein contains small quantities of cobalt bloom, iron and copper pyrites, which first attracted attention, but promising values in gold or silver were not obtained on assay.

The Keewatin rocks accompanying these veins are quite schistose, igneous and sedimentary. To the north of the first mentioned deposit there is a whitish altered porphyry which shows phenocrysts of orthoclase and plagioclase in a groundmass



Fig. 12.—Auriferous quartz and schist deposit, Davidson claim 5372.

of feldspar and quartz, with much sericite and calcite. Near this altered porphyry there is ashy weathering chert, or Iron formation. Part of the south wall of the deposit is schistose quartz-porphyry with conspicuous phenocrysts of quartz.

Intruding the schist in the north parts of these claims there is a red orthoclase porphyry that has been referred to previously as gold-bearing. Iron pyrites occurs abundantly in portions of this rock, and there has been considerable oxidation, resulting in the breaking down to a red earthy material or loose fragments on the surface, that has involved a certain amount of surface concentration. This condition varies greatly in different parts of the property; on some of the knolls there are only a few inches or less of oxidized rock, but one trench shows over six feet of loose oxidized material. Consequently, for a proper examination of the deposit, it would be necessary to prospect below this shallow rusty surface by means of open cuts through the weathered rock, by drilling, or by shafts.

The porphyry is cut by numerous veinlets of quartz which in places carry visible gold, that frequently occurs near the contact with the porphyry and also in the wall rock, near the veinlets. In one deep trench there are several flat-lying quartz veins from a fraction of an inch to two inches in width. In other places the quartz veins may be irregular in their distribution, the whole mass occurring like a stockwork. It is quite likely the quartz veins are genetically connected with the porphyry, being the filling of tension cracks that have developed on the cooling of the rock, while the gold has accompanied the quartz in the formation of these veins. Sometimes gold can be observed deposited on grains of iron pyrites in the quartz or along the wall rock. A few samples were taken from the Davidson by the writer. One of these, from the surface of the porphyry in a trench on claim 5372, gave on assay $10.00 per ton over a length of 15 feet. The porphyry here was not so altered as is frequently seen, but visible gold was observed in minute quartz veinlets near the place from which the sample was taken.

Another surface sample from a long trench at the northeast corner of the claim gave on assay a value of $15.20 over a length of ten feet in the trench. Several specimen samples of quartz and porphyry carrying iron pyrites gave values of 80 cents to $2.00 per ton. None of these assays are quoted as representative of the actual value of the whole mass of the porphyry, but indicate its gold-bearing character. It may be found on extended examination that there are isolated parts of the porphyry which are sufficiently enriched with gold to be of economic value.

The following is a description of a microscopic examination of gold-bearing porphyry and quartz from Davidson claim 5372:

Orthoclase crystals are set in a groundmass of smaller feldspar crystals with a little chlorite in flakes and scattered crystals of apatite. Calcite is abundant as a secondary mineral. Quartz occurs in small secondary masses and in veinlets. Cubes and irregular grains of pyrite with an oxidized surface of limonite are frequent in the porphyry and also in the quartz veinlets. The quartz veinlets contain clear secondary feldspar, plagioclase and microcline moulded on the older feldspars of the porphyry. Vein calcite also accompanies the quartz in the veinlets, while native gold occurs near the wall rock in the quartz. A small amount of copper pyrites is occasionally seen. None of the rarer minerals, like the tellurides, have been recognized in any of the samples examined.

Otisse Claims (5379-5380).—These claims lie directly east of the Davidson group, and, owing to a somewhat deeper covering of drift and a smaller amount of trenching, the distribution of the rocks is not as well known.

In the northwest part of claim 5379 the orthoclase porphyry is well exposed. There is also a surface oxidation similar to the Davidson, with an amount of loose brown earthy material in which trenches were made. Gold has been found in a number of pits in the same association as in the porphyry on the Davidson.

To the east of this outcrop other occurrences of porphyry have been located by Sam Otisse in heavily timbered country; it is probable that a band of porphyry extends through the northerly part of the claims.

Near the centre line of the claims, a few chains north of the south line, there are outcrops of rusty weathered schist in which native gold has also been discovered.

This band of rock lies to the south of the porphyry band. Below the oxidized surface the rock is light grey in colour and spotted with pyrite. Examined under the microscope it contains much secondary silica, calcite, sericite, and iron pyrites, indicating that the rock has been entirely altered by replacement from its original composition. Mr. Otisse discovered gold at several other places on his claims in rocks which are of different character from those described above.

An examination of these properties in January last resulted in options being taken on these and adjoining claims, and it is expected that during the summer of 1918 a thorough examination will be made to prove their possibilities as gold producers.

Otisse Claim (5376).—This claim lies north of the Davidson claim, 5372. The rocks are largely schistose sedimentary rocks intruded by narrow porphyritic dikes. Six chains north of the Davidson claim there is a quartz vein striking nearly east and west, and three to four feet wide in places. It contains, in parts, copper pyrites, iron pyrites, and galena. Fragments of grey porphyry in the quartz suggest that the vein was formed along an old porphyry dike. Gold values are reported from this vein. A selected sample of quartz, galena, and copper pyrites contained $1.20 in gold per ton.

In the southwest part of the claim there is a narrow red porphyry dike that strikes northwesterly to the Robb claim. It contains quite large crystals of orthoclase, and is probably a narrow dike representative of the stock-like mass of red porphyry on the Davidson. Gold is reported to occur in this dike.

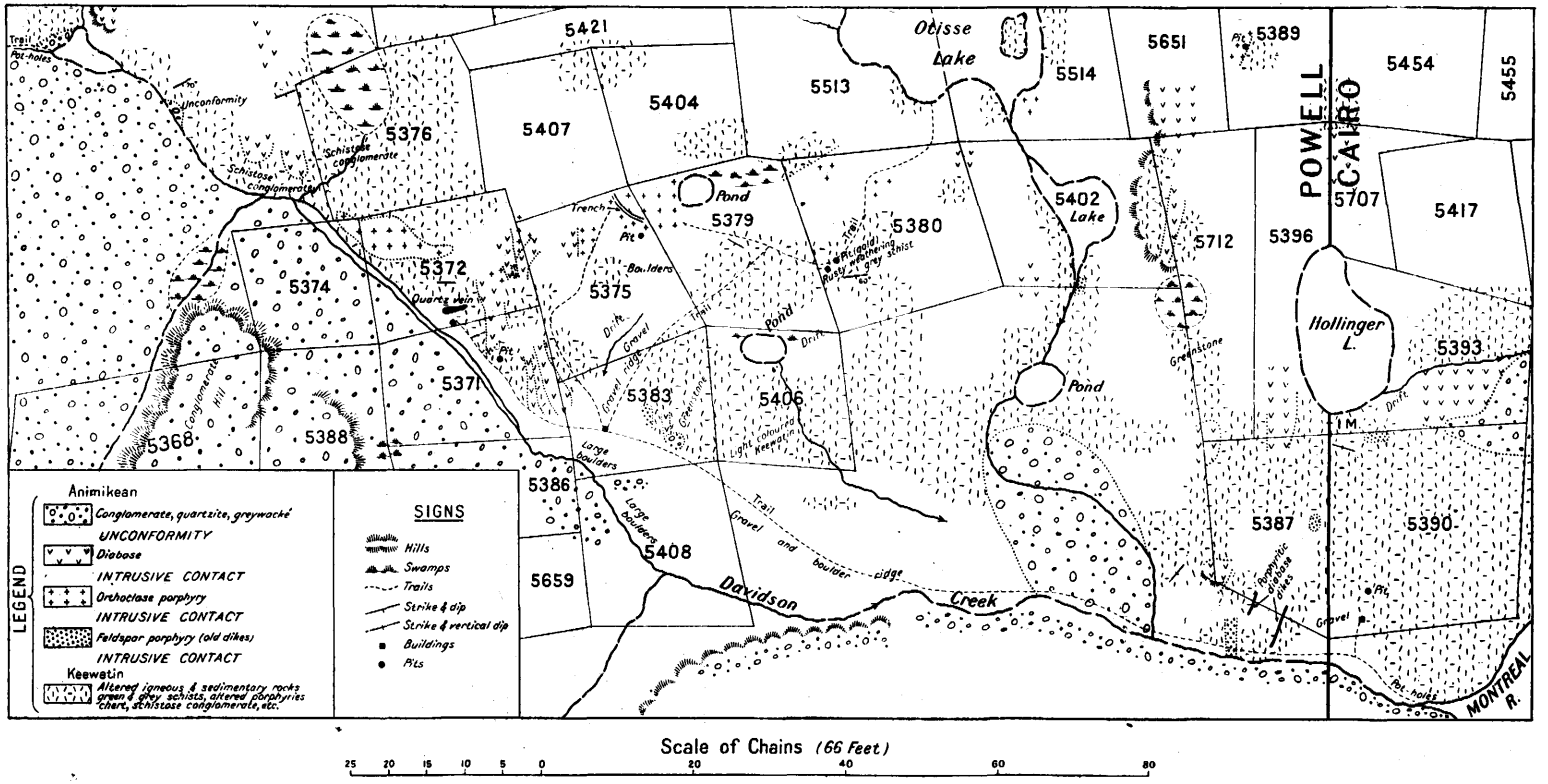
O'Connell Claims (5389-5390).—On claim 5389, adjoining the boundary line between Powell and Cairo, there is a reddish feldspar porphyry dike that intrudes a slate-like rock of Keewatin age. This porphyry is much harder than that on the Davidson and Otisse claims, and does not show so heavy a mineralization with iron pyrites. It is cut by quartz veinlets, and has been partly prospected by stripping and a shallow open cut. Low values in gold from this material are reported by the owners.

On claim 5390, one mile south, work was done on a band of blackish chert-like rock cut by quartz veinlets with pyrite, from which low gold values were also obtained.

Fluorite

Fluorite (fluorspar) has been found in small quantity in a number of quartz veins in Cairo and Alma townships, but none of the deposits examined are of commercial value. Owing to the widespread occurrence of the mineral, it is possible that prospecting might result in the finding of economic deposits. The mineral is of a deep purple colour, occurring in small masses in the quartz or in the wall rock adjacent to the veins. It is also present in the Biederman barite vein. One occurrence where the fluorite is in the quartz is on the Harvey claim, No. 18285, west of the road from Fox rapids north to the Craig claims. This vein is about seven inches wide, strikes N. 75° E., and has been traced several hundred feet. Some pieces of fluorite, two inches across, were taken from the vein. All the showings of fluorite are in the syenite.

GEOLOGICAL SKETCH MAP OF PARTS OF THE TOWNSHIPS OF POWELL AND CAIRO.



MINING CLAIMS

Connell—5513, 5514; Davidson—5371, 5372, 5374, 5375, 5383; O'Connell—5387, 5389, 5390, 5651; Otisse—5376, 5379, 5380; Robb—5402.

Barite

Veins containing barite occur in several parts of the area. These are generally small, but two deposits have been found which would be of commercial value were they nearer railway transportation. These are the Biederman deposit in Cairo township, and a deposit near Yarrow lake in Yarrow township.

Biederman Claim.—This claim (16042) is situated on the west shore of Browning lake, in the north part of Cairo township. The country rock is a red syenite in which there is a barite vein with strike N. 65° W. and dip 80° N. The

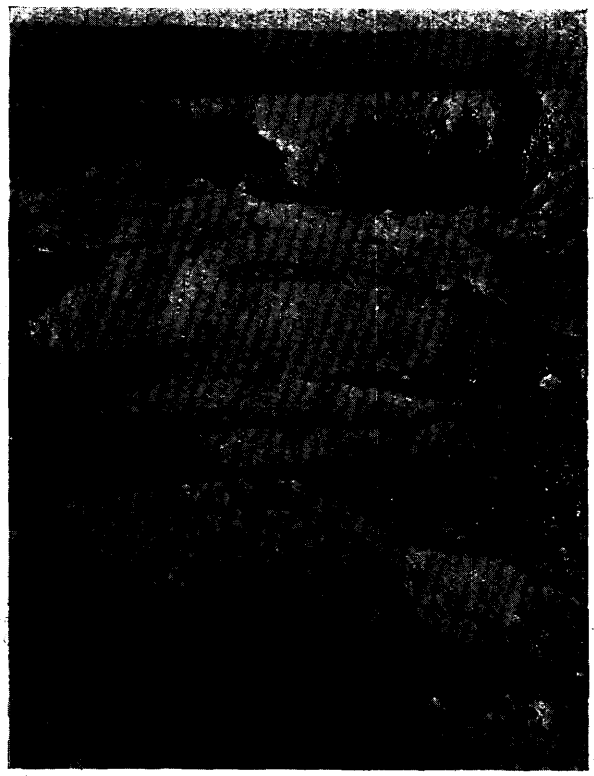


Fig. 13.—Biederman barite vein, on claim 16042, in Cairo township.

deposit can be observed about 100 feet from the shore of the lake where a shallow shaft has been sunk at a point where the vein has been concealed by drift to the east. Here there is a width of 15 feet, and the barite can be traced westerly for 100 feet, decreasing to a width of 7 feet. Beyond this there is drift followed by an exposure of barite about 30 feet in length and three feet wide at the east end, and two feet wide at the west end. The barite is for the most part quite white in colour and of good quality. At the shaft there are minor quantities of zinc blende, galena and specularite and a little fluorite, as impurities. The deposit also contains at this point some large inclusions of syenite. A sample across eight feet, on analysis contains 90.50 per cent. barium sulphate.

Yarrow Deposit.—This deposit occurs along the creek which flows from Yarrow lake to Mistinigon lake. The rocks are slate and quartzite of the Cobalt series, but they are largely concealed by a deep covering of drift along the creek. The deposit was discovered in the bed of the creek, and attempts have been made to open it up by diverting the water by means of a small dam. Two shallow pits were sunk in the bed of the creek on the barite, which is in two veins five feet and six feet wide respectively, separated by a band of quartzite. As the deposit was noted only in the creek bottom its length has not been determined, but owing to its width it is probable that it also has considerable length. This deposit, like the Biederman, will probably be of commercial value at a future time.

Iron Ore

The La Brosse claims, JS 65 and JS 66, situated in Yarrow township, a short distance west of the east branch of the Montreal river, were examined by P. E. Hopkins in August, 1914, and the following account is from his manuscript:

The iron ore, which consists of hematite, in reniform structure and also the highly crystallized specular variety, occurs in a quartz vein that strikes N. 72° E., and dips about vertically. This vein can be traced across two claims, and varies from five feet to thirty feet in width. The iron ore occurs in isolated masses and stringers in the quartz, and in places is brecciated. On the east part of JS 66 is located the largest body of clean iron ore. This ore on the surface is sixty feet long and six feet wide at its greatest width, being in the form of a lens. Another lens is twenty-five feet in length. More work may prove the bodies to be larger, as the vein is partly drift-covered. No kidney ore was observed in other parts of the vein where exposed, but small quantities of specular iron ore occur sparingly in the vein.

Iron ore was observed in small quartz veins in the vicinity in Yarrow township. The country rock that encloses the veins is conglomerate and quartzite of the Cobalt series that dip gently to the east at 10° to 15°.

Waterpower[1]

Mining camps in northern Ontario have been greatly favoured by the proximity of waterfalls capable of development for the generation of hydro-electric energy. Powell township is well situated in this regard, Big Bend or Matachewan falls lying about six and a half miles north of the Davidson and Otisse claims. This water power is located in the township of Baden on the west branch of the Montreal river at a point known as the Great Northern Bend.

Application to develop this power was made in 1916 by a firm of engineers and surveyors, Sutcliffe and Neelands, of New Liskeard, with the object of supplying electric energy to the prospective gold camp in Powell township, and possibly the Gowganda silver camp some twenty miles farther south. Regarding their exploratory surveys in 1900, De Morest and Silvester, with party No. 3, report[2] as follows:

Matachewan falls and rapids, where the river empties into Matachewan lake, have a drop of about forty feet and constitute a very important waterpower, as the length is short and the site comparatively easy of development.

[1] The notes on Waterpower have been supplied by W. R. Rogers, Topographer for the Ontario Bureau of Mines.

[2] Report of Survey and Exploration of Northern Ontario in 1900, p. 87.

The watershed of the West branch is 790 square miles in area. Under natural head the drop at Matachewan falls and rapids is 41 feet, but a dam raising the water at the upper level to high water mark would give a head of 45 feet. Assuming a run-off coefficient of 0.3 cu. ft. per sec. per square mile of drainage area for minimum flow conditions, the possible development without storage would be about 1,000 horsepower.

Permission has been sought to raise the level of Mistinigon lake 25 feet in order to provide storage and also to increase the available head to 70 feet. Another project involves the diversion of the East branch of the Montreal river by way of Kawakinika lake, Cleaver lake and Cleaver creek, to a point on the West branch



Fig. 14.—Matachewan or Big Bend falls, Montreal river, where the West branch enters Matachewan lake.

near the centre of the township of Rankin, a route that marks a former course of the river. Such a diversion would add 210 square miles to the drainage area, making a total of 1,000 square miles, and could be effected by erecting a dam at the first rapids below Obushkong lake near the boundary line between the townships of Haultain and Morel. Both of these projects were suggested late in the fall of 1917, and either or both may not be prejudicial to other interests, such as navigation and lumbering. A Departmental examination of the feasibility of the plans had to be postponed until navigation opened in the spring of 1918. Undoubtedly work on this power will proceed in the near future, the extent of the development depending on the success met with in mining operations in the vicinity.

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End of Part I.

IRON AND COPPER DEPOSITS
NEAR
MINE CENTRE

To accompany Report by A.L.Parsons, in Part 1, Volume 27, Ontario Bureau of Mines.

—1918—

Scale of Miles

1 ¼ ½ ¼ 0 1 2 3

92°50' 92°45' 92°40' 92°35'

48°45'

LITTLE TURTLE LAKE

CAN. NOR. RY.

Olive Siding

Mine Centre

Pontardawe

H.P. 181

H.P. 195

H.P. 105

H.P. 129

K.308

G. 207 H.P. 181

G. 209 H.P. 99

H.P. 253

N.W. ¼

Barber Lake

BAD VERMILION LAKE

Island Bay

Porcupine L.

Mud L.

Portage

Portage

Portage

Finger Bay

Mine Centre

SHOAL LAKE

Obashinsing Lake

Lochart Lake

FARRINGTON

I II III IV V VI

1 2 3 4 5 6 7

SEINE BAY

INDIAN RESERVE

Road

LEGEND

- Algoman granite
- Quartzites etc.
- Conglomerate
- Anorthosite
- Greenstones & schists
- Limestone
- Iron formation

Mining Claims

PORT ARTHUR COPPER Co H.P.187, H.P.181, H.P.253, H.P.99 (N.W.¼), G.207, G.209.

MATHIEU H.P.195.

INTERNATIONAL COPPER Co H.P.105.

HEDBURG K.308, H.P.129.

GOLDEN STAR A.L.114

92°50' 92°45' 92°40' 92°35'

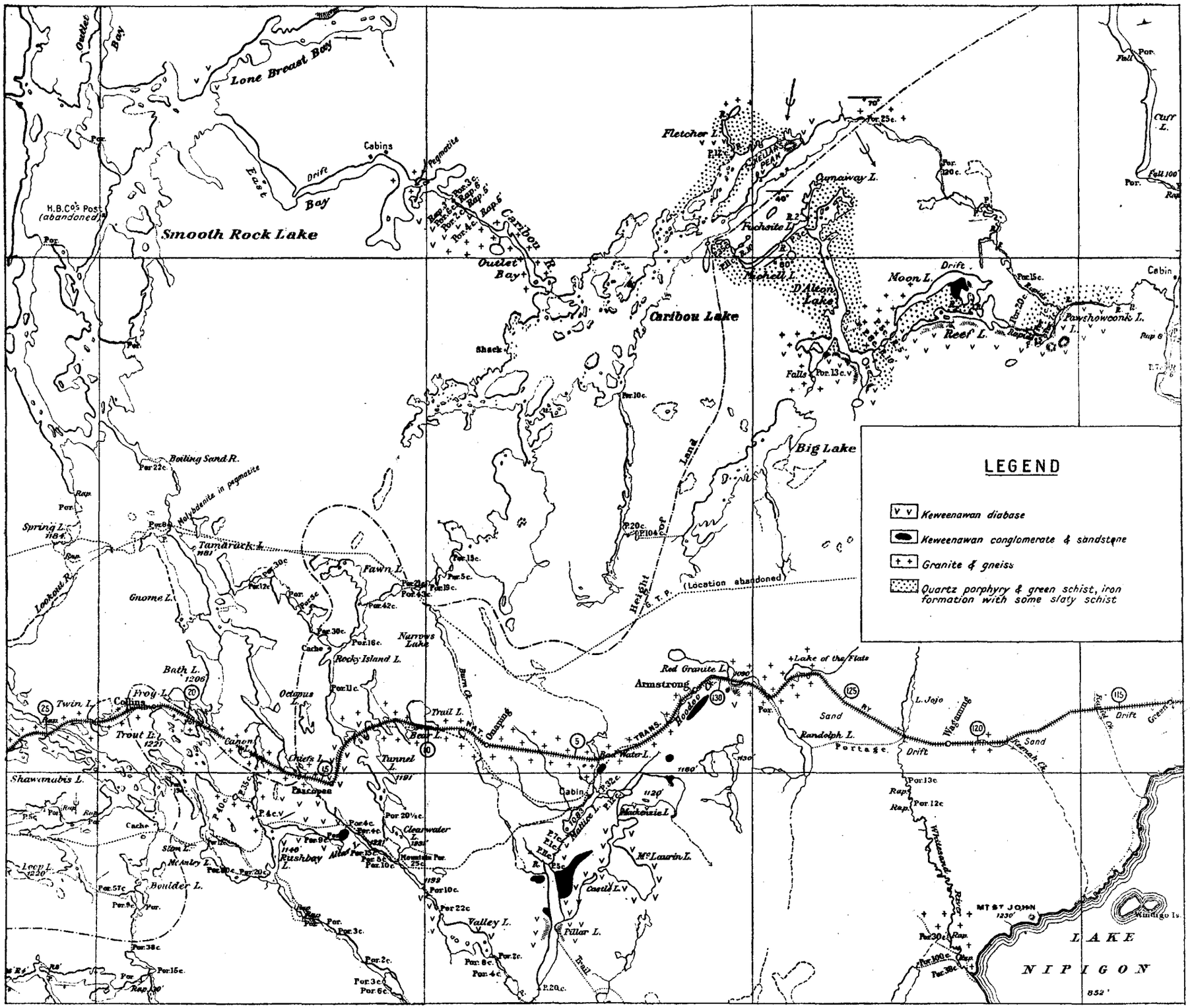
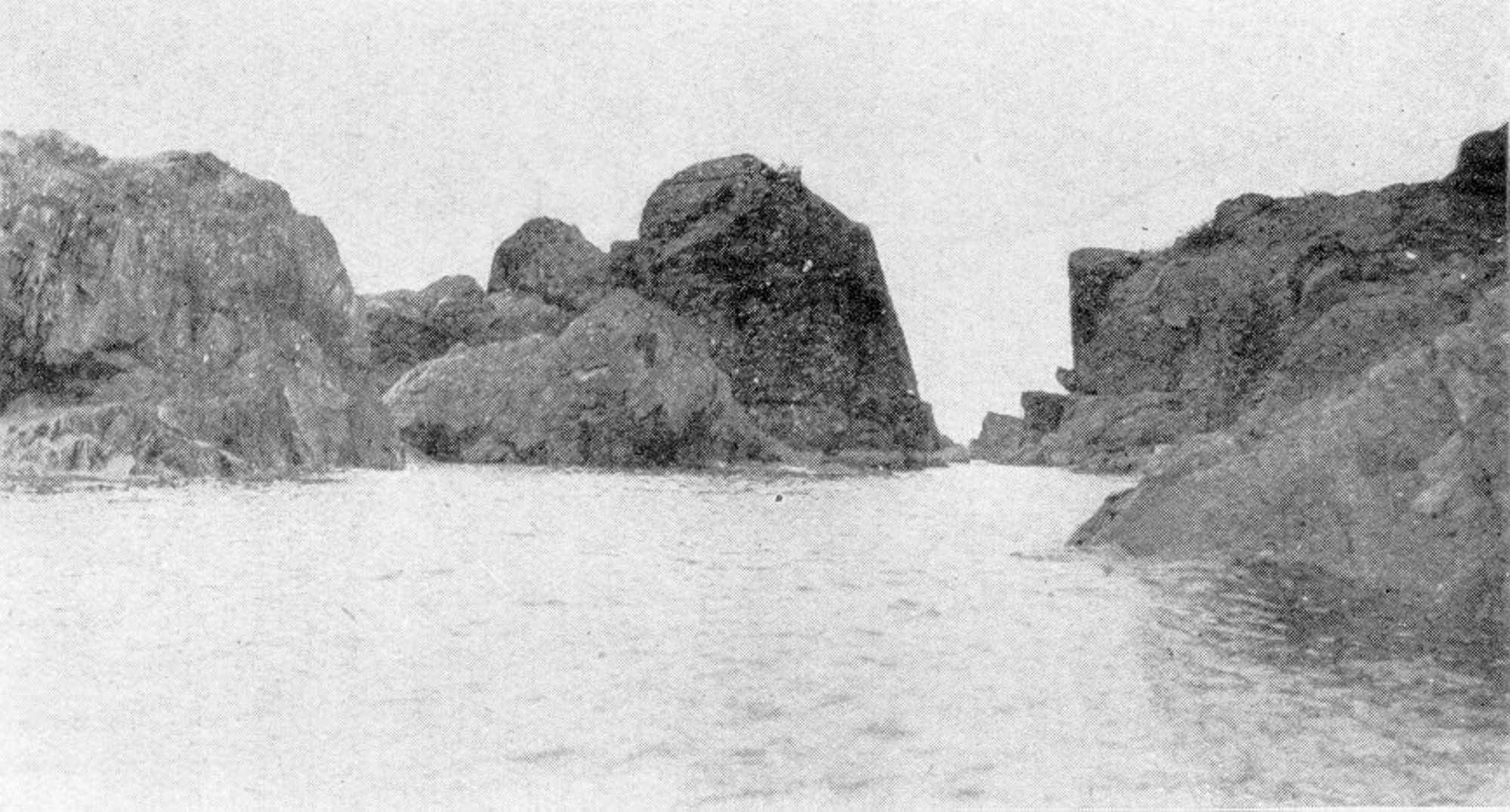
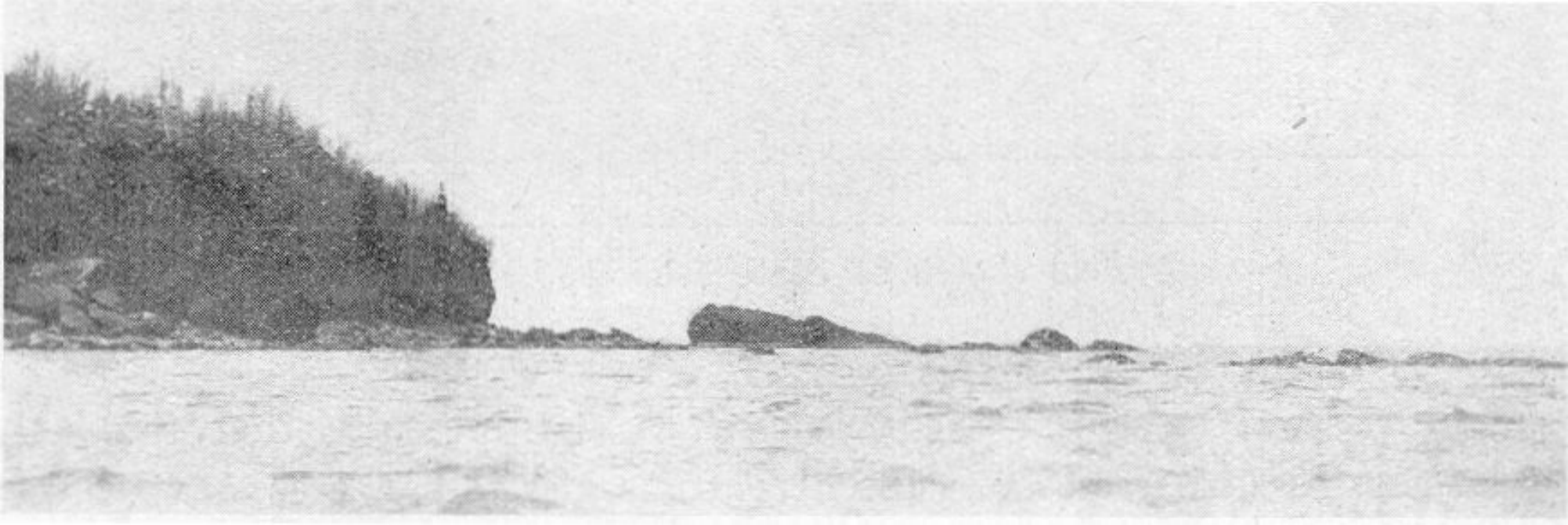


Fig. 4—Route map (scale, 4 miles to the inch) between Collins station and Lake Nipigon, N. T. Ry., showing geology and topography in the vicinity of Caribou and Pillar lakes, not covered by Map No. 993, Geol. Sur. Canada.

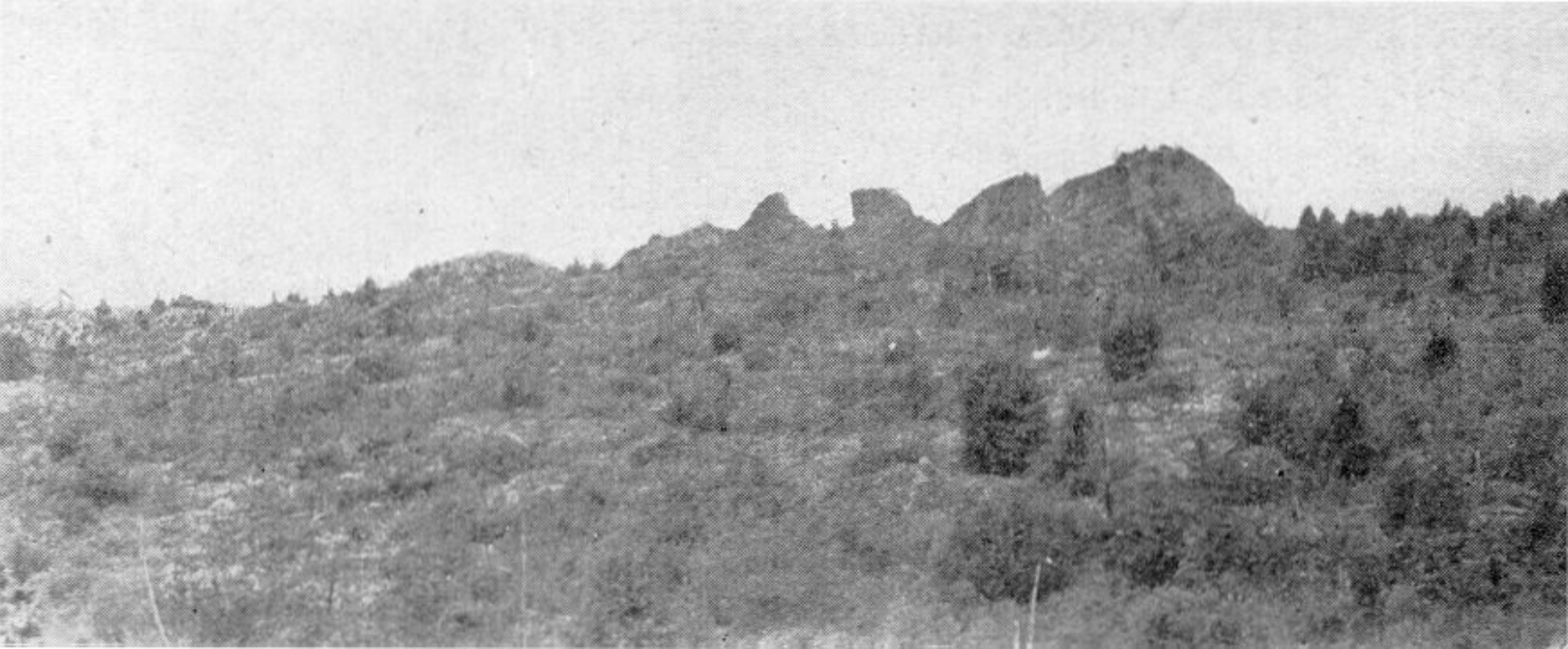




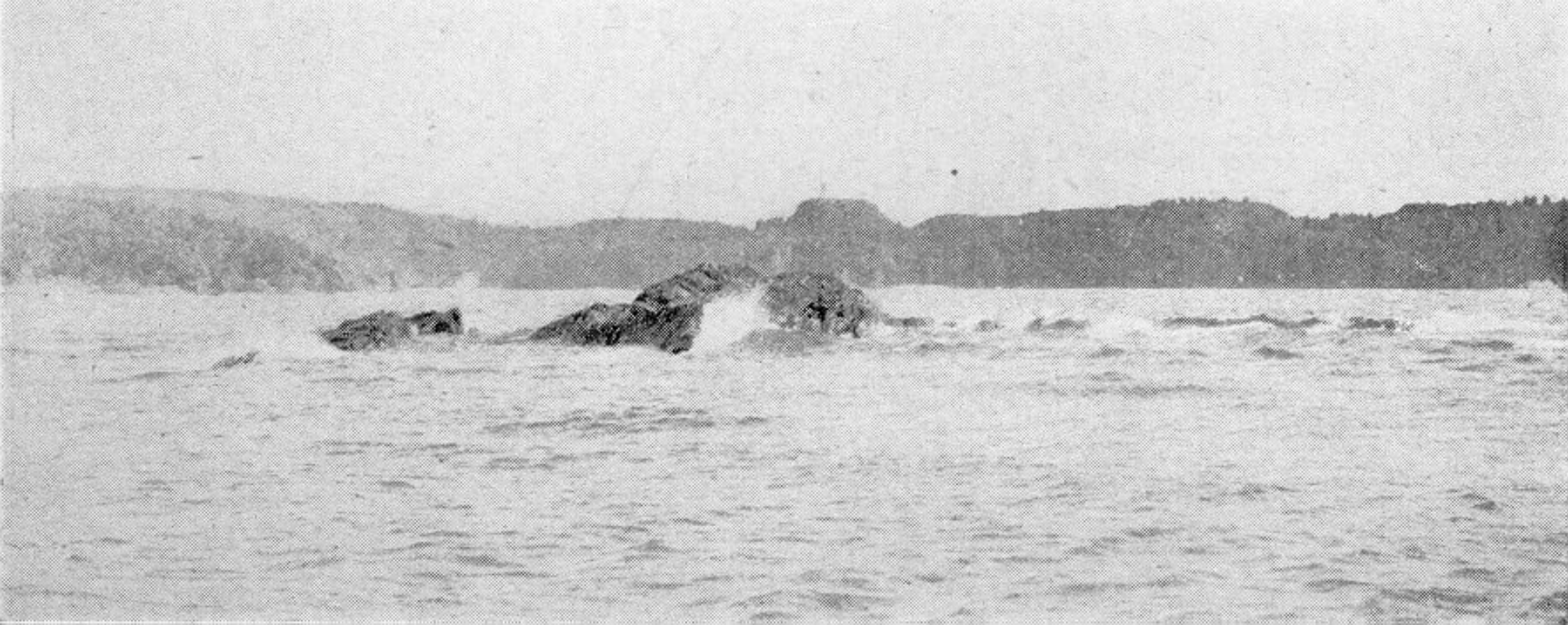


















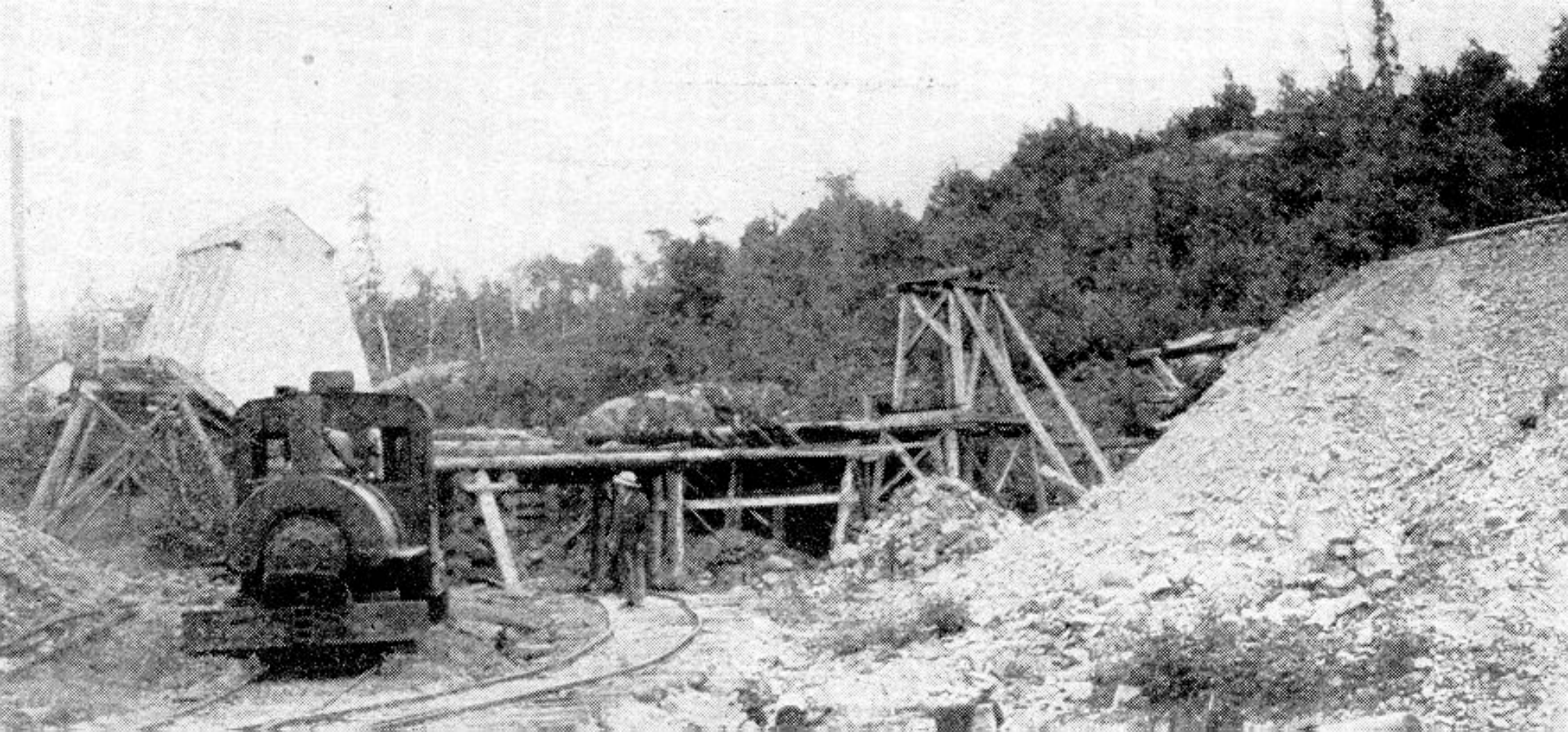




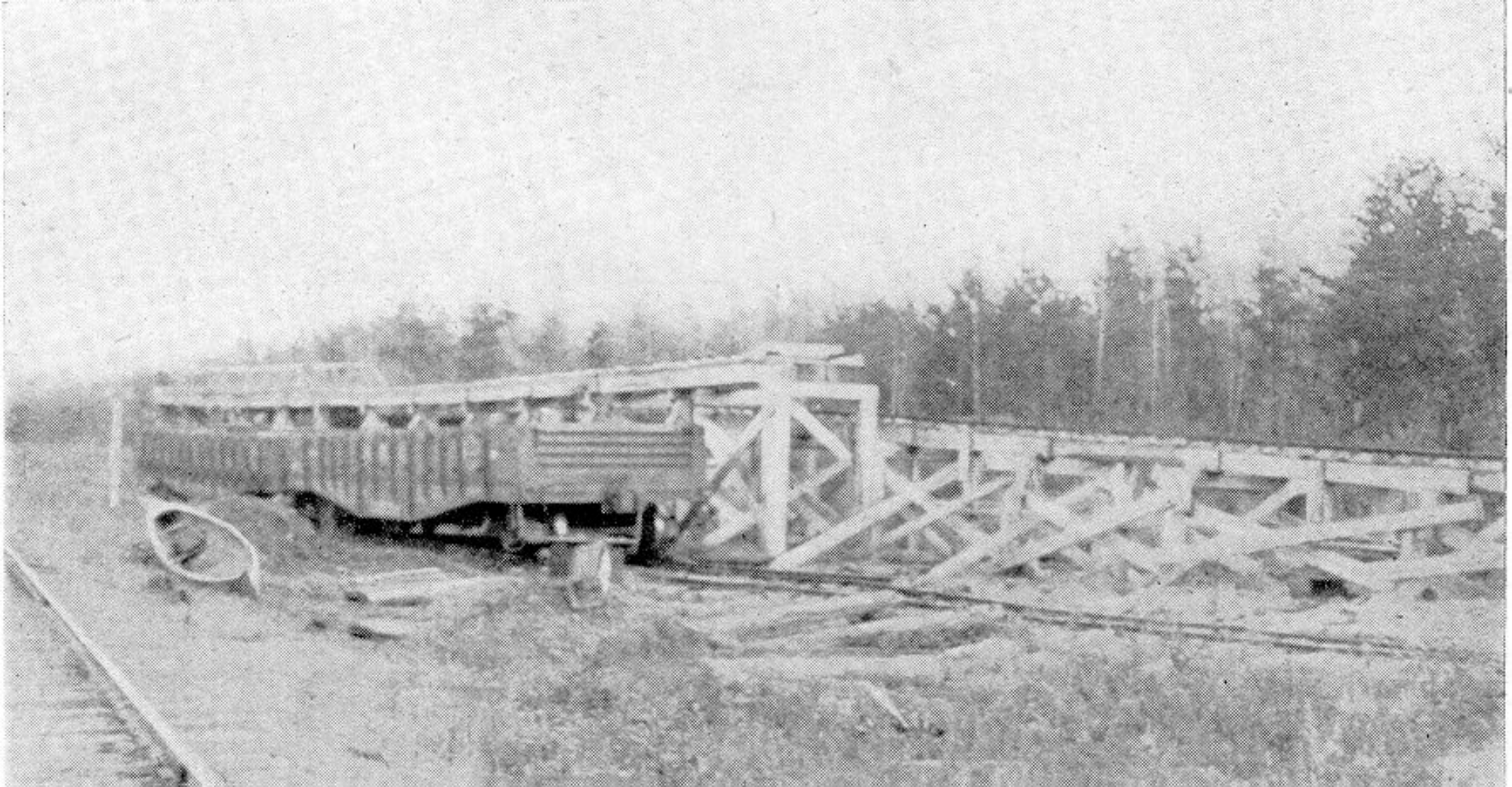
















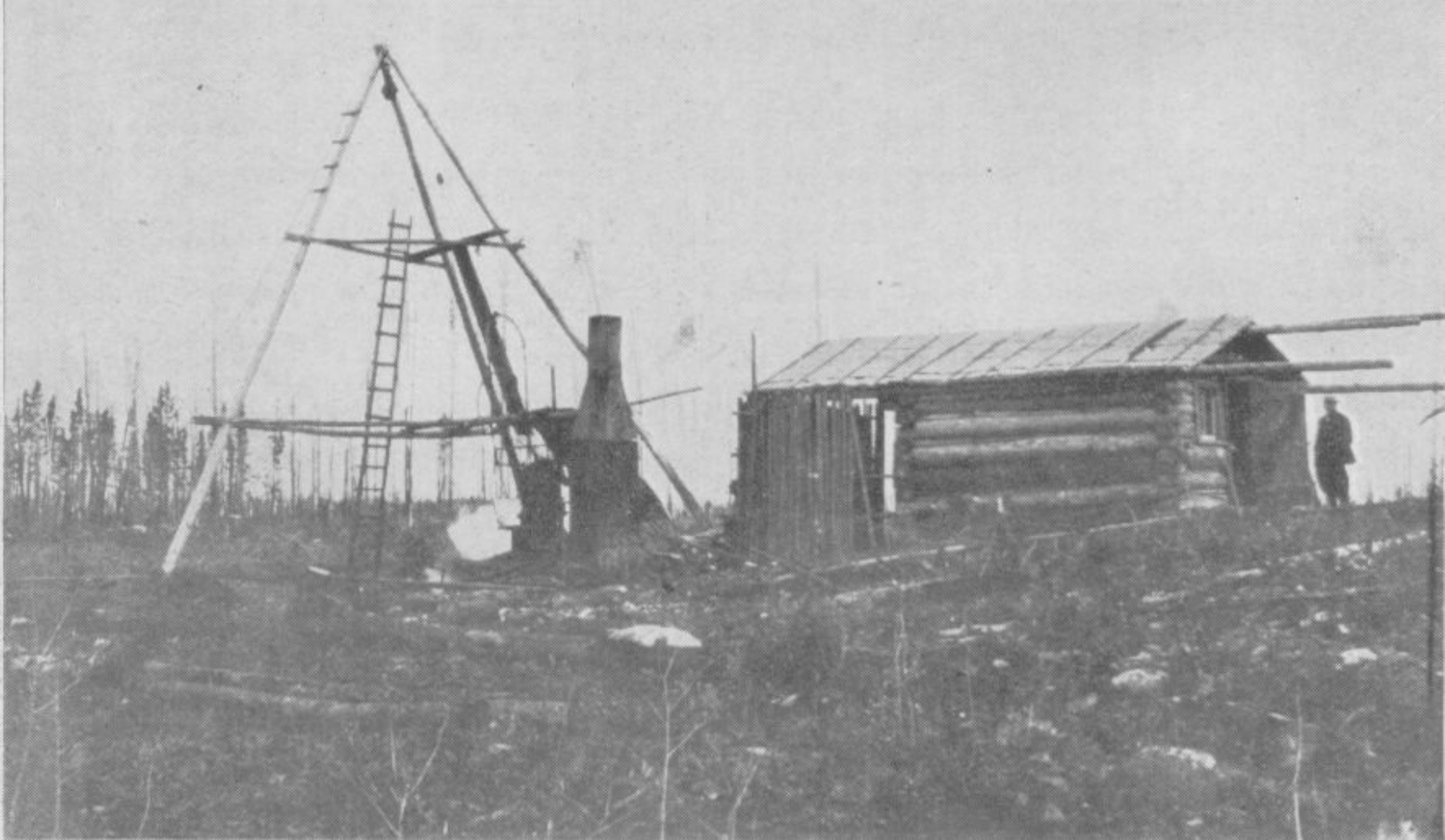












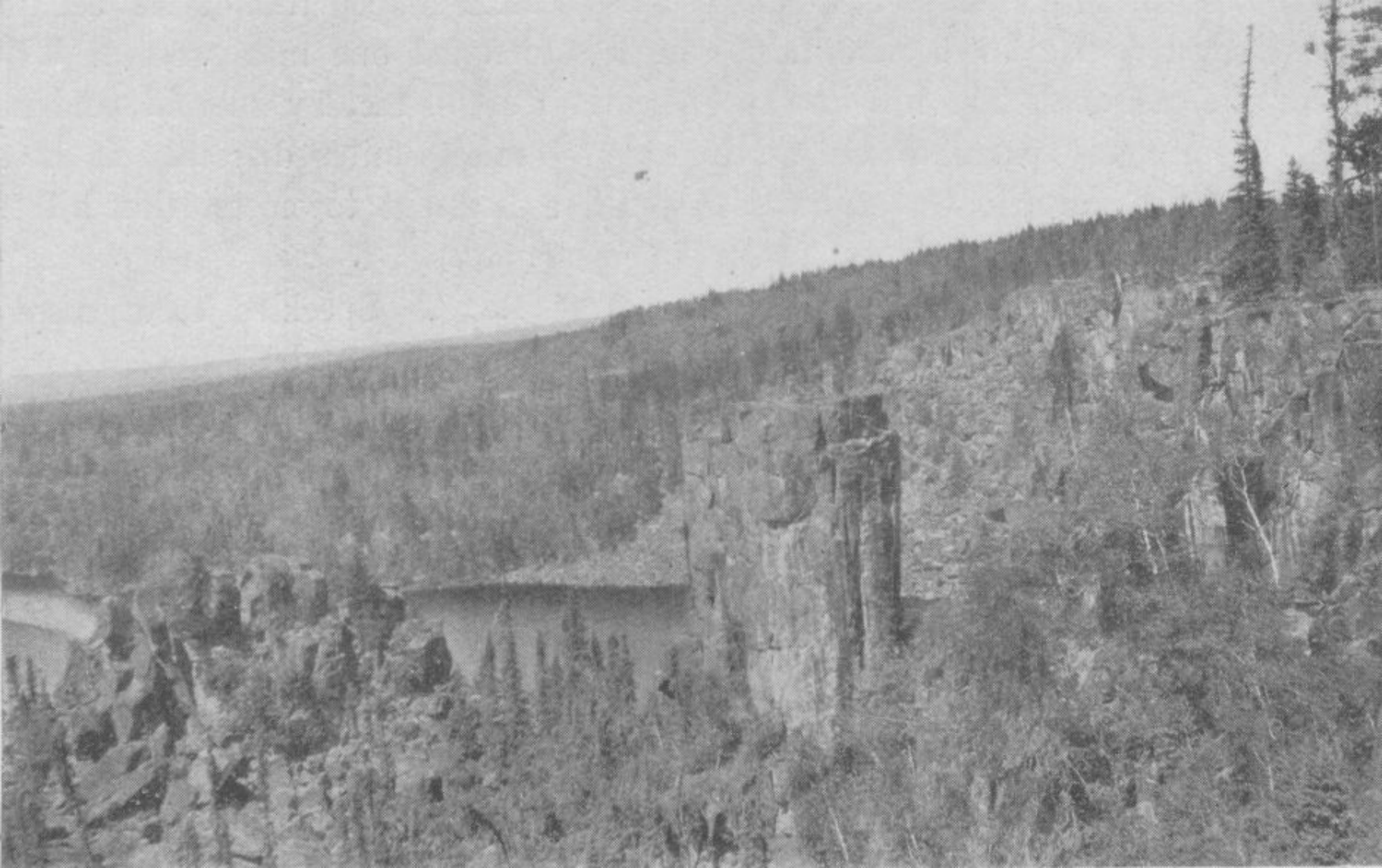


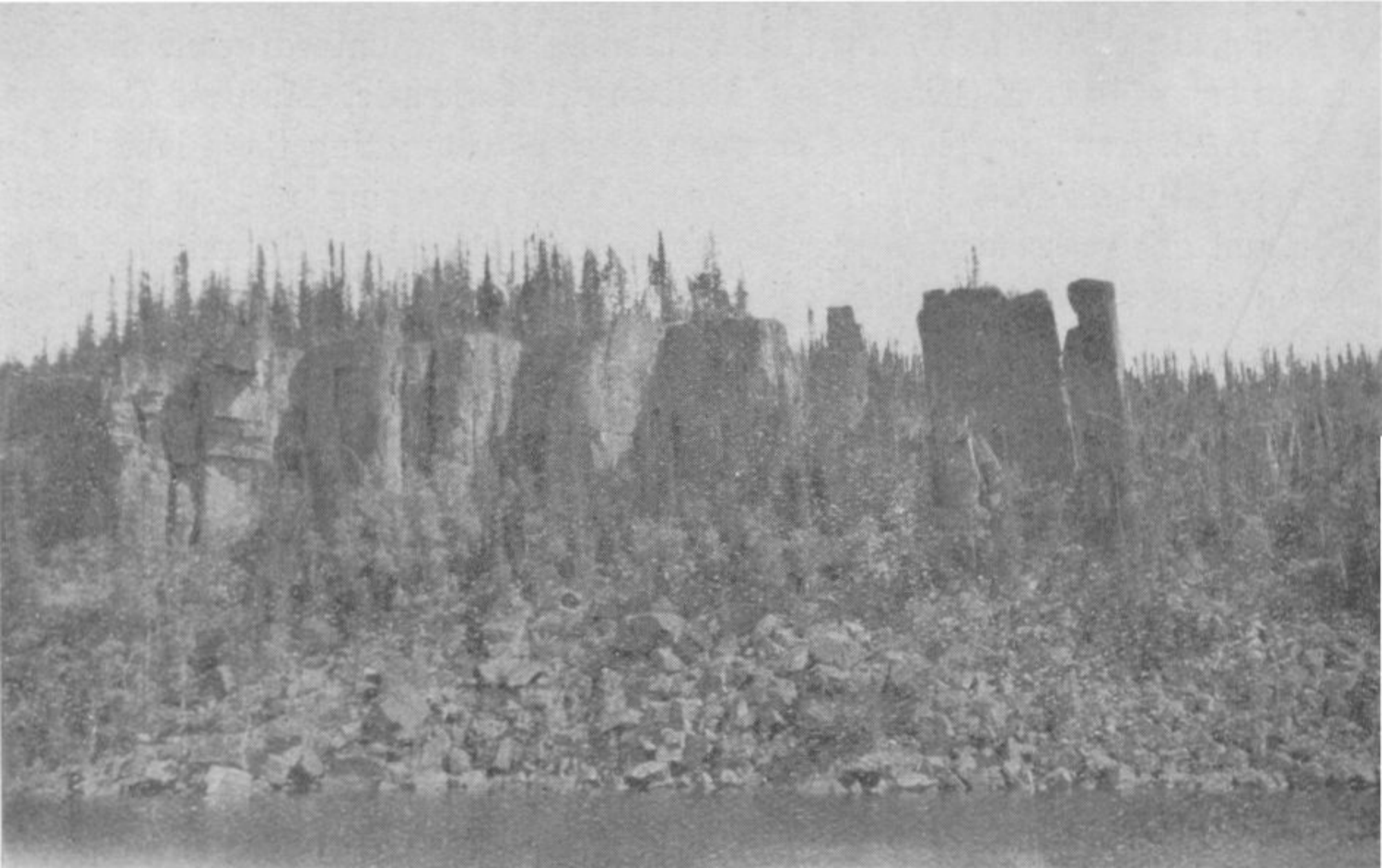






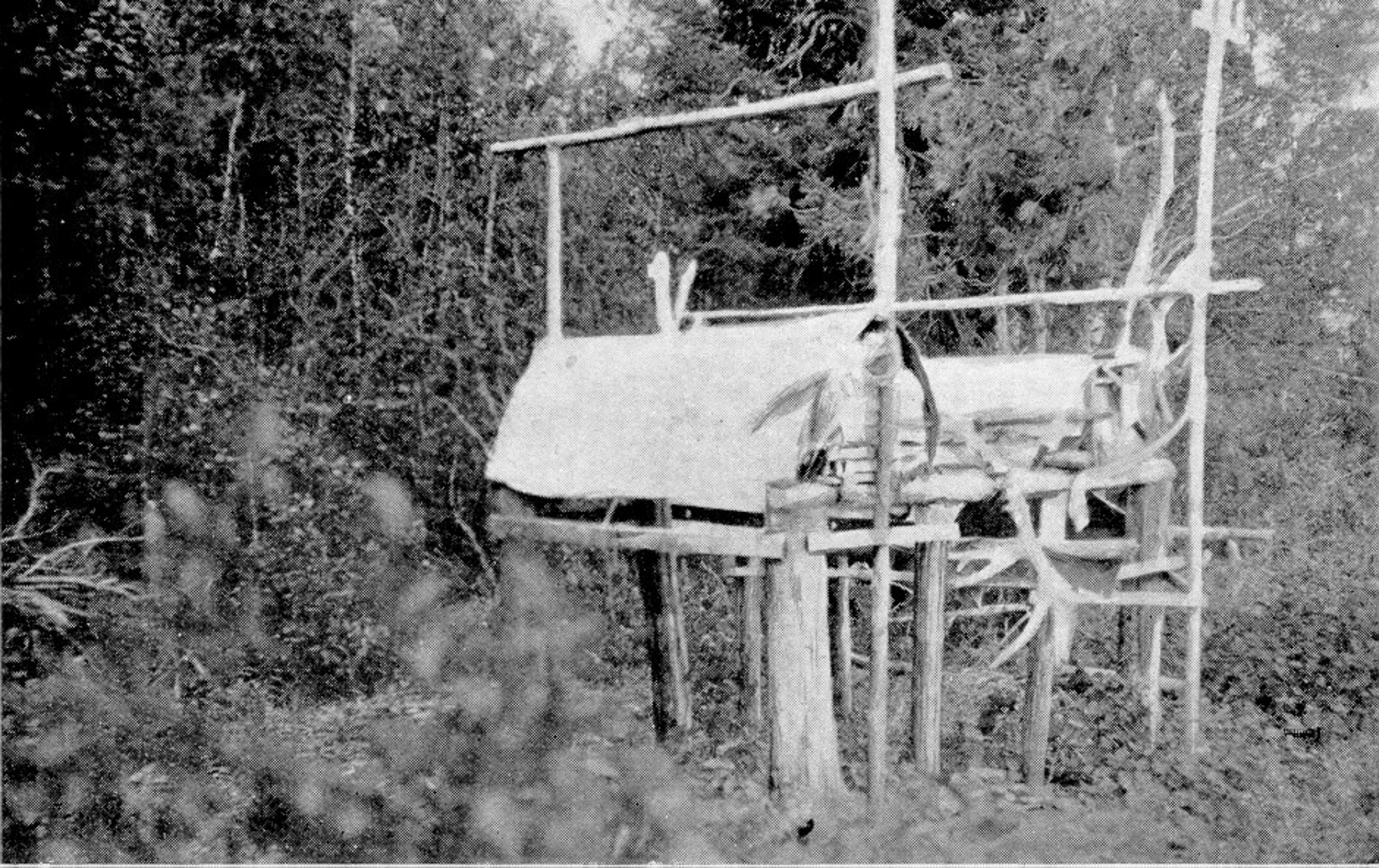














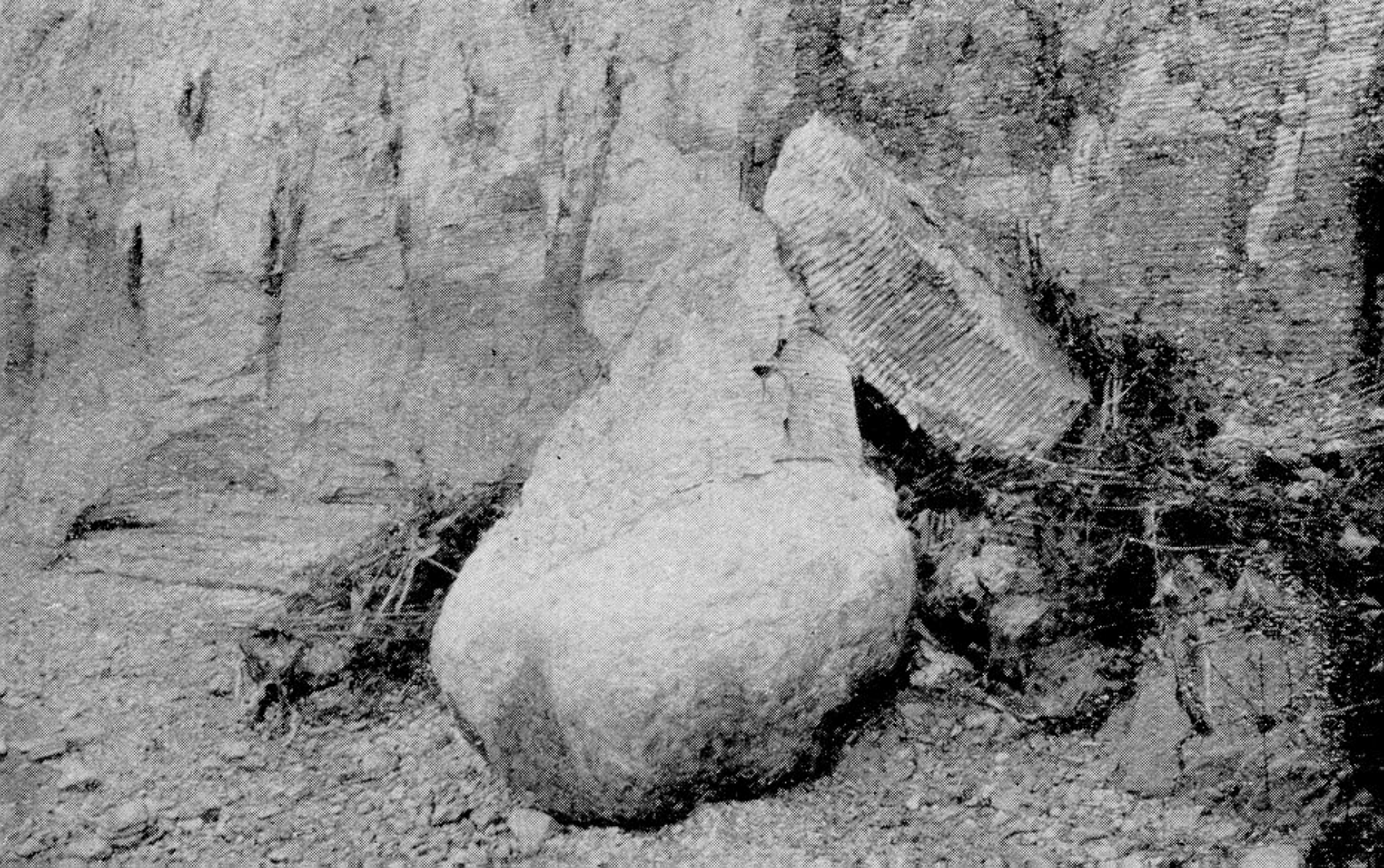


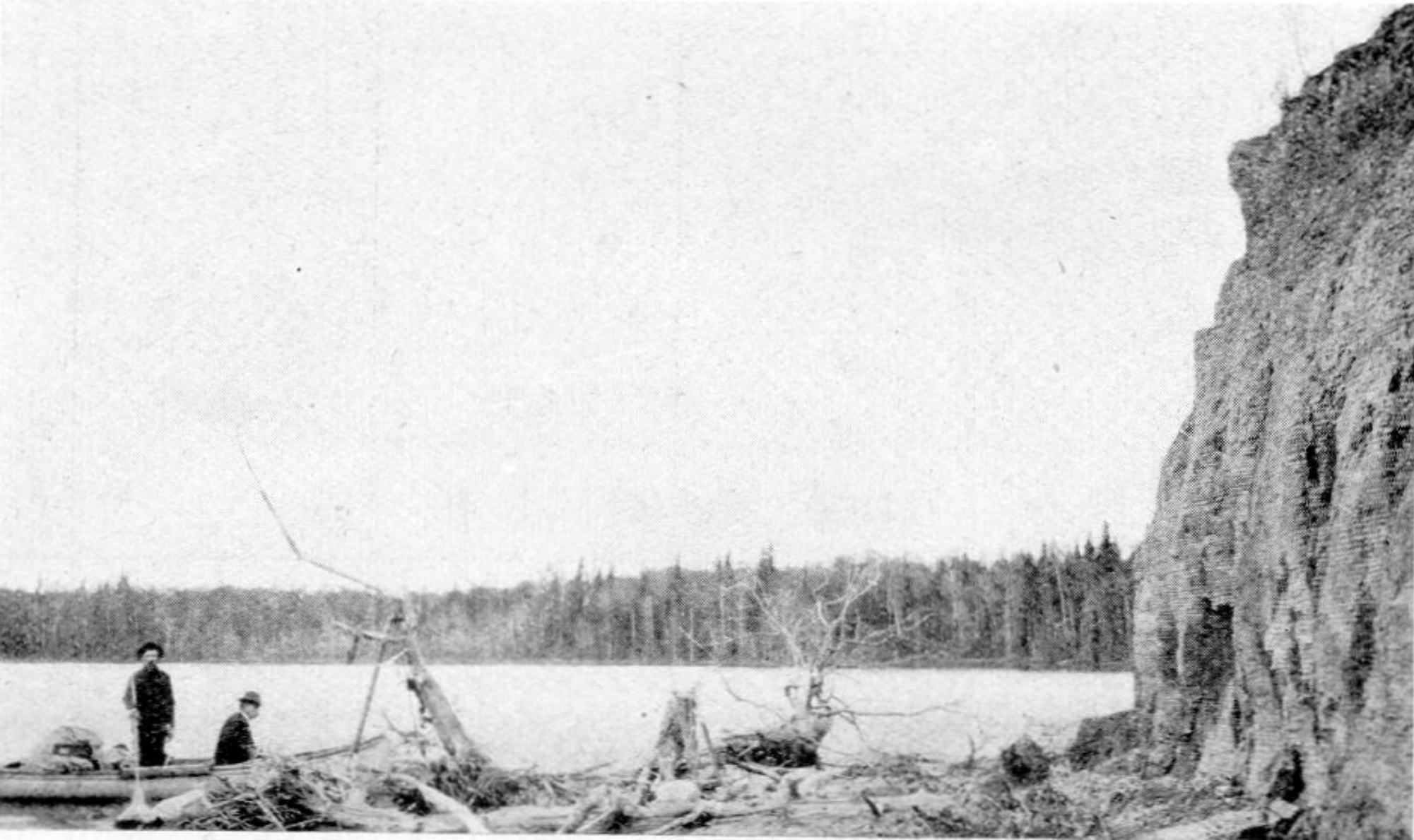


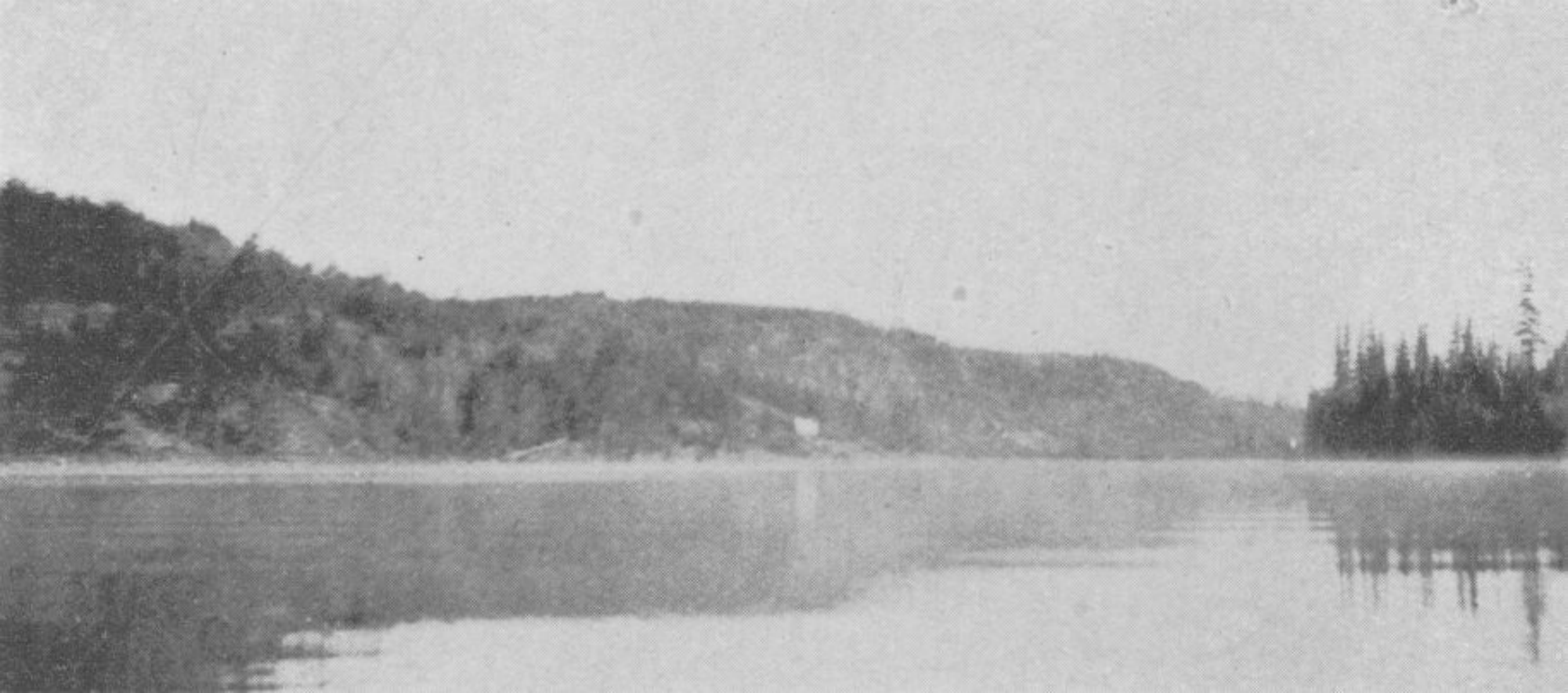


















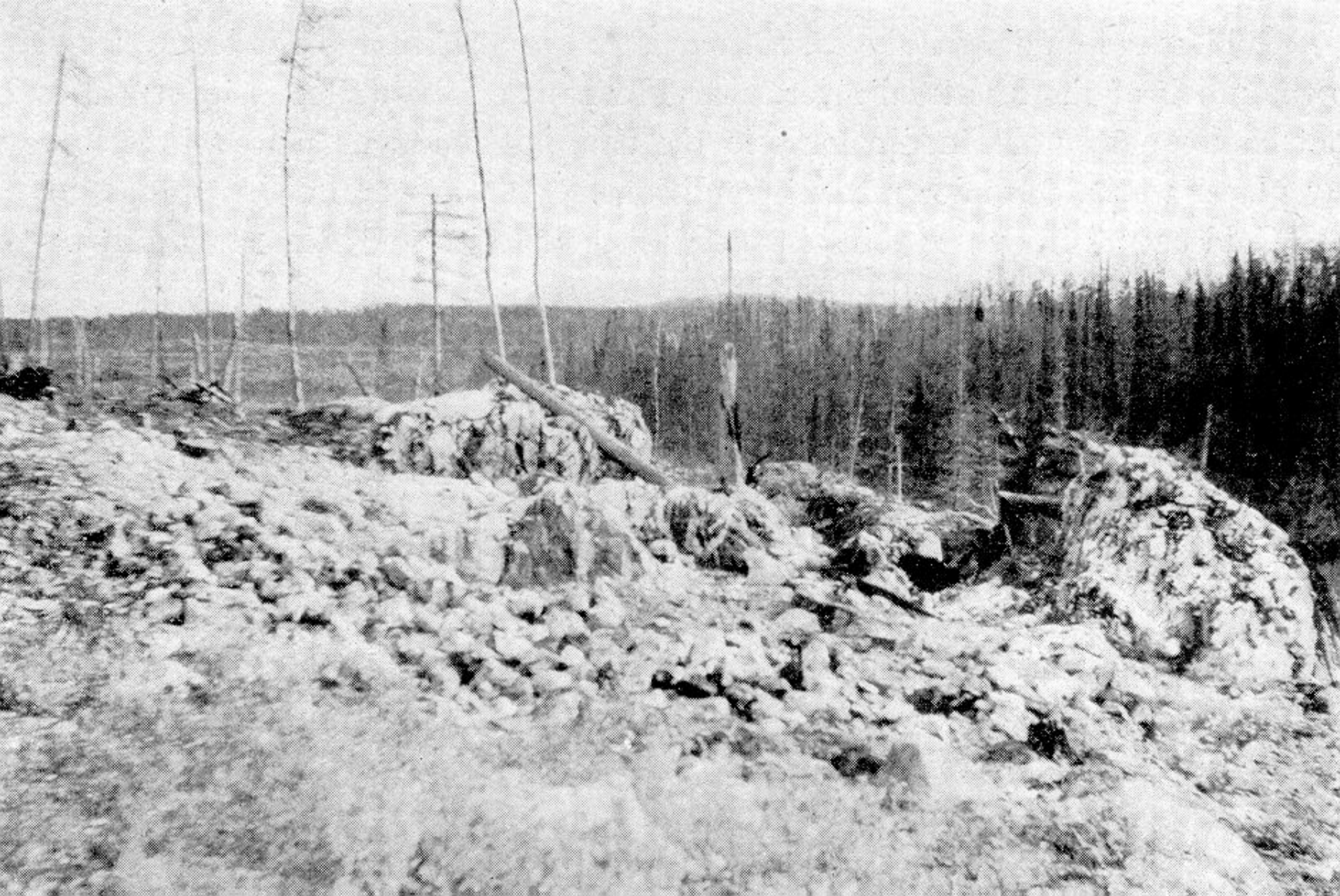








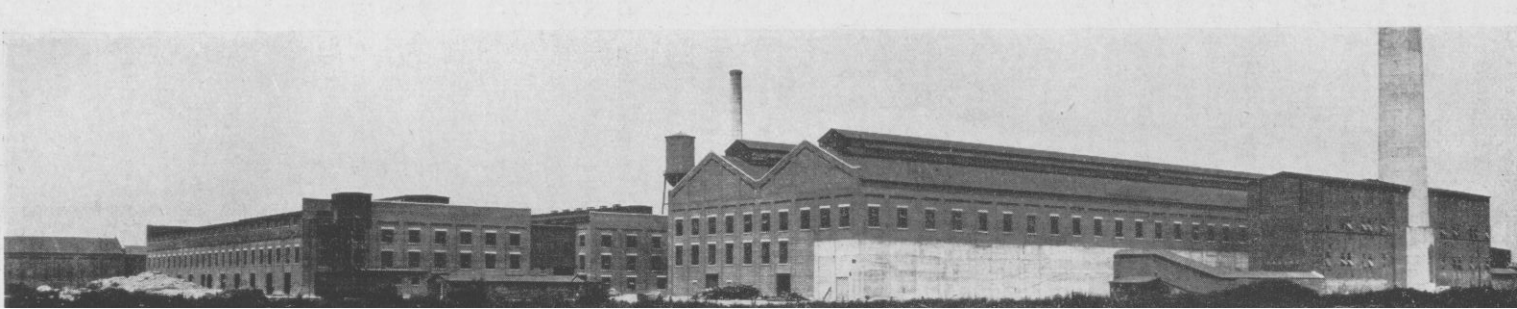




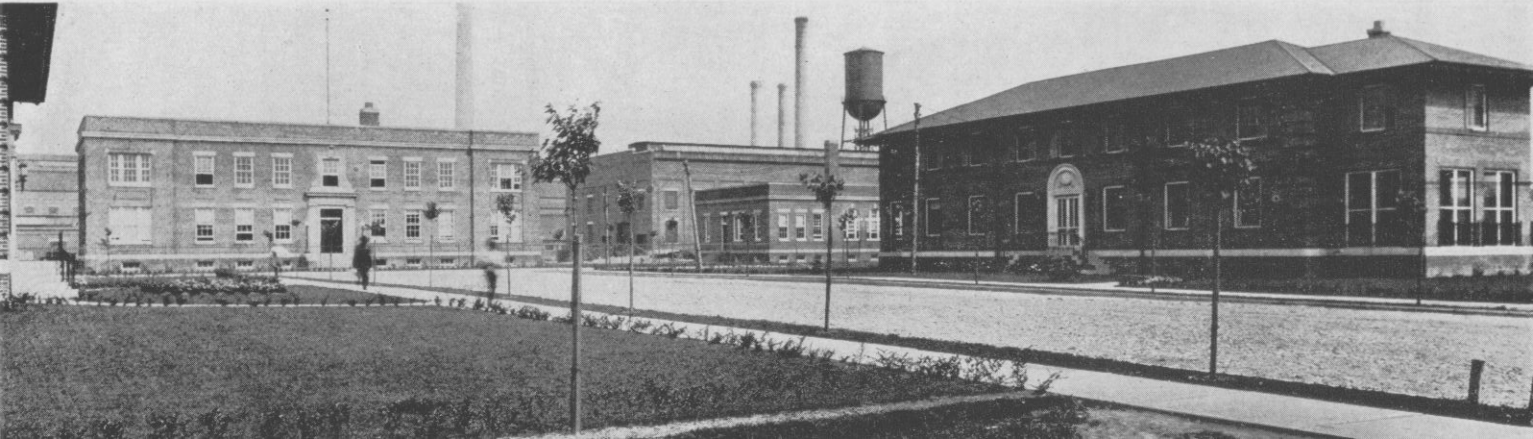


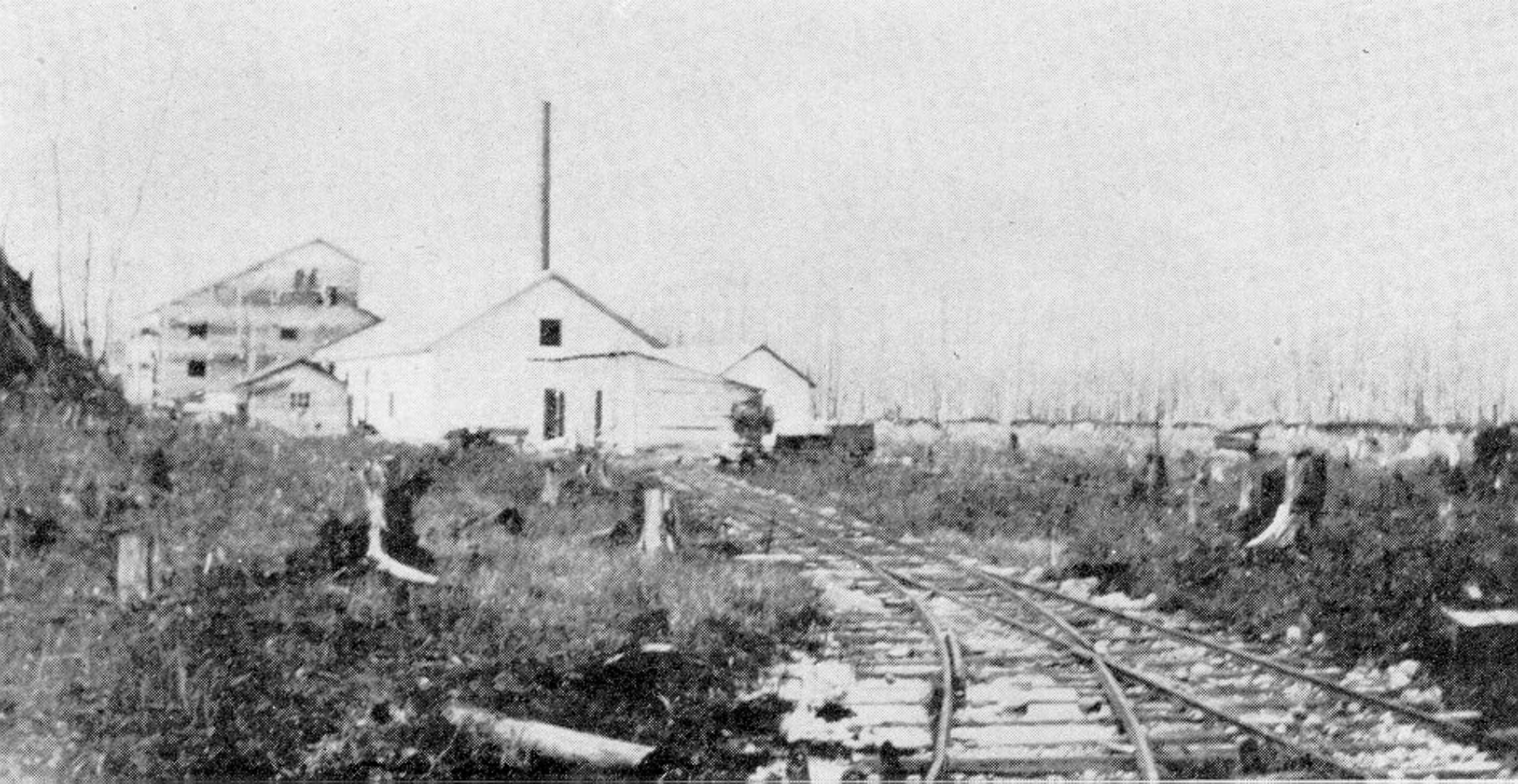


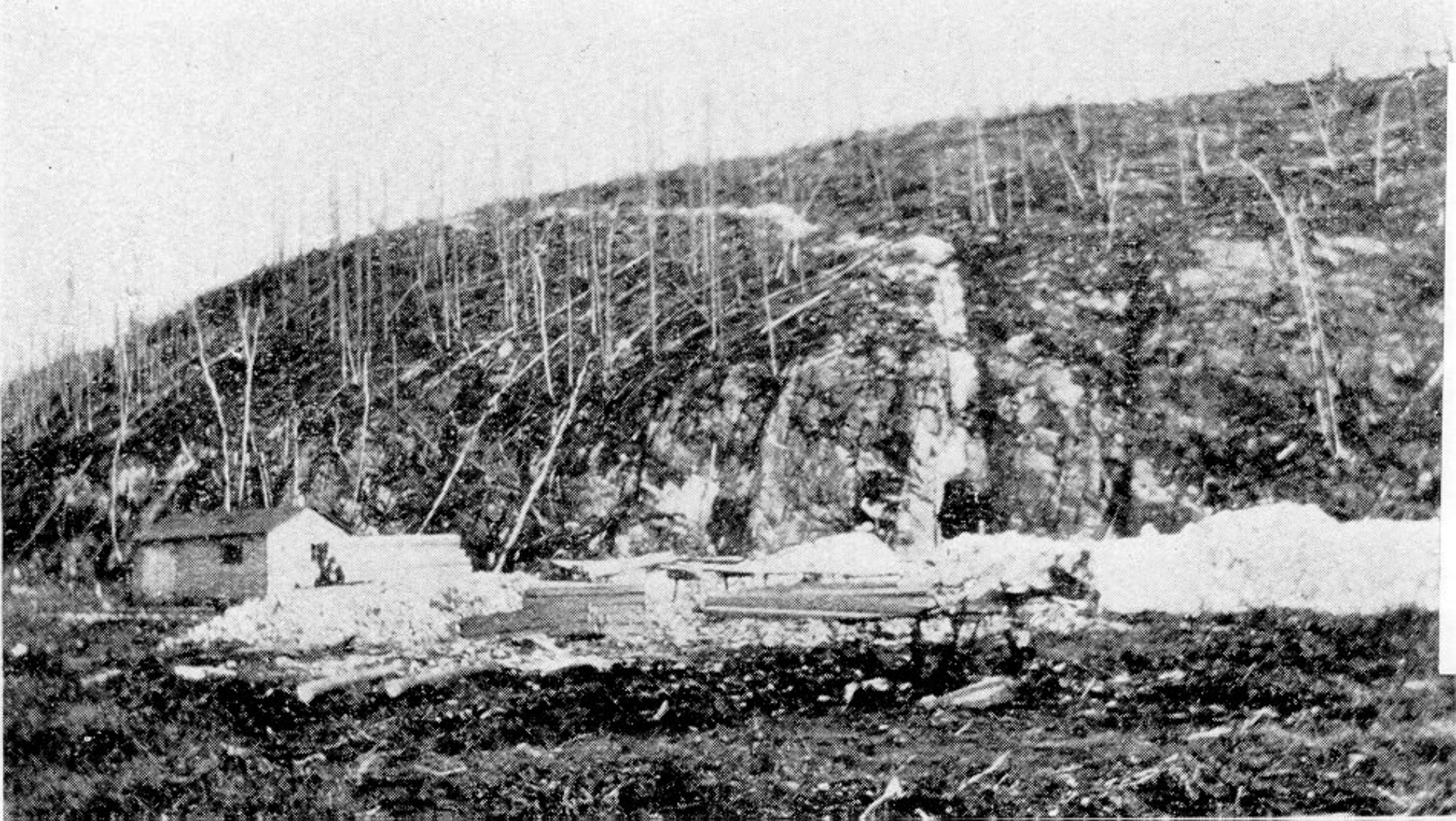




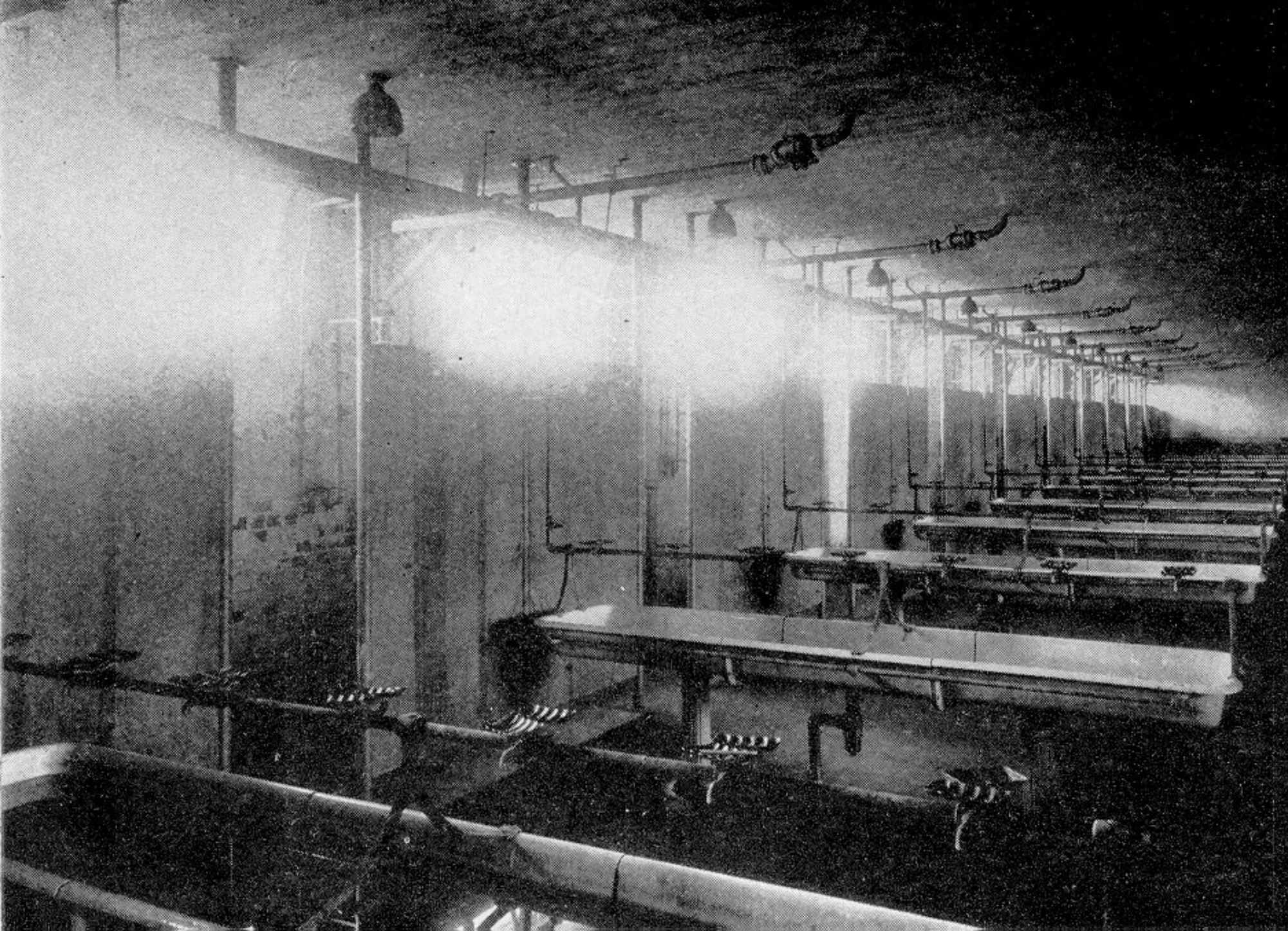
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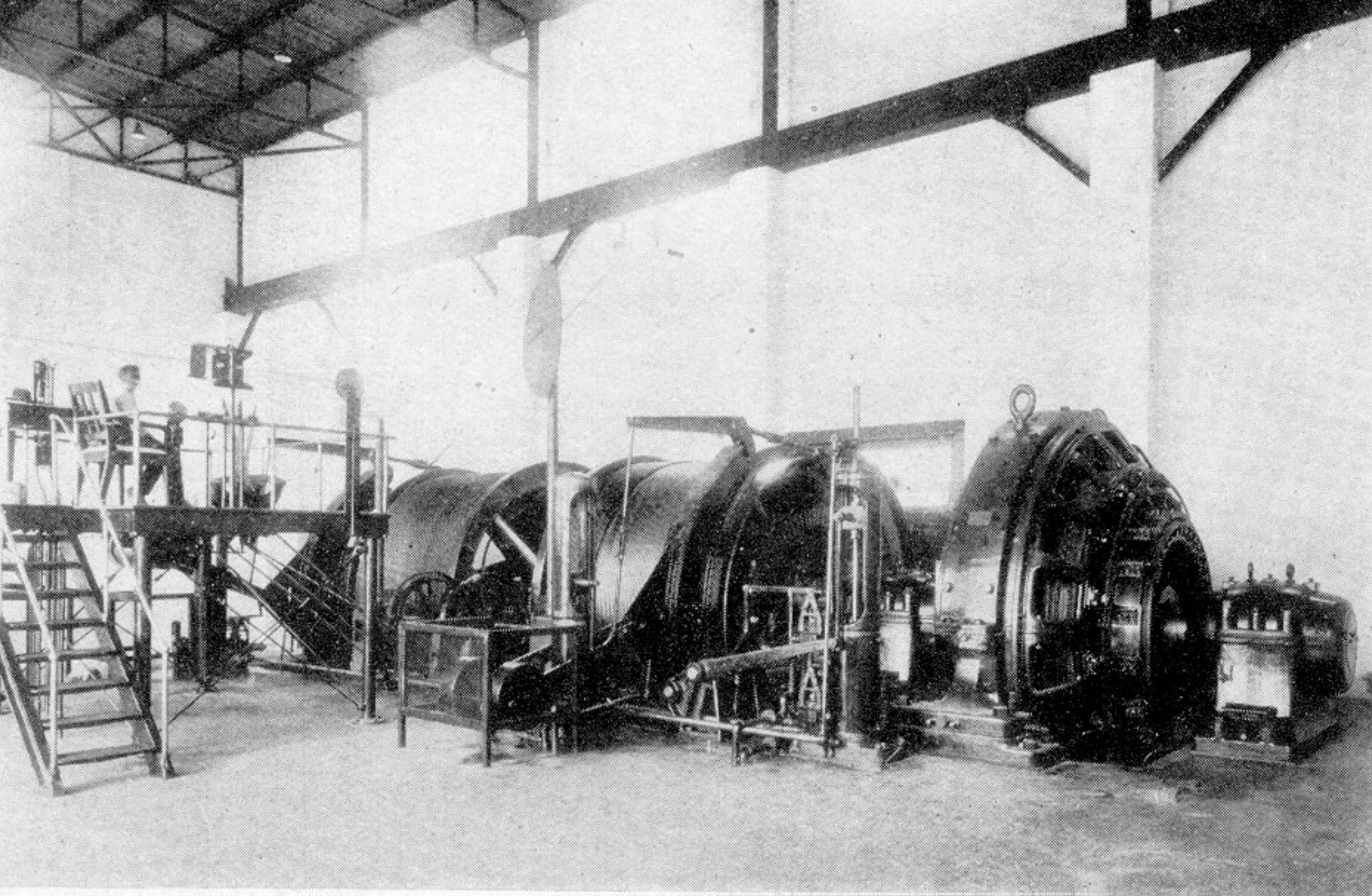


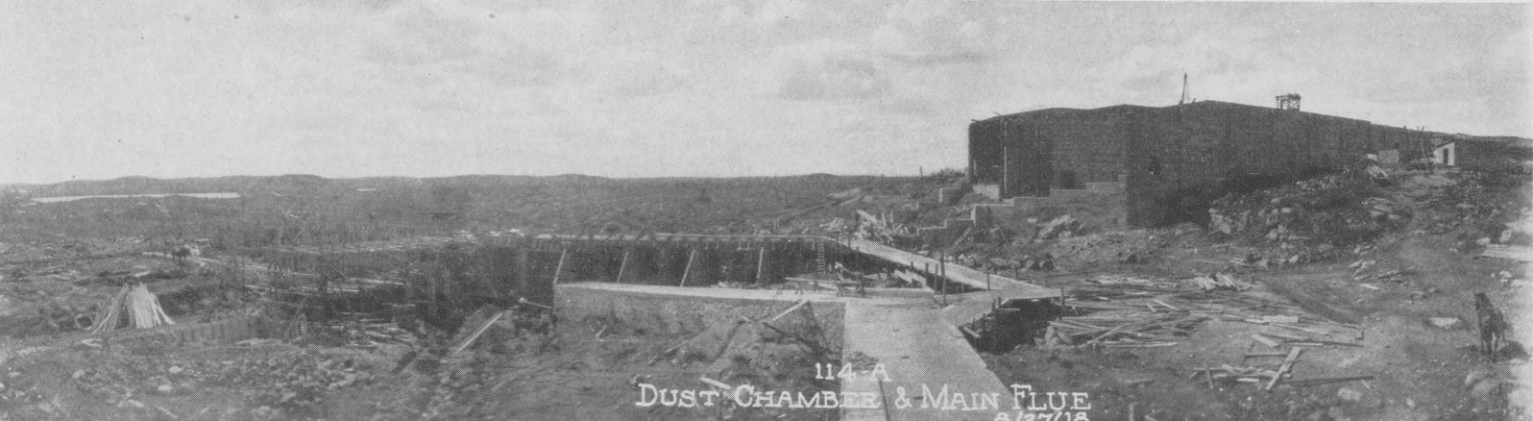






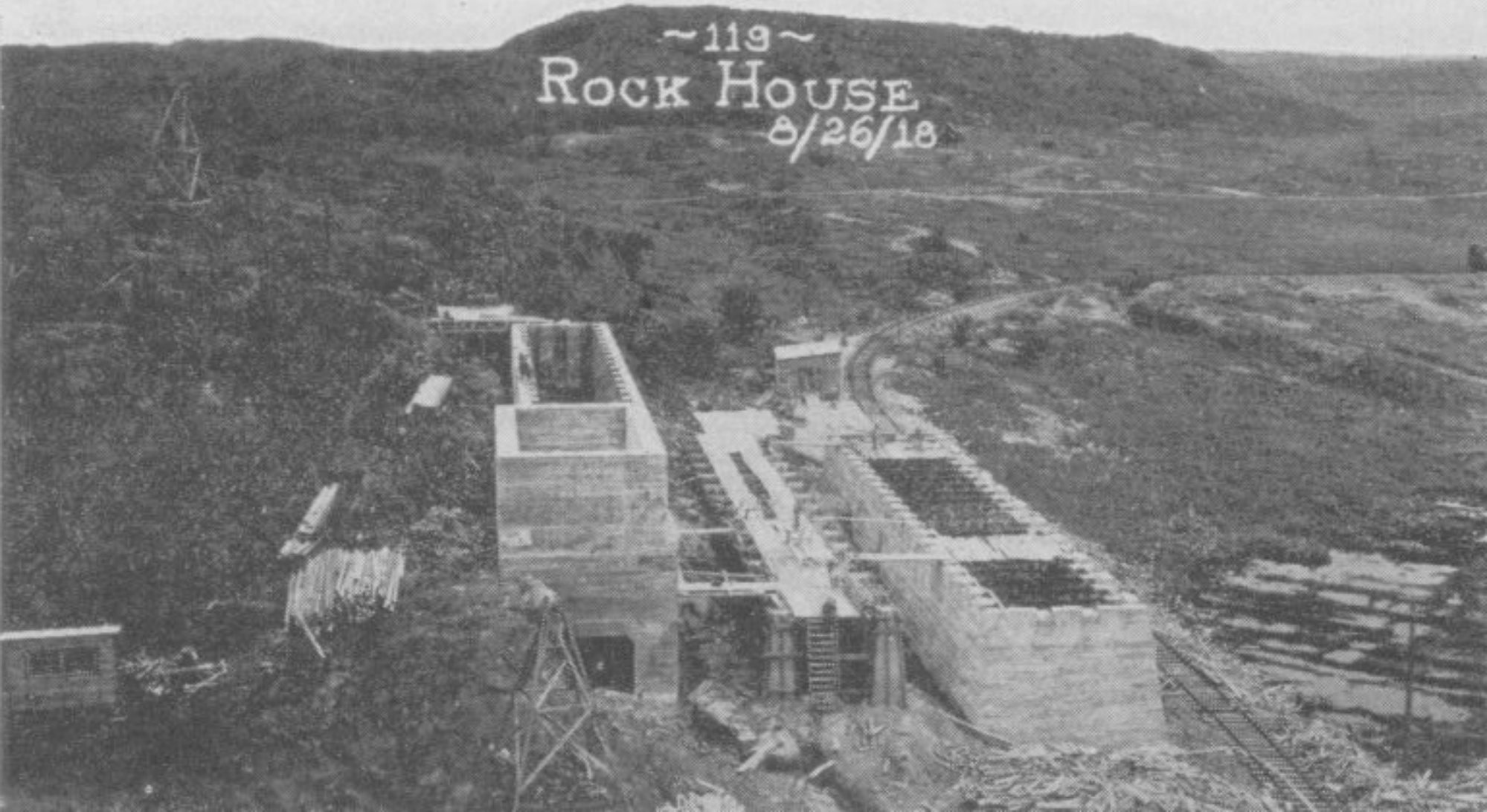


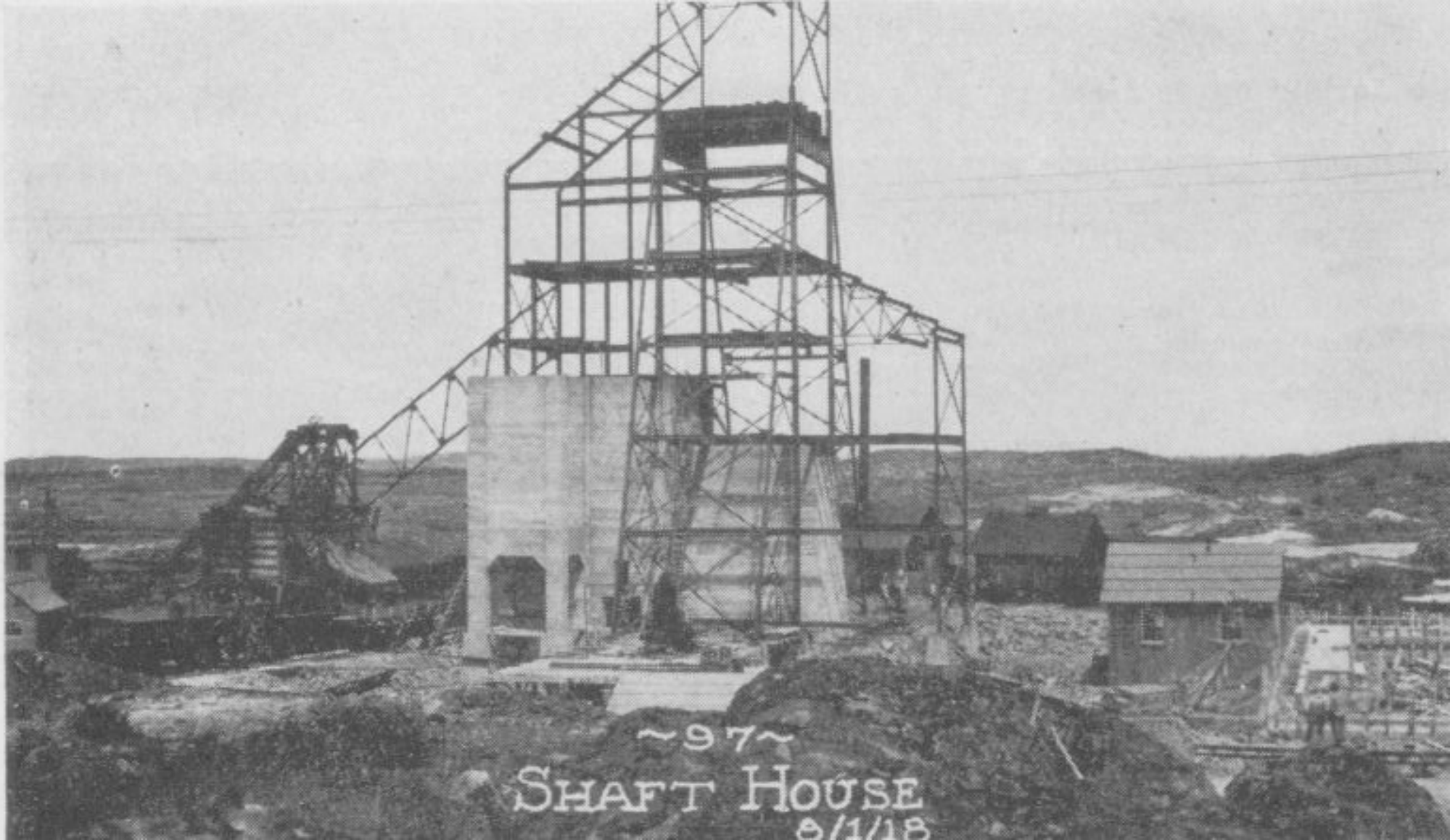


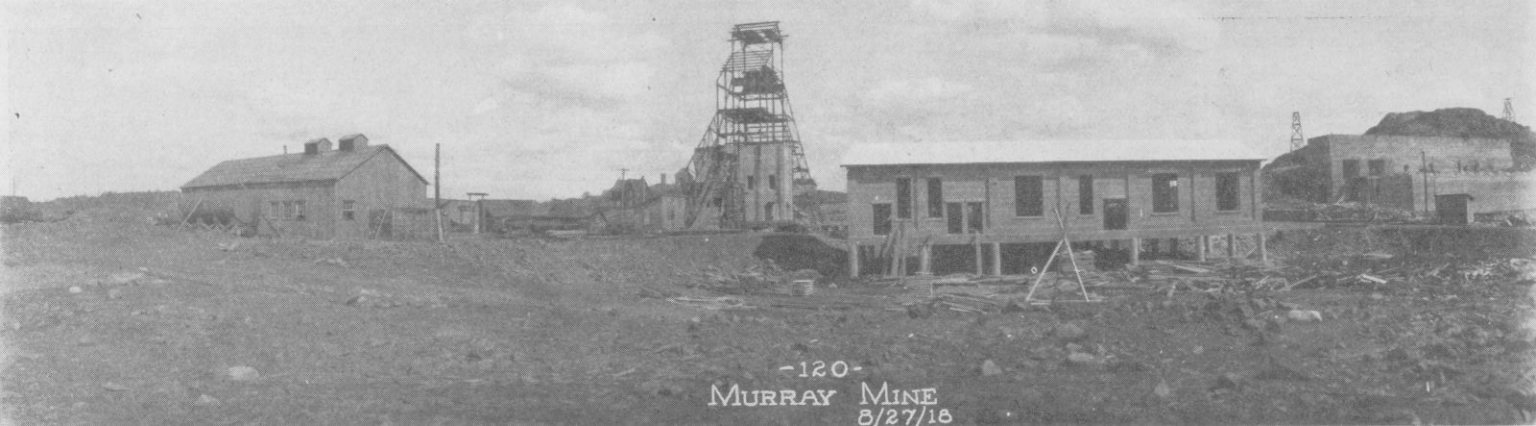


114-A
DUST CHAMBER & MAIN FLUE


~111 B~
B.A.N.C. SMELTER SITE
8/26/18


ROCK HOUSE
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~97~
SHAFT HOUSE
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MURRAY MINE
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REPORT

OF THE

Ontario Bureau of Mines, 1918

BEING

VOL. XXVII, PART II

SAND AND GRAVEL IN ONTARIO

By

A. LEDOUX

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MAP

Map No. 27b—Sand and Gravel producing areas in Southern Ontario ..... *facing* 18

SAND AND GRAVEL IN ONTARIO

By A. Ledoux

Sand and gravel deposits are very numerous in the southern and eastern parts of Ontario. The author visited the most important of these during the summer of 1917. The region examined was practically the whole area of the Paleozoic formations in southern Ontario. Manitoulin Island was not visited; on the other hand, some small parts of the pre-Cambrian belt in the counties of Leeds and Frontenac and district of Muskoka were examined. In each county several of the typical deposits have been chosen and are described with regard to their geological conditions of occurrence and their economic value.

Scope of the Report

The report begins with a review of the characteristic properties of sand and gravel, and the methods of testing applied; these properties have been divided into morphological, physical and chemical. The following chapter deals with the origin and occurrence of these fragmental rocks. Such considerations are sometimes of practical interest, as there may be a close relation between the geological origin and the qualities of sand or gravel. In numerous cases continuous lines of deposits, marking ancient lake shores, may be followed in southern Ontario. On the shores of existing lakes, certain parts are marked by extensive beaches containing abundant reserves of good building material. Attention is also directed to some artificial sands made by crushing soft sandstones, suitable for special purposes such as glass-making and iron-smelting. Several deposits of this kind are worked in Ontario.

The classification of sands and gravels is practically based upon their several uses. The principal use is in connection with building industries. Sand and gravel for construction purposes are cheap, and yield only small profits per yard or ton. Other varieties, such as moulding sand and glass sand, are of greater value, but although these materials are found in the Province, they are ordinarily imported into Ontario.

Compared with most mineral products, the selling price of sand and gravel is very low, and the margin of profit depends upon skilful and economical operation. The small operator frequently produces for a time at low cost, but by unsystematic methods destroys the value of his reserves. The larger operators should pay particular attention to the introduction of labour-saving appliances.

The last chapter deals with the distribution of sand and gravel in southern Ontario. The several counties have been arranged alphabetically; the location of every described deposit has been indicated as far as possible, by its township, concession and lot. The most important sand and gravel producing areas are shown on a general map of southern Ontario (No. 27*b*) accompanying this report.

This report should be considered as only a preliminary one. Deposits in more than forty different counties were visited during four months of field work, thus allowing only a very short time for detailed examination of any deposit. Numerous granular metric analyses and physical tests of samples have

been made; it would be desirable to make a larger number of these tests, accompanied by chemical analyses and tests of mortars and concretes made from the materials.

The writer desires to express his thanks to Prof. T. L. Walker and Prof. A. L. Parsons, of the Mineralogical Department of Toronto University, for assistance in the preparation and correction of this work. He also wishes to acknowledge his indebtedness to Prof. A. P. Coleman of the Geological Department, and to Prof. H. E. T. Haultain and R. F. C. Dyer of the Mining Department of the same institution, for valuable advice and the use of their laboratories.

Most of the experimental investigations were made at the Mineralogical Department of Toronto University.

The chemical analyses were made by the Provincial Assayer, W. K. McNeill and his assistant, T. E. Rothwell. Sketch maps illustrating the report were prepared for reproduction by W. J. Bell, Bureau of Mines Cartographer.

Statistical information has been kindly given by various city and county engineers, municipal officials and by pit owners. The writer would express to all his appreciation.

Properties of Sand and Gravel

Sand and gravel belong to the category of unconsolidated clastic rocks. The component fragments vary widely in size, some passing the 200-mesh sieve, others being more than one foot in diameter. Small grains and large fragments may be associated in the same sample. There is no natural limit between sand and gravel; for practical use, we call sand a material made of grains passing the ¼-inch screen, and gravel a material made of fragments retained on the ¼-inch screen; boulders are fragments larger than three inches in diameter.

Morphological Properties

Size.—The size of the component fragments of a clastic rock affects a certain number of its physical properties, such as specific gravity, absorption, and permeability. With regard to size, sands are ordinarily divided into fine, medium and coarse varieties, gravels into fine gravel, pea gravel and coarse gravel.

The classification of a sand or gravel is often made at sight, but more accurately by using sieves. A sieve is defined by the number of holes or meshes per linear inch; for instance, a 100-mesh sieve has 100 holes to the linear inch. A sieve may also be defined by the smallest linear dimension or *rating* of the hole, a ¼-inch sieve having holes of ¼-inch as their smallest dimension. This last method may be applied to screens with holes larger than one inch. It should be noted that there is a great difference between a 4-mesh sieve and a ¼-inch sieve, depending upon the diameter of the wire. If M represents the number of meshes to the linear inch, D the diameter of the wire in mm., the rating R is expressed in millimeters by the following equation:

$$R = \frac{25.4}{M} - D$$

The diameter D is most easily determined by means of a micrometer gauge or by microscopic measurement. The following table gives the number of meshes

to the linear inch, the diameter of the wire and the rating, for the series of sieves used in the accompanying metric analyses, except where otherwise stated:

Sieve	Diameter of wire	Rating	
Mesh	Mm.	Inches	Mm.
4	1.651	.185	4.699
8	.813	.093	2,362
10	.889	.065	1.651
20	.437	.0328	.833
28	.318	.0232	.589
48	.234	.0116	.295
80	.1425	.0069	.175
100	.1070	.0058	.147
200	.0530	.0029	.074

In some sands and gravels, the component fragments are of uniform size; in others they vary widely. This can be tested by granular metric analysis. The principle of such an analysis consists in passing a given amount of the material, say 100 to 500 grams, through a series of sieves, and weighing the amount of the sample retained on each of them after sufficient shaking. The results are given in the percentage of the whole *remaining* or *retained* on each sieve. To express the degree of fineness by a single figure, the percentages passing each sieve are added and the total divided by the number of sieves used. The result is called the per cent. of fineness; if the same set of sieves is used this figure may be used for comparing different sands and gravels. The following table gives the results of the granular metric analyses, and shows the difference in the per cent. of fineness between several grades of sand and gravel:

Sieve	A Fine Sand		B Medium Sand		C Coarse Sand		D Fine Gravel		E Coarse Gravel	
Mesh	Ret.	Pass.	Ret.	Pass.	Ret.	Pass.	Ret.	Pass.	Ret.	Pass.
4	0.0	100.00	0.30	99.70	32.85	67.15	49.80	50.20	80.00	20.00
8	0.0	100.00	3.10	96.90	39.20	60.80	63.85	36.15	83.40	16.60
10	0.0	100.00	6.40	93.60	42.50	57.50	69.50	35.50	84.65	15.35
20	0.0	100.00	16.80	83.20	54.10	45.90	79.10	20.90	87.00	13.00
28	tr.	100.00	25.70	74.30	69.30	30.70	85.55	14.45	89.45	10.55
48	1.25	98.75	60.00	40.00	93.85	6.15	94.45	5.55	98.65	1.35
80	2.00	98.00	93.25	6.75	97.95	2.05	97.55	2.45	99.80	0.20
100	5.70	94.30	98.40	1.60	98.75	1.25	98.55	1.45	100.00	0.00
200	41.50	58.50	99.15	0.85	99.60	0.40	99.30	0.70	100.00	0.00
Total		849.55		496.90		271.90		162.35		77.05
Per cent. of fineness		94.39		55.21		30.21		18.04		8.56

A: Silty sand, very fine. Camp Borden (Simcoe county).

B: Medium sand, Landshore Sand and Gravel Co. (Ontario county).

C: Coarse sand, Markus pit, Pembroke (Renfrew county).

D: Fine gravel, J. Creeper pit, Belleville (Hastings county).

E: Coarse gravel, Bray pit, Port Hope (Durham county).

The results of granular metric analysis may be represented by diagrams, taking as abscissae the ratings of the different sieves and as ordinates the percentage of material remaining on each of them. Joining the different points (fig. 1) we obtain a graphic representation of the granular metric analysis.

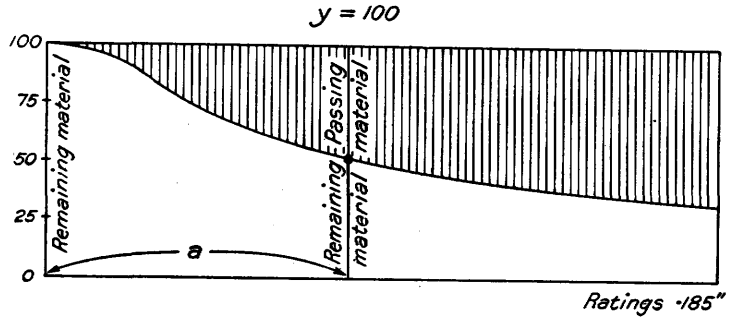


Fig. 1—Diagram of granular metric analysis. The shaded area is proportional to the fineness of the material.

On an ordinate X=a, the length measured between the curve and the axis of the abscissae indicates the percentage of material remaining on a sieve of a rating equal to *A;* the length measured between the curve and the line y=100 represents the percentage of material passing through the same sieve. The area comprised between the curve and the line y=100 is proportional to the fineness

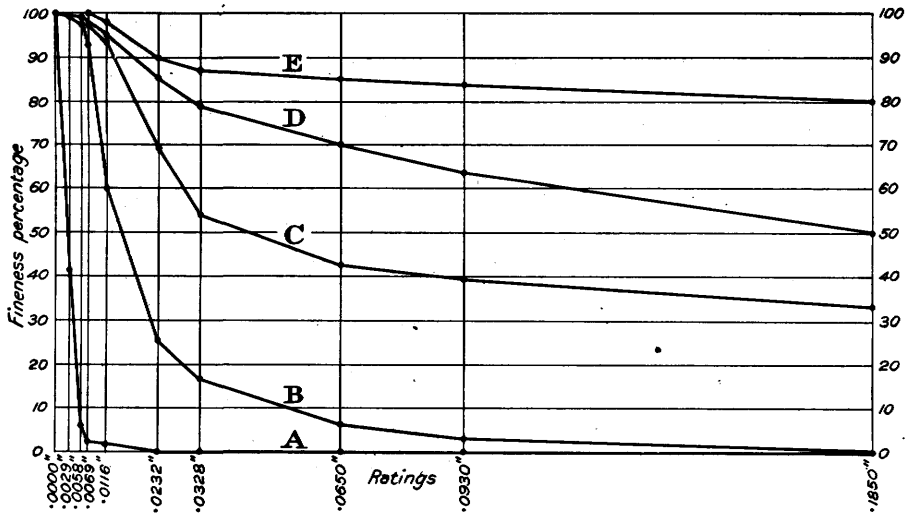


Fig. 2—Diagram of granular metric analyses of five different sands and gravels of various percentages of fineness.

of the material; for fine sand this area is large, it is smaller for medium sand, and becomes very small for coarse gravel. This system of geometrical representation (fig. 2) has been applied to the five granular metric analyses given above. All the curves start from the point 100 on the axis of the ordinates; their general shape is parabolic except near the axis of the ordinate, where there is an inversion point on the curves.

The maximum difference between the quantities of material remaining on two alternate sieves such as 4 and 10, 8 and 20, 48 and 100, etc., is a measure of the uniformity of the clastic material. This difference is called the *coefficient of uniformity.* The number of the intermediate sieve in our scale of sieves represents the *grade* of the tested material.

Shape.—The shape of the component fragments is also variable in character. In sands the grains are rounded or angular. If the latter shape is quite common to all the grains, they constitute a sharp sand, much appreciated for building purposes. The difference between a sharp and a rounded sand can be tested under the microscope; it can also be easily ascertained by rolling the grains between the tips of the fingers. For gravels a similar distinction may be established: the component pebbles are spherical, elliptical, flat, disc-like or angular: hence such terms as round gravel and sharp gravel.

Physical Properties

The following physical properties are of interest in the study of sand and gravel: Specific gravity, Percentage of voids, Permeability, Absorption, Moisture, Percentage of silt, Cementing value, Bonding power.

Specific gravity.—The specific gravity of a sand or gravel may be considered in two different ways. The *apparent* specific gravity of a sand or gravel is the weight of a certain volume of the material, divided by the weight of an equal volume of water. The *real* specific gravity is, on the other hand, the average specific gravity of the fragments composing the material. The real specific gravity is always higher than the apparent specific gravity.

The apparent specific gravity is easily obtained by weighing a known volume of the sand or gravel and dividing the weight of the material by the weight of an equal volume of water. The material should be shaken down as much as possible in order to reduce the volume of voids to the minimum.

Determination of specific gravity.—The real specific gravity of sand may be determined with a glass vessel having a narrow neck with a reference mark. This is filled to the reference mark with water at a standard temperature. A weighed quantity of the sand under examination is poured into the vessel. The pouring should be very slow in order to prevent air bubbles being carried down with the sand. The displaced water is poured from the vessel until the level is the same as before, viz., at the reference mark. This water has been displaced by the sand, and its weight divided into the weight of the sand gives the real specific gravity of the sand. The formula for calculating the specific gravity by this method is as follows:

If "W" is the weight of the sand poured into the flask, and,
"W_1" is the weight of the displaced water, then

$$\text{Real specific gravity} = \frac{W}{W_1}.$$

In order to eliminate the air bubbles, the flask containing the sample and water may be placed in an iron cylinder and connected with an air pump to produce a vacuum.

For very coarse gravels a similar method should be applied, the sample having a weight of at least 1,000 grams. The apparatus should be of metal and of a corresponding size.

Weight per cubic foot.—This value is easily obtained from the apparent specific gravity Da, and is equal to 62,484 × Da lbs.

In referring to the weight per cubic foot the physical condition of the material should be referred to as loose or compact, and the degree of moisture should be stated as wet, moist or dry. Compact sand or gravel may be described as material that has been deposited in a bin from a height or has been shaken down in a vessel.

Percentage of voids.—If Dr is the real specific gravity, and Da the apparent specific gravity, the percentage of voids (v) may be calculated from the following formula:

$$v = 100 \frac{Dr - Da}{Dr}$$

It has been found that in the case of a uniform sand made of equal spherical grains the voids vary between 25.95 and 47.64 per cent., depending upon the arrangement of the grains. In the measurement of sands containing grains of different size and of angular shape the percentage of voids was very often nearly 37 per cent., the average of the two extreme theoretical values. The voids are lower in sands made of grains varying in size than in uniform material: they are also lower in coarse sands than in fine-grained ones.

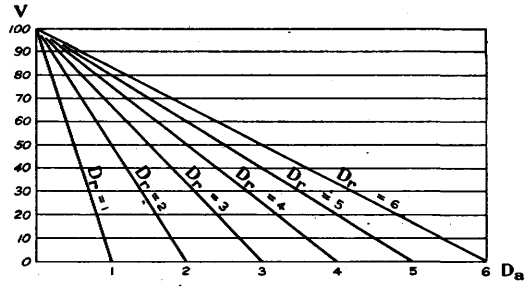


Fig. 3—Diagram of the percentage of voids (v), in function of the apparent specific gravity (Da) for different values of the real specific gravity (Dr).

Diagrams of percentage of voids in functions of the apparent specific gravity, for given values of real specific gravity are straight lines. If the apparent specific gravities are taken as abscissae, and the percentage of voids as ordinates, all the diagrams corresponding to different values of Dr converge at the point v=100 on the axis of the ordinates. The diagram for which Dr=A cuts the axis of the abscissae at a point for which Da=A (fig. 3).

The percentage of voids may be directly measured by using a beaker perforated on the side to admit a siphon, as shown in figure 4.

The beaker is filled with water, and the glass tubing acting as a siphon brings the water in the beaker to a constant level. A volume V of the material to be tested in then poured into the beaker driving a volume V of water out of the beaker through the siphon.

The percentage of voids (v) is given by the following equation:

$$v=100\frac{V-V'}{V}$$

Permeability.—While the porosity of a sand or gravel is expressed by the amount of pore space or the percentage of voids, the permeability is the quality possessed by certain of these materials to permit an easy passage of liquids or gases. This quality depends partly upon the percentage of voids, but also upon the size of the voids. It is a very important factor in moulding sands and filtering sands. If the pores are small, capillarity and friction prevent or lessen the passage of liquids and gases. Coarse material is therefore more permeable than fine grained. Sands uniform in size are also more permeable than sands of a similar grade, made up of various sizes.

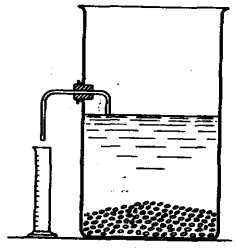


Fig. 4—Beaker for the measurement of the percentage of voids in sands or gravels.

Permeability may be directly measured by filling a tube with a given volume of the material to be tested, and measuring the time necessary for a given quantity of water or air to pass through the material.

Absorption.—On putting a sample of dry gravel or sand into water, a certain amount of water is absorbed by the fragments. The amount depends principally upon the nature of the fragments. The absorption for quartz grains is negligible, but for cleavable minerals such as calcite and feldspar it is larger, and for fragments of porous rocks, such as sandstone, still greater. To measure the percentage of absorption, a sample of the material is placed in water for about one hour; it is then removed and spread on blotting paper and when surface dry, weighed in this state. The sample is then dried over a hot plate to a constant weight. The difference in weight between the surface-dry material and the dried material, multiplied by 100 and divided by the weight of the dried material, gives the percentage of absorption.

Moisture.—The percentage of moisture is obtained by weighing a sample of the material in its natural state—as it comes out of the pit or ready for use—and the sample thoroughly dried. The difference of the two weighings, multiplied by 100, and divided by the weight of the dried sample, represents the percentage of moisture.

Percentage of silt.—This is measured as follows: A weighed sample of the dry material, about 200 grams, is placed in a broad glass tube provided with perforated stoppers and tubes at each end. The tube is placed in the vertical position and a current of water allowed to enter through the bottom and pass away through the top. The tube is shaken from time to time, and the current of water continued till it carries no more silt and is perfectly clear when coming out of the tube. The material is then again dried till the weight is constant. The difference between the weights of the material before and after the experiment, multiplied by 100, and divided by the weight of the sample before the experiment, gives the percentage of silt.

Value in concrete.—Sand is mixed with Portland cement in the proportion, 1 part cement to 3 or 4 parts of sand. The mortar obtained is moulded into briquettes used for tension or compression tests with the ordinary testing machines.

Screened gravel or crushed stone is mixed with sand and Portland cement to produce concrete. The three materials are mixed in different proportions taking into account the amount of sand contained in the gravel. Some proportions in use are:

Cement	Sand	Gravel or Crushed Stone
1	2	3
1	2	4
1	3	6

The concrete is moulded into cubes to be tested for crushing strength.

Bonding Power.—The bonding power is the property of certain sand grains to adhere more or less to one another. It is an essential quality of a moulding sand, as it permits the sand to retain in all its details the form of the mould. A dry sand made of quartz grains only, does not exhibit any bonding power. This quality is principally due to the presence of some cementing material coating the grains. This material is generally clay, though the amount of ferric hydroxide and of moisture also affects the bonding power. It is generally increased by tamping the sand, thus reducing the percentage of voids and allowing more grains to touch one another and to cement together. This property is sometimes artificially increased in foundries, by adding molasses, clay or linseed oil to the sand.

The bonding power is measured by moulding the sand into briquettes, and testing their tensile strength in a specially devised testing machine. The ordinary cement testing machine is not suitable, as it is not sufficiently delicate for testing materials of such low tensile strength.

Composition

The composition of sands and gravels may be determined either by a chemical analysis or by mineralogical examination. For most of their uses the chemical composition is of little interest, as there is no simple relation between it and the physical properties of the material. For some purposes, such as for glass-making and in chemical or metallurgical industries, knowledge of the chemical composition is absolutely necessary. A chemical analysis of sand is a long and tedious operation, and little work of this kind has been done on the several varieties of sand.

As in igneous rocks, there is a relation between the chemical and the mineralogical composition of a sand. Analyses of sand may be calculated in terms of a certain number of standard minerals, by a method similar to the one used for the quantitative classification of igneous rocks (Cross, Iddings, Pirson and Washington: "The Quantitative Classification of Igneous Rocks," University of Chicago Press, 1903). The standard minerals used in the calculations are: Calcite ($CaCO_3$), Orthoclase ($K_2O.Al_2O_3.6SiO_2$), Albite ($Na_2O.Al_2O_36SiO_2$), Anorthite ($CaO.Al_2O_3.2SiO_2$), Corundum (Al_2O_3), Magnetite ($Fe_2O_3.FeO$), Wollastonite ($CaO.SiO_2$), Grünerite ($FeO.SiO_2$), Enstatite ($MgO.SiO_2$), Quartz (SiO_2) and Water (H_2O).

An example of such a calculation follows:

SHARP SAND FROM PIT OF JOHN CREEPER, BELLEVILLE, HASTINGS CO.

	SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	K_2O	Na_2O	CO_2	H_2O	Total
Percentage	55.46	9.99	0.81	1.58	14.88	1.29	2.04	2.62	11.04	0.43	100.14
Molecular Number	.924	.098	.005	.022	.266	.032	.021	.042	.251	.024	
	.....	.....	.....	.....	251	.....	.....	.....	251	.....	Calcite ..25.10
	126	21	.....	.....	.....	.....	21	.....	.....	.....	Orthoclase..11.68
	252	42	.....	.....	.....	.....	.....	42	.....	.....	Albite...22.01
	30	15	.....	.....	15	.....	.....	.....	.....	.....	Anorthite.... 4.17
	.....	20	.....	.....	.....	.....	.....	.....	.....	.....	Corundum 2.04
	.....	.....	5	5	.....	.....	.....	.....	.....	.....	Magnetite 1.16
	32	.....	.....	.....	.....	32	.....	.....	.....	.....	Enstatite 3.20
	17	.....	.....	17	.....	.....	.....	.....	.....	.....	Grünerite 2.24
	467	.....	.....	.....	.....	.....	.....	.....	.....	.....	Quartz ..28.02
	.....	.....	.....	.....	.....	.....	.....	.....	.....	24	Water... 0.43
											Total ..100.05

This calculated mineralogical composition is called the *norm,* and should not be taken for the mode or actual mineral composition of the examined sample. A large amount of calcite in the norm indicates a sand originating from the decay of limestone. The feldspars are usually present as calculated. Corundum is a very rare constituent of sands, but its presence in the norm may be due to the presence of kaolinite or clay in the sand. Magnetite is very common as small grains in sands. Wollastonite, enstatite and grünerite are the three simplest mineral molecules entering in the composition of micas, amphiboles and pyroxenes; their amount in the norm gives an indication as to the quantity of the complex iron, magnesium and calcium bearing silicates present in the sand. Quartz is the more common constituent of sands; its percentage in the

norm is sometimes much lower than the percentage of silica in the chemical analysis, since a large amount of silica may be combined with oxides to form silicates.

A mineralogical investigation is more easily made; the sand or gravel may be examined with the naked eye, or in greater detail under the microscope. The use of heavy solutions allows a separation by gravity of the fragments, which is very useful when the material is made of two or three minerals of very different specific gravity.

Sands are in general composed principally of quartz, which frequently accounts for more than 70 per cent. of the total; the other minerals found in Ontario sands being: feldspar, mica, amphibole, pyroxene, calcite, magnetite, garnet, zircon, kaolin, and limonite. In coarse sands rock fragments are found just as in gravel. A great number of gravels, principally in the southern part of the Province along the Great Lakes, are composed of limestone pebbles with a small proportion of igneous and metamorphic rocks. The limestone accounts very often for more than 75 per cent. of the total, but in some cases the gravel is of sandstone or quartzite pebbles. Slate pebbles should not be present in a good gravel, as the cleavage and softness of slate are a source of weakness either for roadwork or concrete. On roads the slate is very soon pulverized to dust, and in concrete beams it may reduce the compressive strength 75 per cent. In the districts of Ontario near the border of the Laurentian granitic belt, the gravels are composed of igneous rocks as the predominant material.

Origin of Sands and Gravels

Sands and gravels are produced by the weathering of other rocks; and may remain in place or be transported by the action of water or wind. As a rule, the material remaining in place is the most angular, the transported material being well rounded, although some of its grains may be broken into conchoidal chips.

The principal sand and gravel deposits met in southern and eastern Ontario belong to one or other of the following types:

(1) Residuary Sands and Gravels

These represent the products of weathering of rocks which remained at their original place of formation. At the early stages of the decomposition the result is a residuary gravel, but later on each rock fragment is decomposed into smaller pieces and so on until each individual mineral grain is liberated. Of course the products more or less soluble are progressively washed away by percolating waters, and only very resistant minerals such as quartz remain as the final product of the disintegration. The grains are generally angular and the resulting sand sharp. Very often the quartz grains retain a coating of claylike material due to the decomposition of the silicates. The residuary sand generally contains about 70 per cent. of silica, and about 20 per cent. of alumina and iron oxides. The residuary deposits may be found in connection with siliceous limestones, sandstones or shales, and in such cases the original stratification may

be preserved during the weathering process. But generally these deposits are not stratified, especially when derived from igneous or metamorphic rocks. In southern Ontario some deposits of residuary sands overlie Laurentian granite.

(2) Talus Deposits of Sand and Gravel

During the weathering of rocky hills or cliffs the debris does not remain in place, but rolls down to the bottom of the cliffs where it accumulates and forms a talus deposit. This type of deposit is generally a sharp gravel containing fragments of variable size originating from the neighbouring rocks. The disintegration of the large fragments leads to the formation of a sand whose grains roll farther down the slope, forming a talus under the natural angle of repose. Such deposits are found in southern Ontario along important ridges such as

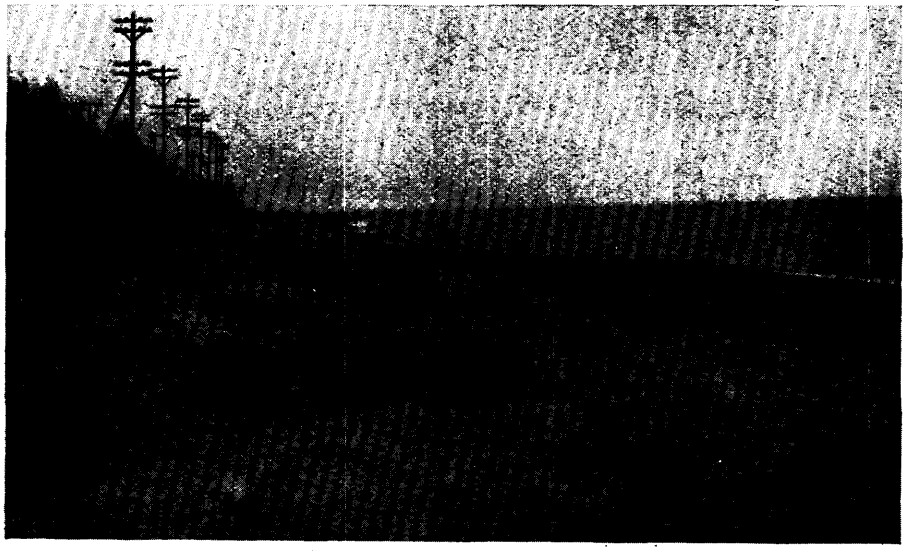


Fig. 5—Alluvial deposit on shore of Toronto Island.

the Niagara escarpment and the granitic ridge marking the southern border of the Laurentian plateau. They do not show any stratification and are generally very narrow.

(3) Alluvial Deposits

The most important of these deposits in Ontario are those formed in connection with the history of the Great Lakes (figs. 5 and 6). Extending over hundreds of miles, these ancient beaches constitute extensive reserves of sand and gravel. The grains are generally rounded and are composed of different minerals, quartz being the most abundant in the sands. The nature of the gravel pebbles depends upon the constitution of the neighbouring rocks. The alluvial deposits always exhibit stratification (fig. 6).

Alluvial deposits are formed not only on the shores of seas or lakes but also in the valleys of rivers; by repeated freshets, the solid particles carried by the water are spread over the soil and increase the alluvial deposit little by little (fig. 7). If the river passes through a lake the basin of the lake may in time be filled by the silt brought in by the river. A similar process goes on where the river flows into the sea; as the current becomes slower, the solid particles are deposited and so begins the building up of a delta.

Alluvial deposits of sand and gravel are most numerous in southern and eastern Ontario, and are generally well suited for building material.



Fig. 6—Lake alluvial deposit of gravel. Note stratification.

(4) Glacial Deposits

These deposits have been brought into their present position by the action of the ice-sheet which covered, in Pleistocene time, the greater part of eastern Canada. Most of the material in these deposits consists of fragments of northern rocks. The material is very often a mixture of sand, gravel and clay, and is known as glacial drift. It is sometimes heaped up in small conical hills or drumlins, as well as in moraines of various types: ground moraine, marginal moraine, and terminal moraine.

These deposits rarely furnish pure sand or gravel.

(5) Dune Sand

This sand is carried by the action of wind. The sand resulting from the decomposition of sandstone, granite or other rocks containing quartz may be carried by the wind for long distances. The deposits formed in this way are

as a rule unstratified; while the grains are more rounded than in other types of sand. Dunes are generally grouped together in long ridges of hills at right angles to the prevalent direction of the wind.

The most important dune formation in southeastern Ontario lies on the western coast of Prince Edward county (fig. 8). Enormous reserves of sand have been accumulated there between Wellington and Sandbanks; this aeolian formation is gradually advancing inland.

Uses of Sands and Gravels

The principal uses of sand and gravel may be enumerated under the following headings:

Concrete or building sand.
Concrete gravel.
Road gravel.
Moulding sand.
Glass sand.
Filtering sand.
Locomotive sand.



Fig. 7—River alluvial deposit. Valley covered by gravel, east of Kincardine.

Concrete or Building Sand

A good concrete or building sand should consist principally of quartz grains ree from loam, dust or vegetable matter. The grains should be angular and sharp; he material should pass a one-quarter inch mesh, but not more than 15 per ent. of the grains should pass the 50-mesh sieve, and not more than 2 per cent. hould pass the 100-mesh sieve.

The tensile strength of a briquette made by mixing the sand with Portland cement in the ratio 3 of sand to 1 of cement must be similar to the tensile strength of a briquette prepared under the same conditions with standard Ottawa sand.[1]

[1] This material occurs as a large deposit of silica sand at Ottawa, Illinois, U.S. Owing to the uniformity of size and composition of this sand it is used as a standard specification sand all over this continent. The grains pass a 20-mesh and are retained on a 30-mesh screen.

There are plenty of reserves of good building sand in Ontario, but in the neighbourhood of the large towns the deposits are more or less exhausted; builders in Toronto, for instance, are forced to bring considerable quantities of sand from pits located 30 and 40 miles away.

Concrete Gravel

The best gravel for concrete is composed chiefly of very fine pebbles, approaching pea-gravel in size. The material should be retained on a ¼-inch screen and pass completely through a 1½-inch screen. The pebbles should be principally hard limestone, sandstone, or granite; pebbles of shale or other fissile rocks should not be present. The proportion of silt ought also to be a minimum.

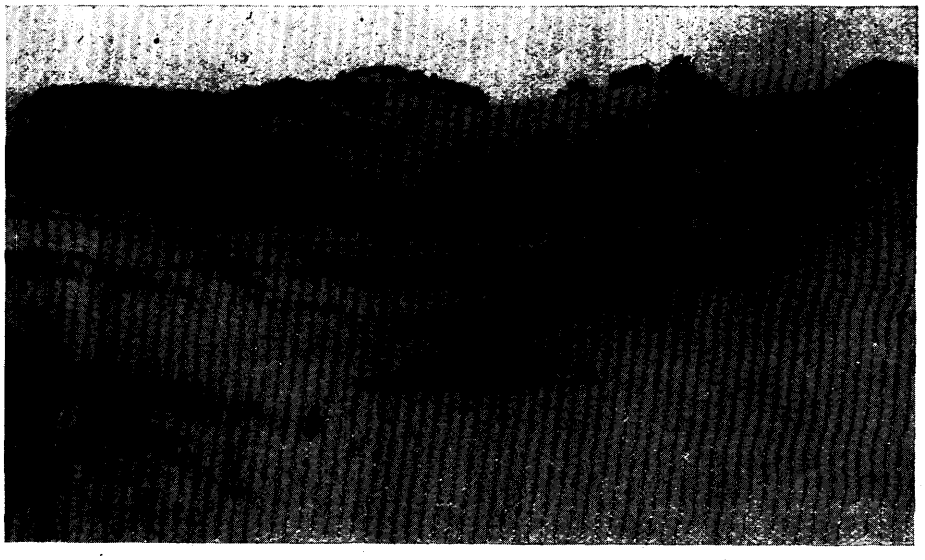


Fig. 8—Sand dunes near Wellington, Prince Edward county.

Road Gravel

This is a coarser grade than concrete gravel, and is usually the run of the pit. Pebbles larger than two inches in diameter should be discarded or may be used in the foundation of the road, but on the upper part of the roadbed it is advisable to place finer material. The presence of shale and loam in the gravel is objectionable. Such gravel should be carefully avoided, since these materials are quickly crushed to dust by the traffic.

Moulding Sand

The essential qualities of moulding sand are its permeability to gases and vapours, its bonding power by which the sand holds the form in which it has been moulded, and its infusibility at high temperatures. The most important of these qualities is the bonding power, which depends more or less upon the amount of clay, iron hydroxide and water mixed with the sand, but the relation

of the chemical composition of the sand to the bonding power is not as yet well understood. All the methods proposed to get quantitative figures on the bonding are only approximate. A foundry foreman usually determines the bonding power by squeezing a sample in his hand, and noting whether it holds its shape.

For a long period nearly all the moulding sand used in Canada was imported into this country from the United States. There are, however, several important deposits of moulding sand in Ontario, occurring in very similar conditions to those found in the states of New Jersey and New York. In Ontario, the moulding sand appears generally as a deposit under the superficial soil, when this soil comes in contact with an underlying sand formation (fig. 9). The moulding sand, which around Hamilton and Toronto seldom exceeds more than two or three feet in thickness, seems to owe its origin to the circulation of water and to



Fig. 9—Surface modification in sand formation by the roots of trees, St. John's Cemetery, Kingston Road (York county).

the action of vegetable and other organic life. It occurs in very different grades of fineness, the coarsest material being used for large and rough castings, while very fine moulding sand is used for brass and copper castings. As this is a high-priced sand which can be exploited without expensive equipment, there is a possibility of developing a considerable industry in this material for Canada.

Glass Sand

Sand for glass manufacture should be as pure as possible, and approach in composition the standard of pure silica. The constituent grains should therefore be essentially of white quartz; all other minerals, and especially the ferro-magnesian ones, must be considered as impurities. The presence of iron in the sand imparts to the glass a peculiar green colour, and seriously impairs the quality. Various processes have been proposed to neutralize this green-iron

coloration through the addition of manganese, nickel oxide or selenium. Certain iron-bearing minerals can be removed from sand by magnetic separation. As a rule a good glass sand should contain more than 99 per cent. of silica and less than 0.2 per cent. of iron oxide. A small percentage of alumina and alkalies in the form of feldspar grains is valuable in a glass sand, as it reduces the quantity of these materials to be added to the batch.

Following is the analysis [1] of a typical New Jersey glass sand:—

	Per cent.		Per cent.
SiO_2	99.40	CaO	0.008
Fe_2O_3	0.0058	MgO	0.012
Al_2O_3	0.2752	Organic matter and moisture	0.231
TiO_2	0.0737		
		Total	100.0057

The shape of the grains is without importance for glass sand. Sometimes this pure sand is obtained directly from the pits. In other cases it is prepared by crushing a more or less disintegrated sandstone, as at the plant of the Oneida Lime and Sand Co., near Hagersville.

The size should be a good medium; the majority of the grains should pass a 30-mesh sieve and remain on a 100-mesh sieve. The coefficient of uniformity ought tc be greater than 50, and the grade between 5 and 7.

The presence of grains smaller than 0.1 mm. causes the formation of "seed" in the glass.

Filtering Sand

Filtration sand or gravel must be very clean, and contain only a small amount of silt, loam, or other impurities. The fineness of the material depends upon the kind of filtration to be done. Washed material is always to be preferred for this purpose to the ordinary pit material.

Locomotive Sand

Sand for this purpose should consist of hard grains; it is used to prevent the slipping of engines and cars on railway tracks. It must be very clean and well washed material, in order to prevent the stopping of the sand pipe.

The finer grades of gravel are used on roofs. Sand is used as an abrasive for cutting and polishing stones; also as a filler for paper, as filling material for fireproof safes, for the making of sand paper, as a raw material in pottery and brick manufacture. The production of white sand-lime brick requires a good, clean and sharp sand, quite free of alkalies.

Distribution of Sand and Gravel in Ontario

Sand and gravel deposits are very numerous in older, or southern and eastern Ontario, and may be found in every county (Map No. 27*b*). The lake shores sometimes present very good material, and they are at some places extensively dredged. Above Sault Ste. Marie, gravel is pumped out of Lake Superior. Along the Lake

[1] The Mineral Industry, 1913. Silica, p. 667. Analysis by R. B. Gage, N.J. Geol. Survey.

Huron and the Georgian Bay shores mention should be made of large deposits of sand and gravel near Collingwood (fig. 10) in Nottawasaga bay, at Owen Sound, Southampton, Port Elgin, Kincardine, Goderich and Sarnia. Sand and gravel are dredged out of the St. Clair river and sold principally at Detroit. Among the deposits located along the Canadian Shore of Lake Erie, the principal ones are the bars near Point Pelee and Pelee Island, in Essex county. Other deposits of some importance are located near Point aux Pins, at Rondeau Park; at Long Point Bay; south of Simcoe; on the bar formed in the lake at the mouth of the Grand River (Haldimand county); and at the eastern end of Lake Erie, where a large sand deposit is found in the township of Humberstone south of Sherks, the sandhills extending probably as far west as Port Colborne.

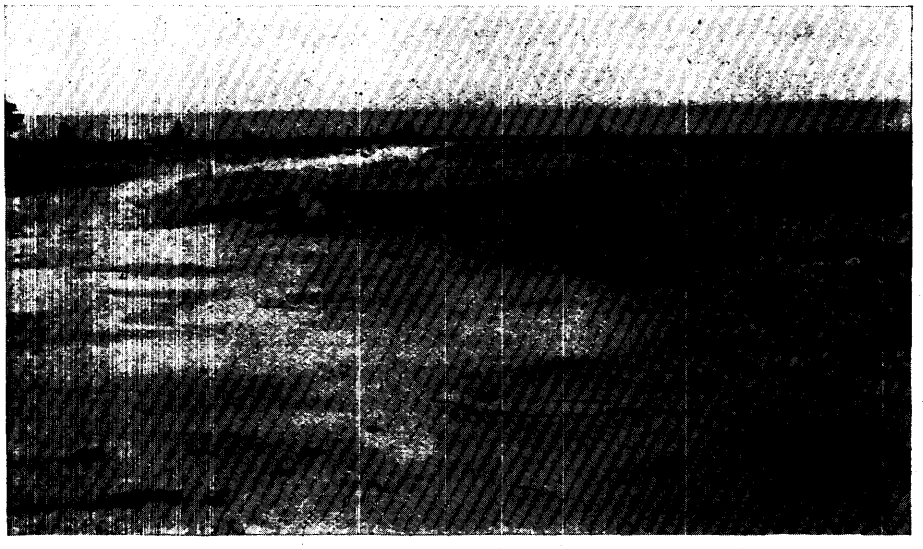


Fig. 10—Gravel formation, east of Collingwood (Simcoe county).

There is a gravel bar at the mouth of the Niagara river in Lake Ontario, which was used in building the new Welland canal. No commercial deposits occur on the shore of Lake Ontario between Port Dalhousie and Burlington, but at the latter place there is a sand bar controlled by the Burlington Beach Commission.

There is nothing of commercial value from Hamilton to Toronto, where some sand and gravel is found along the beach and on the Island at the entrance of Toronto harbour. Gravel and sand are at present being dredged from the lake at Dunbarton, Whitby, Port Hope and Frenchman's bay. Large deposits are found on the shore of Lake Ontario in Prince Edward county, near Wellington and Picton. Some sand and gravel is to be noticed along the Bay of Quinte, east of Belleville. A gravel bar is forming at the northeast extremity of Amherst island in Addington county, and another on the south shore of Simcoe island in Frontenac. Some gravel and sand is taken out of the St. Lawrence, near Brockville, and out of the Ottawa river, at Ottawa.

The largest supply of sand and gravel, however, comes from pits located on ridges or terraces marking the shores of extinct lakes or old rivers.

It has been considered useful to trace the general approximate position of the ancient shore lines of Lake Iroquois and Lake Algonquin in Ontario (Map No. 27*b*), as a great number of sand and gravel deposits are located along these shore lines. The map was compiled from the work of A. P. Coleman, T. W. Goldthwait, Frank B. Taylor, Frank Leverett, and W. A. Johnston. One of the best marked ridges of this kind is the old shore of Lake Iroquois. A series of deposits is found along this line in Ontario, from Lewiston on the Niagara river, westward to Hamilton and Dundas, and from Dundas northeastward to Trenton. (*See* map of Lake Iroquois, by A. P. Coleman, in Thirteenth Report of the Ontario Bureau of Mines, 1904). The average distance between the old shore line of Lake Iroquois and the present shore line of Lake Ontario is five miles. On the north shore of Lake Ontario east of Toronto, the Canadian Northern railway follows quite continuously the shore line of Lake Iroquois.

Old shore lines are not so definitely marked north of the present shore of Lake Erie, although a certain number of sand and gravel deposits at about five miles from the shore belong very probably to the shore of the lake when the level was 50 or 100 feet higher.

A certain number of deposits located on a ridge about 10 to 15 miles from the present shore line of Lake Huron, indicate the old shore line of glacial Lake Algonquin; it passes through Copleston and Petrolia, Parkhill, and Exeter.

Most of the sand and gravel deposits in southern and eastern Ontario are thus very closely connected with the geological history of the Great Lakes. Just as the present shore lines do not show continuous deposits of sand or gravel, the old shore lines are marked by isolated zones or areas more or less parallel to the present shore lines.

In the following description, the several counties and districts are examined in alphabetical order, and typical deposits are described in each.

Algoma District

In this very large district only the area in close vicinity to Sault Ste. Marie was visited. Three groups of geological formations appear there: (1) The pre-Cambrian granite which outcrops about five miles north of the St. Mary river at the Sault, forming a ridge very characteristic of the local topography. (2) The Ordovician sandstones of Potsdam age. (3) The Recent and Glacial formation made of gravel, sand and clay, covering the greater part of the area between the granitic ridge and the St. Mary river. This formation, principally of clay, shows a variable thickness, from 10 feet to more than 271 feet, as indicated by the records of well borings. The principal pits are indicated on a sketch map of the area around Sault Ste. Marie (fig. 11).

I. J. Downey and Sons, East Street, Sault Ste. Marie.—Some gravel is dredged for this firm at Point aux Pins, five or six miles above the Sault, by Capt. McLean, who possesses a dredging outfit.

I. J. Downey and Sons also have a gravel pit on the Canadian Pacific railway at mile 123, about ten miles east of the Sault, and just east of Garden river. Pebbles and boulders up to 6 feet in diameter were observed (fig. 12), which are principally composed of granite or gneiss.

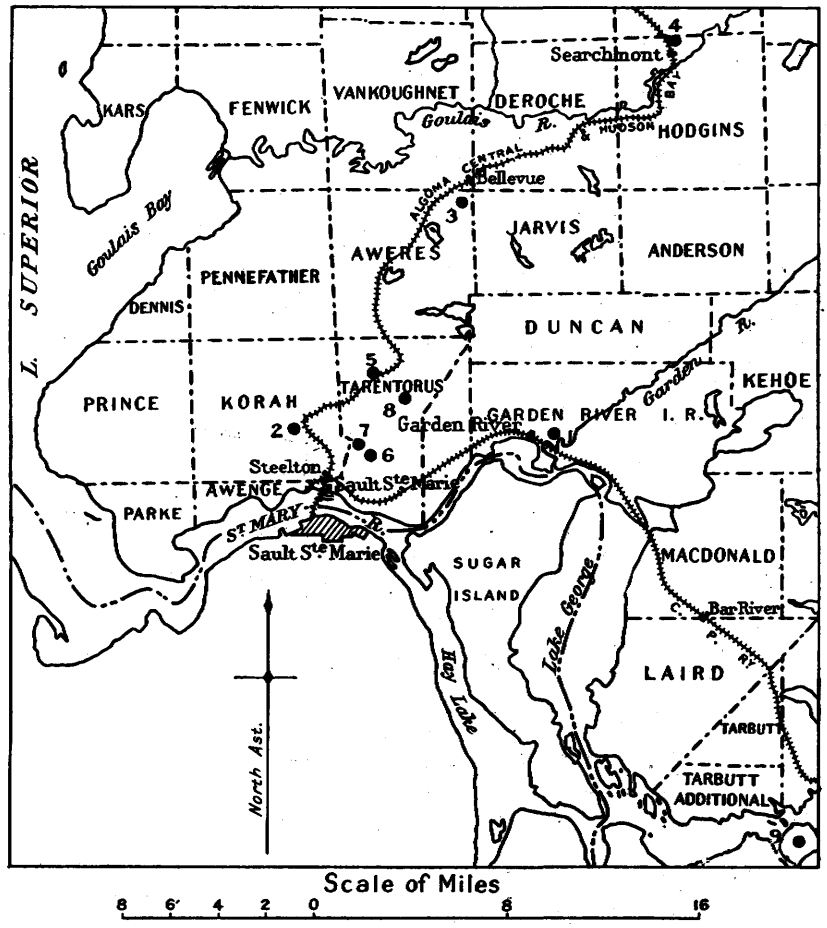


Fig. 11—Map showing location of the principal sand and gravel deposits in the vicinity of Sault Ste. Marie, district of Algoma. 1. I. J. Downey, Garden River. 2. McPhail & Wright, Steelton. 3. McPhail & Wright, Bellevue. 4. Lyons Fuel Co., Searchmont. 5. Algoma Central Railway Co. 6. Municipality of Tarentorus tp. 7. Everett, Sault. 8. The "Landslide." 9. Campment D'Ours island.

Other pebbles are of diabase or of some metamorphic rocks with pegmatite veins, or of quartzite. The pebbles are angular, and the gravel is used for ballast. The section of the pit is about 150 feet high and between 1,200 and 1,500 feet wide. There are special tracks. In August, 1917, the pit was idle; the output had been reduced in 1916, when it was about 460 carloads, averaging about 28 yards per car, or a total of 13,000 cubic yards. The production in 1912 was eight or nine cars a day, and for the whole year between 50,000 and 60,000 cubic yards. This gravel was sold at an average price of 80 cents on dock, and delivered in town at $1.50 a cubic yard.

McPhail and Wright.—This Sault St. Marie firm owns a sandpit at mile 3 on the Algoma Central railway. It is located three miles north of Steelton, and about 300 yards northwest of the city graveyard. The worked excavation is about 150 by 150 by 35 feet; 12 acres of the deposit having been already excavated. The deposit extends as far as half a mile to the northwest, and the company owns 40 acres more of it on which test holes have given between 35 and 40 feet of sand. This

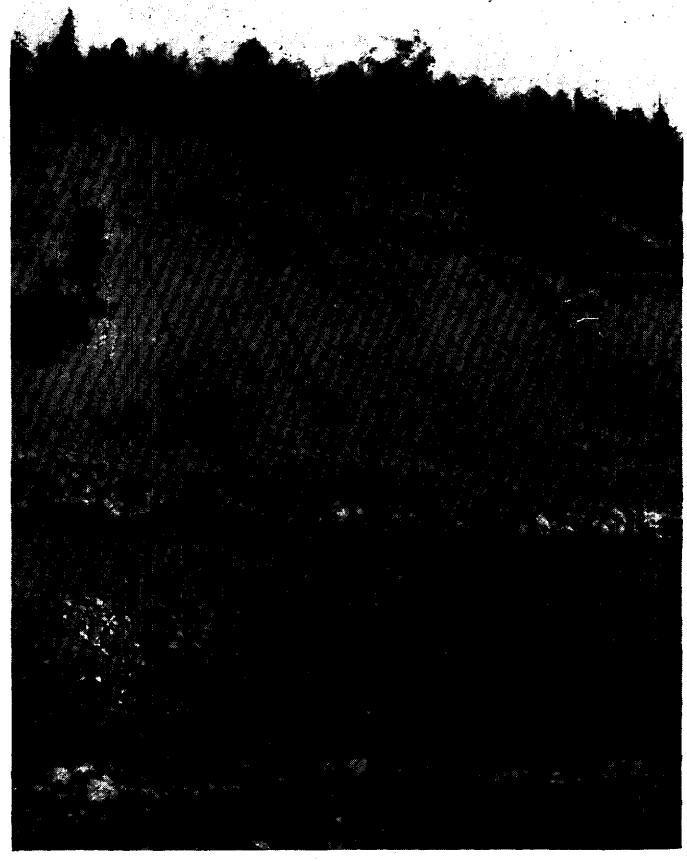


Fig. 12—Downey gravel pit, Garden River (Algoma).

sand shows generally an oblique stratification; it becomes a little coarser in the upper parts of the pit to the north. This coarse part is used for locomotive sand. The following is a granular metric analysis of this variety:—

Mesh.	4	8	10	20	28	48	80	100	200
Percentage retained ..	0.55	2.80	4.20	9.60	17.20	55.00	86.65	95.90	99.65

Per cent. of fineness, 58.72.

The average sand is used for building purposes and for making cores, but about 90 per cent. is used by the steel plants at the Sault for their blast furnaces. The ordinary building sand gave the following results by granular metric analysis:

Mesh	4	8	10	20	28	48	80	100	200
Percentage retained.	0.0	1.30	2.50	8.85	19.25	75.65	96.30	98.65	99.30

Per cent. of fineness	55.35	Apparent specific gravity	1.525
Percentage of absorption	4.9	Weight in lbs. per cubic foot	95.288
Percentage of moisture	1.73	Percentage of voids	43.5
Real specific gravity	2.701		

At the southern part of the sandpit, the surface is a little lower, and the sand near the surface a little browner and shows some bonding power, so that it is used for moulding work. There is a railway siding into the pit. Most of the work is done by hand. On an average three men are employed about 175 days a year. Two 40-ton cars are loaded daily, though the number of cars shipped in 1916 was only 163. The material is sold at $1.00 per yard delivered at the Sault, from which must be deducted the freight charge of 35 cents a yard.

Quartz Quarry.—McPhail and Wright have also a quarry of pure quartz rock located at Bellevue, at mile 21, on the Algoma Central railway. They ship from 6,000 to 8,000 tons a year of this material, which is principally used by the Algoma Steel plant. The rock has a faint pink tinge. It sells at $1.25 to $1.50 per ton f.o.b. at the quarry. The freight costs about 40 cents per ton. Mr. Warden, the chemist of the Algoma Steel Corporation, has kindly contributed the following chemical analysis of this rock:—

	Per cent.		Per cent.
SiO_2	97.25	MgO	0.16
Fe_2O_3	1.86	H_2O	....
Al_2O_3	0.25		
CaO	0.10		99.62

Lyons Fuel Co., Steelton.—This company owns a gravel pit near Searchmont, at mile 34 on the Algoma Central Railway. The output in 1916 was 29,556 yards; 15,000 yards being sold at 65 cents and the balance at 85 cents a yard. This price includes 45 cents freight rate. The bulk of the output was used for the construction of the new power canal, and the remainder for general work.

Algoma Central and Hudson Bay Railway Co.—This company has a gravel pit located along the railway near the fifth base line in the township of Tarentorus. The excavation is very large, being about 300 yards long, 40 yards wide, and probably 40 feet deep. The Root river passes through the excavation and disappears partially underground in the gravel. This gravel extends as far south as the springs of Coldwater creek, and constitutes a natural filter for the supplying of pure water in the Coldwater creek ravine. The gravel of the pit was mostly used for ballast.

The company owns another gravel pit on lots 8 and 9, in the sixth concession of the township of Hodgins. At the bottom of this pit there is a bed of sand, probably 20 or 30 feet deep, which is said to underlie the whole territory.[1] The sand which is covered by 20 to 25 feet of gravel and boulders is fine grained, as shown by the following granular metric analysis:—

Mesh	4	8	10	20	28	48	80	100	200
Percentage retained...	0.0	0.0	0.0	0.0	tr.	5.05	49.35	74.05	94.35

Per cent. of fineness	75.24
Co-efficient of uniformity	69.00
Grade	No. 7

The chemical analysis by W. K. McNeill, Provincial Assayer, of the sand from this deposit is as follows:—

	Per cent.		Per cent.
Silica	73.38	Potash	1.78
Alumina	12.14	Soda	3.58
Ferric Oxide	2.00	Water	0.73
Ferrous Oxide	2.71	Carbon dioxide	0.52
Lime	3.00		
Magnesia	0.24	Total	100.08

This sand contains too high a percentage of alumina to make a good glass sand.

The norm calculated from the chemical composition is as follows:—

		Per cent.		Per cent.
Calcite		1.20	Enstatite	0.60
Feldspars 52.63	Orthoclase	10.56	Grünerite	3.30
	Albite	30.39	Quartz	38.70
	Anorthite	11.68	Water	00.73
Magnetite		3.02		100.20

The large proportion of acid feldspars and quartz plainly indicates the granitic origin of this material.

Under the microscope the sand is seen to be composed of angular grains, which for the most part are quartz, though there are also grains of tourmaline, mica and feldspar. Minerals rich in iron are absent or rare.

Tarentorus Municipal Pit.—This pit is located on the eastern side of the Great Northern road in the southwest quarter of section 29. It has produced gravel and sand for the past five years, the material being used for building purposes and road work. The ratepayers are allowed to take the gravel to put on the roads near their lots. At present the pit is a circular excavation about 100 feet in diameter and 3 to 7 feet deep. Most of the material is brown in color. The brown sand contains considerable gravel, and is of inferior quality owing to the presence of much loam. Some layers of gravel are black, the pebbles being cemented by some black material.

[1] C. H. E. Rounthwaite, engineer of the Algoma Central railway.

Everett Gravel Pit.—This pit is located about 100 yards north of the Tarentorus pit and along the west side of the Great Northern road. The size of the excavation is about 150 by 100 by 10 feet. The pit was previously owned by the city of Sault Ste. Marie. At present it is idle, and the greater part is flooded. The gravel is a little coarser than that in the Tarentorus pit. The two pits mark a gravel ridge striking across the road at N. 60° W. This ridge is from 50 to 75 yards wide, covering an area of about five acres, the average depth being 7 feet.

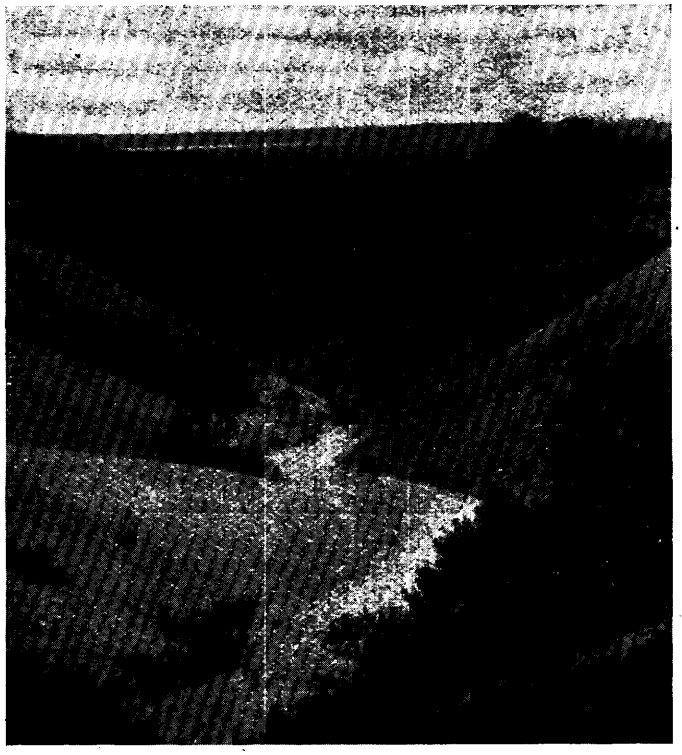


Fig. 13—Landslide along the Garden River road, near the falls of Silver creek, Sault Ste. Marie (Algoma).

Landslide Gravel.—A large amount of gravel is available at a place called "The Landslide," located about five miles north of Sault Ste. Marie, near Silver Creek falls (fig. 13). This gravel is principally composed of granitic material. A granite ridge is located a little north of the "Landslide," and makes at this point a great bend in a southeasterly direction.

Campment D'Ours Glass Sand.—White sand said to be suitable for glass-making is available on Campment D'Ours island. This island, 1,240 acres in area, is located in the St. Joseph channel, Lake Huron, near Desbarats station, on the Canadian Pacific railway. The post-office is Maclennan.

Brant County

The city of Brantford for the most part is built on beds of gravel. The principal operators of sand and gravel pits in the city of Brantford are given in the following list:—

Name and address.	Location of pit.	Nature of material.
Brantford Lands Co., Brantford	Erie Ave.....	Sand and gravel.
J. B. Stratford, Ava Rd., Brantford	W. Brantford ...	Gravel.
J. M. Callock, 53 Palmerston Ave., Brantford....	Baldwin Ave.	Gravel.
City of Brantford Corporation, City Hall	St. Paul Ave.	Sand.

Brantford Lands Co. Pit.—This pit is located on the western side of Erie Ave., in the southeastern part of Brantford. The excavation measures at present 200 yards by 150 yards by 10 feet, and has been worked for ten years. The deposit consists of gravel and sand, the pebbles being principally limestone or dolomite, with some fragments of granitic and metamorphosed rocks. About 75 per cent. of the material is limestone. The average pebbles are not larger than two inches. A granular metric analysis of this gravel follows:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained ...	54.75	60.95	63.80	72.95	84.15	95.40	98.35	99.15	99.65

Per cent. of fineness: 18.98.

The output is about 10,000 cubic yards per year, the gravel being sold at $0.40 a load of 1.25 yards. There remains a reserve of about 600 feet by 45 feet by 10 feet, a supply for two years. The material is of good quality for concrete, sidewalks and road-building. On the exhaustion of this pit other pits will probably be opened in the northwest part of the city.

The Cockshutt Plough Co. secured in 1916 about a thousand yards of moulding sand on lot No. 1, on the north side of the Brantford-Paris road, owned by Messrs. M. McEwen, J. Watkins, and T. W. Henderson, of Brantford. This farm has an area of 175 acres and is completely covered by about 1½ to 2 feet of moulding sand under 6 inches of sandy loam. This moulding sand is sold at 75 cents per yard, two yards making a load of average size.

Brantford City Pit.—This is located on St. Paul Avenue, opposite the hospital, and consists of two excavations, the eastern one being 200 by 200 by 12 feet in size, the western one 200 by 100 by 15 feet. They are separated by a sand ridge 200 feet long and 30 feet wide, this ridge being the principal reserve in sight. The sand is rather sharp, and contains a small proportion of pebbles not larger than 0.5 inch. The granular metric analysis gave the following results for this sand:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	12.25	13.45	14.35	19.60	40.00	95.10	98.65	99.20	99.60

Per cent. of fineness 45.31
Percentage of absorption 0.30
Percentage of moisture 0.10
Real specific gravity 2.762
Apparent specific gravity 1.59
Weight in lbs. per cubic foot ... 99.35
Percentage of voids 42.4

There is about one foot of moulding sand at the top of this deposit.

Other Deposits.—Besides the Brantford deposits there are sand and gravel deposits in Brant county at Paris, belonging to Jos. R. Moyle, and at Mt. Pleasant belonging to the National Sand and Material Co., Ltd., Welland. There is gravel on a number of other farms near Paris, but most of the deposits have not been opened.

Bruce County

In this county the principal sand and gravel deposits are to be found along the shore of Lake Huron. Good sand and gravel beaches are found at Southampton, Port Elgin, and Kincardine. In the last-named town, the beach material is used for roads, concrete buildings, and sidewalks.

This beach extends about 40 miles north of Kincardine and about 30 miles to the south. Along the shore outcrops of limestone, gravel and sand appear. The gravel is composed principally of limestone pebbles with some fragments of granitic, igneous and metamorphosed rocks. The pebbles are various in size, some being as large as 4 inches in diameter. The gravel extends in some places as far as 1½ miles from the lake shore, and is about 5 feet deep, being most abundant and best washed near the shore.

Granular metric analyses of Kincardine gravel and sand:—

GRAVEL.

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained.	71.05	87.30	91.55	95.55	96.10	97.90	99.75	99.95	100.00

Per cent. of fineness 6.76

SAND.

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained.	4.05	5.25	5.50	5.70	6.00	30.35	95.65	99.10	99.25

SAND ANALYSIS.

Percentage of absorption 0.21
Percentage of moisture 0.0
Real specific gravity 2.673
Apparent specific gravity 1.61
Weight in lbs. per cubic foot 100.59
Percentage of voids 39.4

Carleton County

The principal market for sand and gravel in this county is Ottawa. Large quantities of these materials are dredged in the Ottawa river, near Kettle island, MacLaren island, and Duck island, east of Ottawa. All these islands are sandy with a rocky base. The average depth of the sand is three to four feet.

The principal deposits of sand and gravel near Ottawa are indicated in fig. 14.

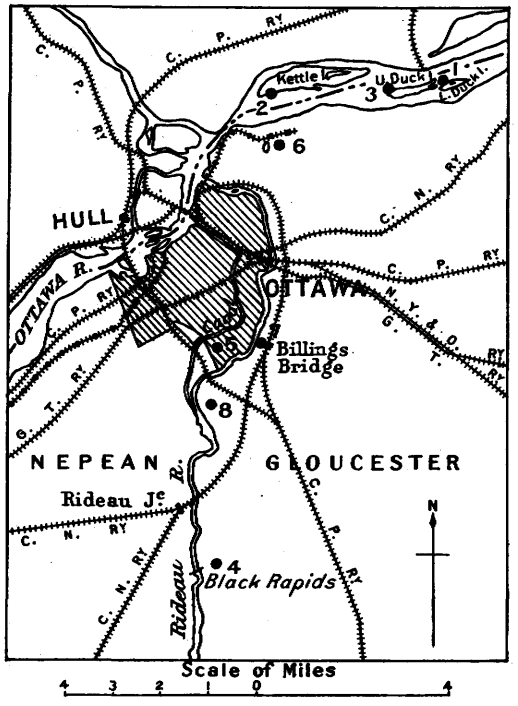


Fig. 14—Sketch map showing deposits of sand and gravel near Ottawa. 1. Beaton and Johnson. 2, 3, 4. Rideau Canal Supply Co. 5. Carnochan. 6. Chas. Keefer. 7. R. A. Nesbitt.

Beaton and Johnson, Ottawa.—This firm have a dredging outfit in the channel of the Ottawa river, near Duck island. In 1916 their total output was one hundred large loads of 120 yards per load, which sold on the wharf at 45 cents per yard. This sand is sharp and of very good quality, and is used for building purposes. The results of a granular metric analysis of this Ottawa sand follow:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained.	0.0	0.0	0.10	6.30	34.80	83.60	92.95	97.20	99.60

Per cent. of fineness 53.94
Percentage of absorption 0.33
Percentage of moisture 0.27
Real specific gravity 2.626
Apparent specific gravity 1.56
Weight in lbs. per cubic foot ... 97.48
Percentage of voids 40.6

The Rideau Canal Supply Co.—This company also dredges a large quantity of sand near Duck and Kettle islands. In 1916 its output was 19,260 yards, which was sold for delivery in Ottawa at 90 cents a yard. It is all used for cement work.

The same company has a sandpit near Black rapids, on the Rideau river, about five miles south of Ottawa. The pit is 60 feet deep and covers an area of one acre; there are 14 acres in reserve. The output in 1916 was 9,493 yards. For delivery in Ottawa the price is 90 cents per yard. This sand is used for building purposes, and asphalt work.

Carnochan's Sand and Gravel Pit.—Mr. Carnochan owns a pit in the south-western part of Ottawa, between Hopewell avenue and Glen street, west of Leonard street. This pit is 60 feet by 100 feet in area, with an average depth of 10 feet and a maximum depth of 20 feet. It was opened twenty years ago. The upper 12 feet are gravel, with the largest pebbles on top. In general these pebbles are not larger than four inches, and are principally limestone, angular in shape. Eight feet of good sharp sand, mixed with small pebbles, underlies the gravel. The stratification is oblique and irregular, and indicates a delta formation. The deposit is not nearly exhausted, but the pit cannot well be worked much longer owing to near-by buildings. The present output is about 200 yards per year, and sells at an average price of 70 cents a yard at the pit.

Rockcliffe Sand and Gravel Pit.—Ch. Keefer, 310 Bank Building, Sparks street, Ottawa, kindly furnished the following information about the deposit he works in the northeastern part of the city, known as Rockcliffe sand and gravel pit. The location of this deposit is Block 15 B of lot 2, junction gore of the township of Gloucester, near the shore of Hemlock lake. The whole area is 34 acres, of which 17 are sand and gravel. The area worked up to the present time covers 4½ acres, the average depth of the workings being 15 feet. The pit supplies principally sharp sand, which has been extensively used for concrete work in Ottawa. The output in 1916 was 2,854 yards of sand, which sold at 25 cents a yard at the pit. The following tests were made by the testing laboratory of the Public Works Department at Ottawa, in December, 1913.

Granular metric analysis:—

Mesh	4	8	10	20	30	50	80	100	200
Per cent. retained.	0.	0.	0.	6.2	42.9	75.8	93.6	95.2	98.6

Per cent. of fineness, 54.19

N.B.—This value of the per cent. of fineness should be used for an approximate comparison only with other values given in this report, as the analysis was made by means of a different series of sieves.

Real specific gravity 2.64
Apparent specific gravity 1.45
Weight in lbs. per cubic foot 90.60
Percentage of voids 45.3

Tensile strength—Mixture 1: 3

7 days	Standard sand	306	pounds
	Rockcliffe sand	322	"
28 days	Standard sand	356	"
	Rockcliffe sand	362	"

The bottom of Hemlock lake is composed of sand, and large reserves could be worked by a pumping dredge.

R. A. Nesbitt's Sand and Gravel Pit (south of Ottawa).—This property is located east of the Rideau river a little north of Billings Bridge. There are two pits of 250 feet in diameter near the River road, Stanley road and Billings avenue. The whole block is about 3 acres in area. The greatest part of the deposit is worked out, and the wall is close to buildings. This wall is 14 feet high; the upper five feet are loamy and mixed with large stones without value. Then comes one foot of sharp sand and under it three feet of gravel, which is mixed with at least 60 per cent. of sand. The pebbles are between two and four inches in size, and about 90 per cent. of them are limestone, the remainder being primarily granite and gneiss. Under the gravel is two feet of sharp sand, and as one goes deeper this sand becomes much finer. This material was sold at 75 cents a yard for the gravel, and 50 cents a yard for the sand at the pit.

J. Blair's Pit.—There are some deposits of sand southeast of Arnprior, in the northwest corner of the county of Carleton. One of the most important is J. Blair's pit, in the township of Fitzroy, lot 22, fourth concession. The pit is at present 200 by 60 by 25 feet. The upper three feet are loam, and then there are 22 feet of gravel. The pit is located three miles from Arnprior, near the G. T. Ry. tracks. The G. T. Ry. Co. estimates that there are 15 million yards in reserve on an area of about eight acres. The gravel is composed of rounded pebbles of limestone and granite and other materials averaging from one to two inches in diameter. At the north end of the pit sharp sand of good quality overlies the gravel, the contact dipping to the north at an angle of 40°. This sand is not worked at the present time, but the gravel is used for roadwork and ballast. The approximate output in 1916 was 500 yards, sold at 25 cents per load of 1½ cubic yards.

Granular metric analysis of gravel from Blair's pit:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained.	97.15	97.50	97.60	97.85	98.05	98.75	99.25	99.50	99.80

Per cent. of fineness 1.84
Coefficient of uniformity 97.50
Grade ..... No. 1

Patterson's Gravel Pit.—Mr. Patterson, of Arnprior, owns a pit in Fitzroy township, lot 27 in the third concession, which is 300 by 100 by 15 feet and contains layers of coarse sand, and pea gravel showing sometimes auto-cementing properties. Mixtures of 1 to 7 make good concrete with this gravel. The output in 1916 was 500 yards, which sold at 20 cents per ward. There is a reserve of two acres of gravel on this property.

Dundas County

In this county the principal deposits are located in the townships of Williamsburg and Matilda, around Williamsburg, Morrisburg and Iroquois (fig 15).

Styles' Sandpit.—On lot 16, first concession, township of Williamsburg. This pit lies about four miles east from Morrisburg station, north of the Grand Trunk railway and half a mile north of the St. Lawrence river. The sand in this region forms a ridge of drumloid hills. The upper two feet of the deposit are loamy and the material is not used. Under the loam are 11 ft. of good sharp sand used for building concrete and sidewalks. The principal hill worked at present is 100 yards long and 30 yards wide. The ridge extends to Morrisburg, but the sand becomes too fine in size and of poor quality toward the west. The

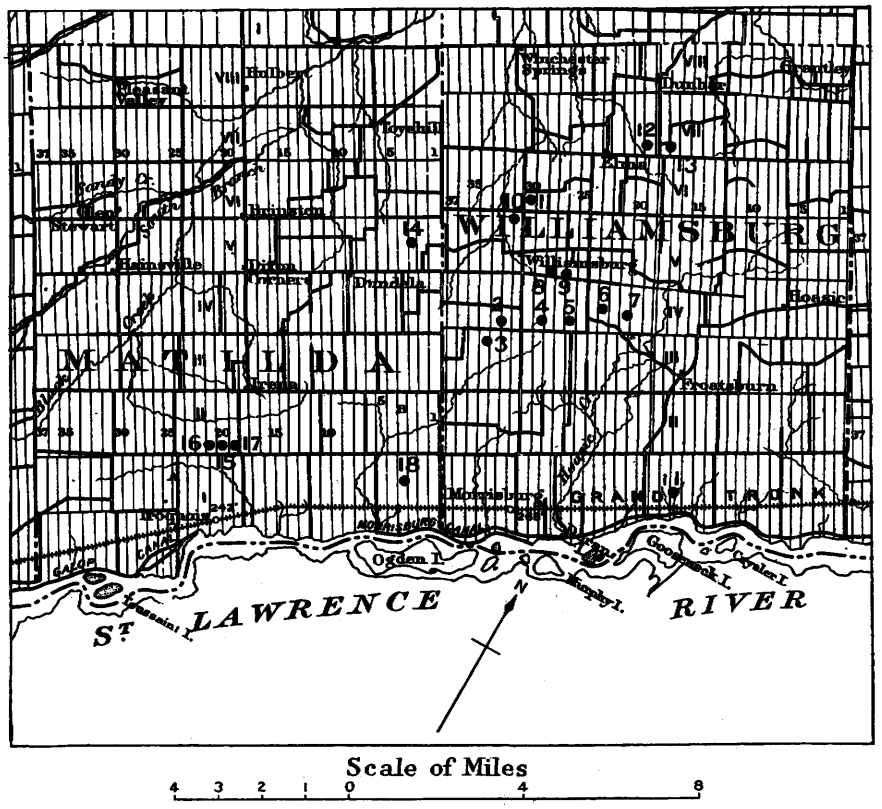


Fig. 15—Map showing location of sand and gravel deposits in the southern part of Dundas county. Sand pits:—(1) Styles, (17) Armstrong. Gravel pits:—(2) Shanette, (3) Coghlan, (4) Froats, (5) Hall, (6) Colquhoun, (7) D. Gillard, (8) Carlough, (9) Casselman, (10) Whittaker, (11) Weaver, (12) and (13) McMillan, (14) Merkeley, (15) Shaver, (16) Brouse, (18) Beckstead.

output of this pit is about 100 cubic yards a year, and is sold at 50 cents a yard at the pit and $1.75 delivered at Morrisburg. There is an available reserve of at least 10,000 cubic yards.

Shanette's and Coghlan's Gravel Pits.—The former is on lot 34, concession four, and the latter on the same lot in concession three, Williamsburg township. These pits are located on both sides of the third concession road and west of the road from Morrisburg to Williamsburg. The gravel strata are 10 feet higher than the level of this road, the upper part being of large pebbles

or boulders, generally of a dark blue crystalline limestone. In the lower part, smaller pebbles become more abundant, the gravel being more sandy at the bottom. The pebbles average three inches in size, and they consist predominantly of Silurian limestone containing numerous fossil shells. Some granitic and metamorphic pebbles are also present. The Shanette pit is an excavation 150 by 30 by 8 feet. The Coghlan pit is newly opened, the gravel being exposed for a length of 120 feet. These deposits are part of a forest-covered ridge and contain a reserve of 2½ acres.

Granular metric analysis of Shanette's pit gravel:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained.	67.15	73.25	76.85	87.05	93.15	98.75	99.55	99.70	99.85

Per cent. of fineness 11.63

N.B.—The pebbles remaining on the 4-mesh sieve include 46 per cent. larger than 1 inch, and 21.15 per cent. smaller than 1 inch, or total 67.15 per cent.

Harry Froat's Gravel Pit.—On lot 29, concession four, Williamsburg. This deposit is nearly exhausted, and comprises several small pits lying under water. There remains in reserve an area of about 50 yards by 20 yards, the gravel having a depth of nearly 5 feet. This material is used as cement gravel, and sells at 50 cents a yard at the pit.

Hall's Gravel Pit.—On lot 26, concession four, Williamsburg, there is an excavation of 150 by 30 by 3 feet. The pebbles, which are predominantly of limestone with some granite, sandstone, and quartz, are large in size and mixed with boulders.

R. Colquhoun's Gravel Pit.—On lot 23, concession four, Williamsburg. The pit is at present 100 by 50 by 4 feet in size. It lies behind the farm buildings at the top of a ridge, on which there remains half an acre in reserve. Most of the material is subangular limestone gravel, with numerous boulders. The lower part of the pit is more sandy.

David Gillard's Gravel Pit.—On lot 21, concession four, Williamsburg. This pit, which has been idle for some years, is 100 by 40 by 5 feet in extent, with a great variety of pebbles of limestone and igneous rocks. The reserve covers about one acre.

Jacob Carlough's Gravel Pit.—On west half lot 28, concession five, Williamsburg. The excavation, which is 200 by 100 by 6 feet, is located on a hill running in northeast-southwest direction. The average pebbles are 3 inches in diameter, but towards the east the pebbles are larger and interspersed with boulders. No gravel has been sold from this pit for several years.

Miss Casselman's Gravel Pit.—On lot 27, concession five, Williamsburg. The excavation is 200 by 100 by 4 feet. The pebbles are angular and of different sizes down to 4 inches in diameter; they consist of limestone, metamorphosed and igneous rocks, and become more sandy in the lower parts. The material is used as concrete and road gravel.

H. M. Whittaker's Gravel Pit.—On lot 31, concession four, Williamsburg. This pit is located about three-quarters of a mile north of Williamsburg, on a ridge running approximately in a north and south direction. The deposit has

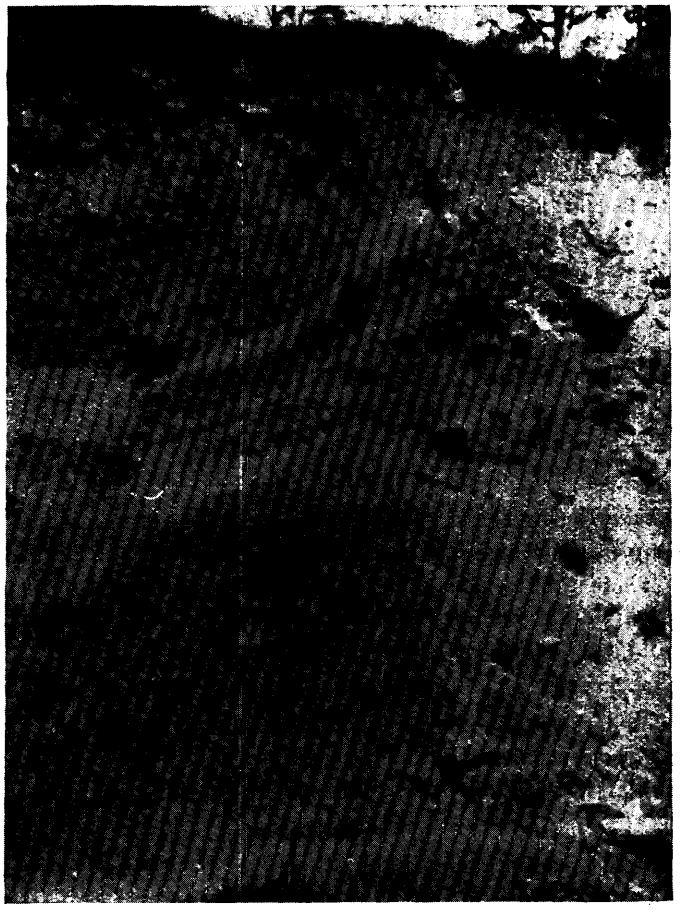


Fig. 16—Whittaker pit, showing inclined stratification, Williamsburg, Dundas county.

been worked from the north, on an area of 500 yards by 40 yards, the wall becoming higher at the southern part, where it is 15 feet high. The stratification is oblique (fig. 16) the layers dipping at an angle of 30°. The seams are of different grades and about one foot thick; there is a little loam and about 40 per cent. of the deposit is sand, a portion being blue and calcareous. There are some large boulders, but most of the gravel consists of angular pebbles of limestone and granite, not exceeding two inches in diameter. Eruptive and metamorphosed rocks are more abundant among the large stones than among the

small pebbles, where limestone is predominant. This gravel is at present used for concrete making in a bank building at Williamsburg. One team hauls about 10 loads a day from the pit to Williamsburg. The available reserve extends over four acres south of the present pit.

Thomas Weaver's Gravel Pit.—On lot 30, concession six, Williamsburg. This pit is located on the northeast prolongation of the Whittaker pit, and was closed two years ago. The ridge extends still farther in a northeast direction, but is all under crop.

Arthur McMillan's Gravel Pit.—On lot 18, concession seven, Williamsburg. This pit is located about one mile east of Elma, on both sides of a north and south road to Dunbar and Chesterville. The gravel ridge has a direction N.60°E. The gravel is of good quality, consisting principally of limestone with a certain amount of igneous material. The average pebbles are 2 to 3 inches in diameter; large pebbles being scarce. The excavation on the west side of the road is 300 by 90 by 6 feet; that on the eastern side 600 by 200 by 4 feet. The pits are completely covered with vegetation and have not been worked for several years. The reserve extends over 4 acres.

Charles Merkeley's Gravel Pit.—On lot 2, concession five, township of Matilda. This pit is located near the road from Williamsburg to Dundela. About 600 by 100 by 4 feet have been taken out, but work has been discontinued for several years, although there seems to be an equal reserve lying north of the pit, under the orchard. The work was to start again this year, as one-quarter of an acre of this property was sold to the council of Matilda township.

Edgar J. Shaver's Gravel Pit.—On west half lot 20, concession two, Matilda township. This pit is southwest of the Iroquois graveyard. It is about 100 by 50 by 7 feet. There are large stones at the top, but the lower 5 feet are of good limestone gravel, the pebbles being on an average ¼ to 2 inches in diameter. This material sold this year at 75 cents a yard.

Brouse's Gravel Pit.—On lot 21, concession two, Matilda. The excavation has the form of a circle, 100 feet in diameter. There are 6 feet of grey sand at the top on the eastern side, and under it the gravel formation is 10 feet thick. The gravel is similar to that from the Shaver pit, the pebbles being a little larger.

Armstrong's Sand Pit.—On lot 19, concession two, Matilda. The pit is 200 by 100 by 12 feet in size, and is not worked at present. There is a reserve of good building sand about 200 by 100 by 6 feet in sight. Some large stones, probably rejected from the gravel, have been dumped in the centre of the pit.

Granular metric analysis of Armstrong sand:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained.	0.0	0.35	0.50	1.30	3.65	33.50	70.90	86.90	97.50

Per cent. of fineness 67.27
Real specific gravity 2.713
Apparent specific gravity 1.54
Weight in lbs. per cubic foot.... 96.23
Percentage of voids 43.2

Albert Beckstead's Gravel Pit.—On lots 3 and 4 in concession one, Williamsburg township. The excavation is now 150 yards by 20 yards by 2 yards (average). On the top of the ridge there is about 1½ feet of loam and under it 8 feet of gravel. There is a reserve of about 75 yards by 20 yards by 2 yards. The gravel is composed of angular pebbles, principally limestone. These vary in size from one-tenth to five inches, while some boulders reach 1 foot in diameter. The proportion of sand is small. This gravel was used for concrete making in the Morrisburg canal, as well as for bridges, houses and road building. It was sold at 50 cents a yard at the pit and $2.00 for delivery in Morrisburg. The output is at present small, although in some years it reached 1,000 yards.

Durham County

In this county there are some sand and gravel deposits around Port Hope and Bowmanville.

Thos. A. G. Bray's Gravel Pit, Port Hope.—On lot 2, concession four, township of Hope. The excavation is 150 by 150 by 4 feet, the available reserve covering an area of 7 acres. The top of the deposit is covered by boulder clay under which there is a coarse gravel consisting of large pebbles and then about 5 inches of limestone gravel, mixed with about 20 per cent. of sandy material.

Granular metric analysis of limestone gravel:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained.	80.00	83.40	84.65	87.00	89.45	98.65	99.80	100.00	100.00

Per cent. of fineness, 8.56.

The 80 per cent. remaining on the 4-mesh sieve is composed of 48.05 per cent. pebbles larger than 2 inches, 17.85 per cent. nut pebbles about 1 inch in diameter, and 14.10 per cent. pea gravel smaller than 1 inch.

Hiram Walker's Gravel Pit, Port Hope.—On lot 18, concession three, Hope. The pit lies on top of a rounded hill. The present excavation is 300 by 150 by 4 feet in size, but gravel was found to a depth of 8 feet. The available reserve is approximately 1,200 by 150 by 4 feet. The pit is located one-quarter of a mile south of the Canadian Northern[1] Railway tracks. The gravel is composed of limestone pebbles which at the top are large, but smaller near the bottom, where they are mixed with a certain amount of sand. This deposit extends in a northerly direction through concession four, where it has been worked largely by the C. N. R. for ballast.

There are several other gravel deposits at an average distance of six miles north from the Lake Ontario shore at Port Hope. These deposits belong to the old Lake Iroquois beach, and are abundant near Quay. This shore line of Lake Iroquois is very well marked through the whole of Durham county, and the

[1] Now, since change to Government ownership, called Canadian National Railways. See also on subsequent pages.

C. N. R. tracks follow more or less this line of gravel deposits. Some deposits are located outside of this general ridge, this being the case for the gravel pits lying north of Port Hope and Charlecotte.[1]

Gravel pits, Hope township.—On lot 9, concession two, behind the Pomeroy house is a circular pit 100 feet in diameter by 12 feet in depth. The gravel is very coarse at the top and finer near the bottom; it is principally composed of limestone. Fifty yards west of this pit is a second circular pit about 200 feet in diameter and of similar character. A little farther north on the west side of the road there is a third pit worked for road gravel by P. Sleemon, of Port Hope. The excavation is 200 by 150 by 12 feet in size. At the time of the writer's visit, it was worked by 9 men and 5 teams. The gravel was sold at 15 cents a yard.

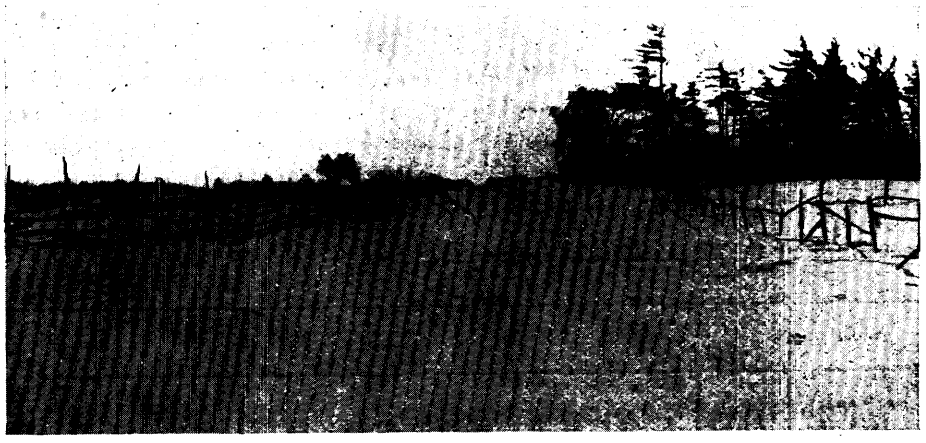


Fig. 17—Inland dune, invading cultural areas, north of Charlecotte, Durham county.

Sandy formation between Charlecotte and Clarke.—This formation extends along the road between Charlecotte, Hope township, and Clarke, in the township of Clarke, as a ridge of sandy hills. It lies in concession two of Hope township and concessions one and two of Clarke township. The reserves are very large, and at some places gravel pits have been opened, but the greatest proportion of the deposit is a fine ferruginous sand which was used for making mortar. This sand, as it contains almost no bonding material and is unprotected by vegetation, is transported by the wind over the adjacent agricultural lands, forming inland dunes (fig. 17).

Similar formations occur around Kendal and Orono.

Sand and gravel on shore of Lake Ontario at Port Hope.—This beach is composed principally of recent sand, which has been shipped by the carload for building purposes. The beach is about 60 yards wide near the station, where there is also some fine limestone gravel. Farther west the beach narrows to 3 or 4 yards, and the gravel becomes coarser, certain pebbles being 4 inches in diameter.

[1] See L. Reinecke, Road Material Surveys in 1914, Geological Survey of Canada, Memoir 85, pp. 141 *et seq.*

Granular metric analysis of lake shore sand, Port Hope:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained.	0.0	0.0	tr.	0.10	0.35	17.55	87.15	97.25	99.75

Per cent. of fineness 66.43
Apparent specific gravity 1.62
Real specific gravity 2.706
Weight in lbs. per cubic foot 101.22
Percentage of voids 40.1

Township of Darlington.—In the immediate neighbourhood of Bowmanville there are no important deposits of sand or gravel, but farther north there are some deposits near the C. N. R. tracks along the old Lake Iroquois beach principally near Tyrone station. The pits are generally small, and the deposits not very deep. The gravel contains about 75 per cent. of limestone pebbles. Beds of good sharp sand alternate sometimes with the gravel beds. Great quantities of this gravel were used for ballast, but there remains yet along this old shore line in the township of Darlington an available reserve of more than one million cubic yards.

Elgin County

There are several deposits round St. Thomas and Port Stanley. M. U. Ferguson, the city engineer of St. Thomas, kindly furnished information and assistance respecting these deposits. Gravel is very abundant in the city of St. Thomas, where it occurs in Kettle creek as river-washed gravel, and there are also pit deposits. The creek gravel is good concrete gravel, but, lacking bonding material, is not suited to road making. The pit gravel contains enough clay to make good road gravel, but is not good concrete material.

Ponsford's Gravel and Sand Pit, St. Thomas.—This pit is in the township of Yarmouth, on lot 17, concession eight. The excavation is about 500 by 250 by 20 feet; there are about 12 to 14 feet of gravel on the top and 6 to 8 feet of sand at the bottom. There is at least an area of 50 acres in reserve. The upper part of the deposit consists of alternate layers of gravel of various coarseness: the pebbles range in size up to 4 inches in diameter. Limestone is predominant, and accounts for 60 per cent. of the whole material, the remainder being granite, gneiss, etc. Some parts of the fine material are sharp and contain no clay; other parts nearer the surface are mixed with clay. The sand is screened and used in the manufacture of silica bricks. The output of this pit in 1916 was 2,700 loads (about 4,000 yards) of gravel, which sold at 40 cents a load.

Granular metric analysis:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained.	5.5	8.6	10.8	16.4	21.85	49.00	84.45	96.75	99.45

Per cent. of fineness 56.35
Real specific gravity 2.774
Apparent specific gravity 1.69
Weight in lbs. per cubic foot 105.59
Percentage of voids 39.1

City of St. Thomas Pit.—This pit is located behind the city park and supplies gravel and sand. The pebbles are not larger than half an inch in diameter. It makes a good pea gravel in macadam roads as a binder between larger pebbles. The sand is sharp and used for mortar making. The output in 1916 was 2,700 yards.

Granular metric analysis of gravel:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained.	24.60	34.45	39.75	50.25	59.50	86.20	96.10	97.40	98.30

Per cent. of fineness, 34.83.

Axford's Pit.—This pit is located southwest of the city pit, and the material is coarser, there being less sand and more gravel, the latter of good quality for concrete. The wall of the pit is 15 feet high and the reserve covers 40 acres.

Gravel within the city limits of St. Thomas.—In excavating for the construction of sewers and waterworks in St. Thomas, 3 or 4 feet of gravel of good quality were found underlying the whole city.

Sand deposit at Port Stanley.—On both sides of the Kettle valley running into Lake Erie, there are very high ridges made of silt and sand lying on a blue clay. The contact between the two formations is about at the lake level, and constitutes a line of weakness along which the clay is washed away so that the overlying sand and silt crumbles down. The ridge is between 100 and 150 feet high. This process of undermining is going on steadily. The sand and silt are of little importance for economic purposes. A little garnet sand and some coarse and sharp building sand are found on the beach.

Essex County

The most important deposits in this county (fig. 18) and among the largest in all Ontario are on the sand and gravel bars in Lake Erie near Point Pelee and Pelee island. There are some other gravel deposits near Leamington, and along the electric railway between Leamington and Windsor, and also south of Windsor, near Ojibway. In many creeks running south and north through this county, the gravel accumulates in the bends. In the pits, gravel and sand generally occur in alternate layers and the gravel is very often sandy.

Point Pelee; Cadwell Dredging Co., Windsor.—This company owns eight dredges each carrying 75 carloads of gravel which can be loaded in two and a half hours. The output in 1917 from the opening of navigation till the end of August was 151 dredge loads.

Point Pelee forms a peninsula in the shape of an acute triangle, the centre of Pelee island lying about 12 miles south of the point. The peninsula is continuously reduced in size by the washing of the lake, and since 1913, 1,300 feet have been removed from the end of the Point. The life-saving station erected by the Dominion government in 1914, 200 feet from the eastern shore, is now

only 90 feet from the shore, and during strong gales the bottom of the boathouse is washed by the waves. In April, 1917, it was 800 feet north of the end of the end of the peninsula, but in August of the same year this distance was reduced to 500 feet.

The area worked by the Cadwell Dredging Co. extends as a bar to the west of the peninsula and stretches from three miles south of the point to two miles

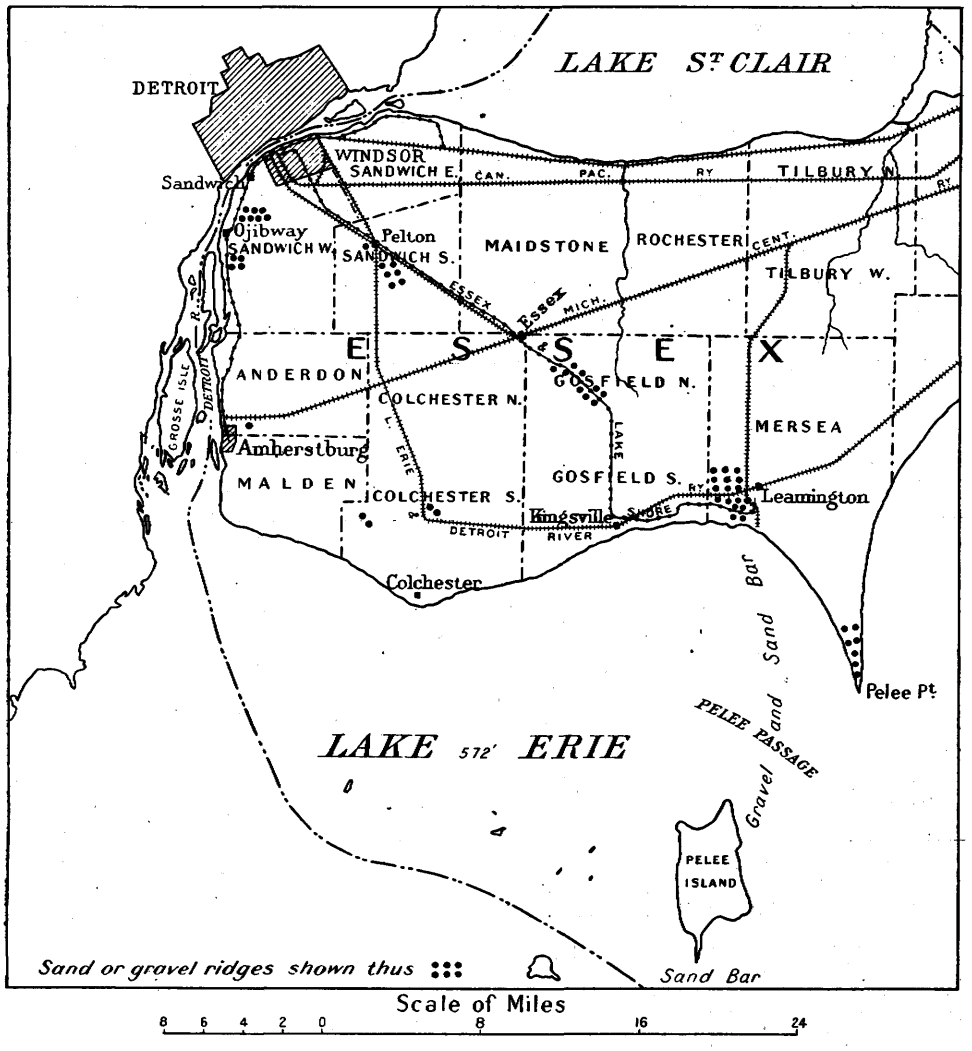


Fig. 18—Sand and gravel deposits in Essex county.

north. The dredges work about one mile from the point. South of Pelee island most of the gravel has been removed and only sand remains. It is very probable that the material taken from the bar south of Point Pelee is replaced by sand and gravel coming from the point. The peninsula is composed principally of gravel and sand layers which may be seen on both shores. Near the shore there

is a little zone, 20 feet wide, of sharp white sand, then comes a zone of gravel about 6 feet wide, and higher up a zone of very fine red garnetiferous sand. The southern part of the peninsula is covered by trees, mostly cedars. Three or four miles north of the point, where the peninsula becomes wider, sand dunes and sand ridges appear parallel to the western shore. They are about 10 feet high and consist of very white, fine sand. Farther north, the clay is nearer to the surface, and a clay dike has been built up to protect the farm land from incursions of the lake.

Nearer Leamington, sand and gravel are seen only in a narrow strip along the lake shore, the central part of the peninsula being composed mostly of silt and clay and constituting a fine agricultural region. Fifty rods from the shore the bottom of the lake is clay, the average depth being 15 feet. This clay also underlies the Pelee peninsula, and its gradual destruction is due to the washing away of the clay by a process similar to the one noticed at Port Stanley in Elgin county.

Most of the material dredged near Point Pelee goes to Cleveland, Toledo, and Detroit, in the United States.

Granlar metric analysis of white sand from shore at Point Pelee:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained.	0	traces	0.50	10.60	37.30	83.65	98.05	99.65	99.80

Per cent. of fineness 52.27
Real specific gravity 2.664
Apparent specific gravity 1.667
Weight in lbs. per cubic foot ...104.161
Percentage of voids 37.4

Granular metric analysis of garnetiferous sand, Point Pelee:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained.	0	0	0	0.20	1.05	40.05	92.60	99.20	99.90

Per cent. of fineness 63.00
Real specific gravity 3.403
Apparent specific gravity 2.165
Weight in lbs. per cubic foot ...135.278
Percentage of voids 36.4

Sandwich West township.—A ridge containing both sand and gravel is to be seen, south of Windsor, near Ojibway, on the property of the Canadian Steel Corporation, Ltd. This company expects to obtain 30,000 yards of sand from this deposit, though it may be necessary to remove an equal amount of overburden. There is about 8 to 10 feet of sand or gravel over the glacial boulder clay. This deposit was not being worked in August, 1917.

Frontenac County

This county is as a rule rocky, and sand deposits are not common. Some pits are located at Glenburnie and Cataraqui, and sand from the shore of Lake

Ontario is obtained, principally at Big Sandy bay, on the southwest corner of Wolfe island. Professor M. B. Baker suggested in a recent report[1] that the white lower beds of Potsdam sandstone might be valuable as a source of glass sand, as they are free from iron.

The Kingston Sand and Gravel Co., Raglan Road, Kingston.—The sand brought to Kingston by this company comes from pits located at Glenburnie, 7 miles north of Kingston. Between Kingston and Glenburnie, the north and south road runs through the Ordovician limestones. A sand ridge is situated east of Glenburnie in the direction of Maple Lawn. The pits are in concession

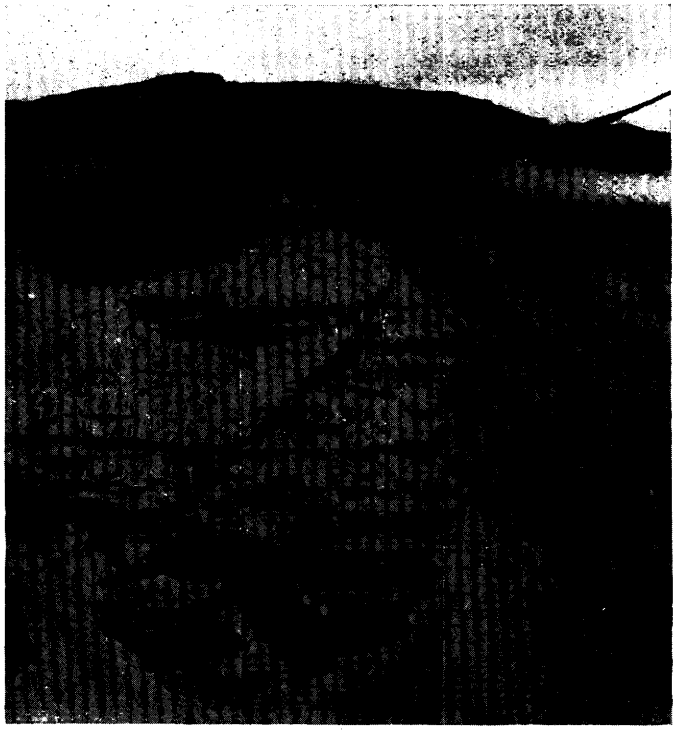


Fig. 19—Calcareous concretions in sand, Glenburnie, Frontenac county.

five, and between lots 30 and 35, township of Kingston, and are 20 to 30 feet deep. The three principal pits have areas of 100 by 150, 200 by 400, and 200 by 600 feet. The whole deposit is about 1,000 feet wide in a north and south direction, and more than 2,000 feet east and west. The sand is sharp and intermixed with small angular gravel of granitic nature. The upper part of the sand is brown for about 2 feet and shows some bonding power; below this part the colour becomes paler, and the greater part of the deposits consists of white sand. This sand contains quartz, feldspar and black mica among its grains, and some calcareous white concretions produced by the circulation of calcareous waters (fig. 19).

[1] 25th Annual Report, Part III, Ont. Bur. of Mines, 1916, The Geology of Kingston and Vicinity, p. 35.

These concretions are more abundant near the water level at the bottom of the pits.

Granular metric analysis of Glenburnie sand:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained.	1.55	2.40	2.80	3.85	5.70	37.95	77.30	90.95	98.45

Per cent. of fineness, 64.34.

Real specific gravity	2.700	Weight in lbs. per cubic foot ...	96.60
Apparent specific gravity	1.546	Percentage of voids	42.8

N.B.—The largest grains contain calcareous concretions.

The sand is hauled to Kingston in wagons drawn by four horses or by steam tractors. As the cost of transportation is high, it sells delivered at $1.40 per cu. yard. It is used principally for building purposes, but also for core-making at the locomotive works in Kingston.

Robert Harpell, Cataraqui.—On lot 16, concession three, Kingston township. This sand pit is part of a farm of 100 acres owned by Mr. Rixbridge, 4 miles northwest from Kingston. This sand sells at 40 cents a load of 3 cubic yards in the pit, or at $5.00 for a similar load delivered in Kingston.

Big Sandy Bay, Wolfe Island.—A little of this sand is brought by boats to Kingston; it is sharp, and suited for building purposes. It is proposed to load this sand by pumping it directly in the scows which bring it to Kingston.

Glengarry County

In the township of Kenyon, forming the northwest part of this county, there are some sand and gravel pits round Alexandria, Maxville and Dunvegan (fig. 20).

Most of the material is coarse gravel used for road work, and is not always of first quality. The gravel is very coarse, principally near the top, and contains many boulders, sometimes larger than one foot in diameter. In some pits more than 50 per cent. of the pebbles should be rejected on account of their size. Near the bottom the fragments are smaller, and the material may become a pea gravel or a coarse sand. The pebbles are mostly angular; from 70 to 90 per cent. are of limestone, but the gravel, considered as a whole, is rather sandy, and 50 per cent. of sand is not rare. The depth varies little from one pit to another, 12 feet being a good average. This material is sold as low as 10 cents a cubic yard. A list giving the names of the owners, location and size of the principal pits and their annual output follows:—

No.	Owner	Township, Con. and Lot	Size in feet	Output	Remarks
1	McKinnon, Alexandria ...	Lochiel III, 37 ..	75 by 50 by 12	.....	Ridge 200 by 300 ft. in area.
2	Wm. Metcalfe, Greenfield	Kenyon IX.	100 by 100 by 12	3,000 yds.	Reserves 500 by 100 by 12 ft.
3	Campbell, Dunvegan	Kenyon VIII, 17 (W½)	50 by 30 by 5	60 loads ..	Reserves 75 by 75 by 10 ft.
4	McLeod, Dunvegan	Kenyon IX, 19	90 by 30 by 4	.....	Two pits about 100 yards apart.
5	Hugh McIntosh, Dunvegan	Kenyon IX, 21 ..	100 by 75 by 10	100 yds.	Reserves 50,000 cubic yds.
6	D. Kennedy, Maxville	Kenyon VIII, 36.	60 by 60 by 20	.....	Reserves 25,000 cubic yds.
7	N. K. McLeod, Maxville.....	Kenyon VIII, 35.	60 by 15 by 4	.....	.....

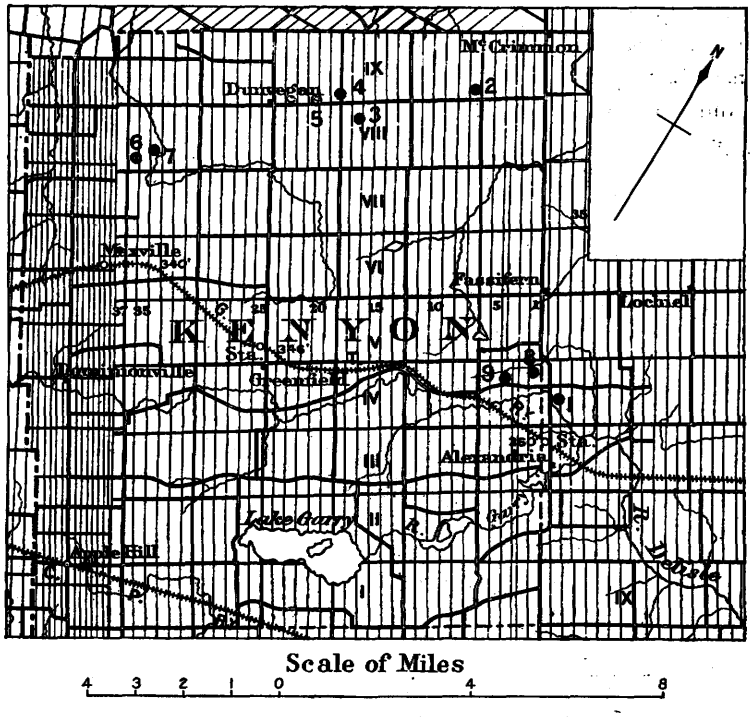


Fig. 20—Map of the township of Kenyon, Glengarry county, showing principal sand and gravel deposits. The numbers refer to the list given in the text.

Granular metric analysis of gravel in Wm. Metcalfe's pit:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained.	82.65[1]	90.70	93.45	95.45	96.75	99.20	99.70	99.80	99.90

Percentage of fineness, 4.71.

[1] The 82.65 per cent. remaining on the 4-mesh sieve is made up of 54.65 per cent. larger than 1-inch pebbles and 28.00 per cent. between 1-inch and .185-inch.

Some of these gravel pits contain sand layers, and this is the case in the Kennedy pit, Maxville. At the bottom of this pit there are two feet of sharp black sand, very good for building purposes. Most of this sand is made of limestone grains.

Granular metric analysis of sand from D. Kennedy's pit:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	6.80	14.30	21.65	58.35	85.25	97.95	98.70	98.80	98.90

Per cent. of fineness 35.5
Real specific gravity 2.722
Apparent specific gravity 1.706
Weight in lbs. per cubic foot ...106.60
Percentage of voids 37.3

Nap. Gauthier's Sand Pit, Alexandria (*No.* 8).—On lot 1, concession four, Kenyon township.—Excavation about 150 by 50 by 5 feet. The pit is not worked at present. The sand is fine and loamy near the top, and becomes coarser at the bottom. It is part of a ridge extending about a mile in an east and west direction and forming a watershed. Some sand of this formation was used for moulding purposes by the shell works in Alexandria.

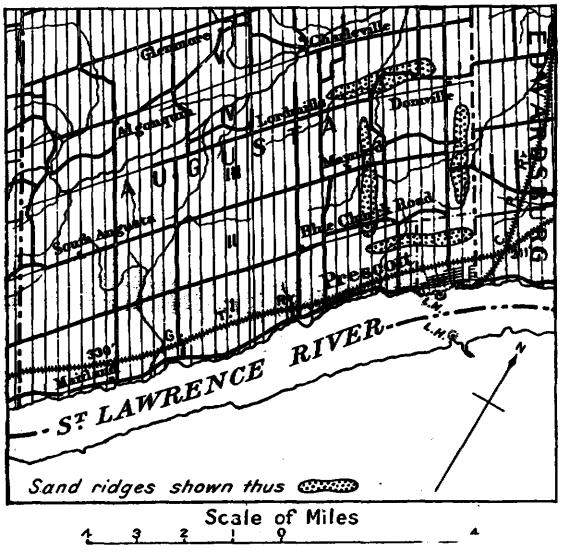


Fig. 21—Sand ridges north of Prescott, Grenville county.

McDonald's Sand Pit, near Alexandria (*No.* 9).—On the east half of lot 4, concession four, Kenyon. This belongs to the same formation as the preceding pit, and contains sand and gravel.

Grenville County

The deposits of sand north of Prescott belong to four ridges of sand dunes extending over concessions one, two and three, (fig. 21). Those dunes are advancing.

The length of the ridges is about one mile, with an average height of 15 feet and an average width of 250 feet. In concession one, this sand ridge

is about half a mile north of the Grand Trunk railway. It has a northwest direction, and extends over the cemetery and Prescott fair grounds. The sand is used for building. The excavations are generally refilled with sand a few days after they are opened. This sand is delivered in the town of Prescott for $1.00 a load of 1.5 cubic yards. There are two similar sand ridges but with a north and south direction, running through concession two, on both sides of the road to Domville. A fourth ridge with an east-west direction is located in concession four, on the grounds belonging to John Fell.

There is an important gravel ridge west of the sand dunes. The general direction of this ridge is N.30°E. Several pits have been opened, the average depth being 10 feet. The gravel contains a good proportion of sand; the pebbles range between 2 and 8 inches, in some places being very angular. About 50 per cent. consist of limestone, the remainder being eruptive and metamorphic rocks. This material is generally sold at 25 cents a yard at the pit. The following list gives the location, size and output of some of these gravel pits:

Owner	Township, Con., Lot	Size in feet	Output	Remarks
Corporation of Prescott	Augusta I, 8.	200 by 200 by 12	.....	Reserve: 1 acre.
Sterritt, Prescott	Augusta II, 10.	100 by 100 by 10	200 yd.	Pebbles smaller than in other pits.
Geo. W. Robinson, Prescott.....	Augusta II, 9.	200 by 200 by 10	.....	Reserve in sight: 300,000 cu. yds.
Wm. Robinson, Prescott.....	Augusta III 8.	.....	small	Large quantities available.

Granular metric analysis of gravel from Sterritt's pit:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	77.00[1]	81.05	83.40	88.90	92.45	96.95	98.15	98.70	99.40

Percentage of fineness, 9.33.

Grey County

The deposits of sand and gravel in this county are few in number. The writer examined a few small sand pits near Meaford. Most of the area between Meaford and Owen Sound is occupied by limestone and glacial deposits.

The Sydenham river at Owen Sound runs through a very deep and steep valley, with three different terraces. Sand and clay are found on each of them. A hole dug in one of the streets of Owen Sound, near the river, shows 1 foot soil, followed by 5 feet of sand overlying clay. There is a large sand pit south of the town on the slope of the second terrace. The excavation made on the side of the hill is about 70 feet high and yields sand for building purposes. South of Owen Sound, at Inglis falls, there is some sand and gravel.

[1] Of the 77 per cent. remaining on the 4-mesh sieve, 52.35 per cent. were pebbles larger than 1 inch in diameter, and 24.65 pebbles smaller than 1 inch.

R. Smith's Sand Pit, Inglis Falls.—On lot 9, concession two, Derby township. The pit is about 100 feet in diameter and 25 feet deep. From testings the sand is known to extend 25 feet deeper. The deposit covers about 2½ acres, making an available reserve of about 200,000 cubic yards. In this pit there are alternate layers of gravel for rough-casting, filtering sand and plastering sand. Near this pit is another containing only gravel. The output in 1916, when the pits were owned by Mr. Neelands, was about 300 yards. Selling prices were 15 cents a yard for road gravel taken at the pit and $1.20 a yard for filtering sand delivered at the filtering plant of Owen Sound, located about one mile from the pit. Rockford station on the Owen Sound branch of the C. P. R. is about one mile east of the pit.

Granular metric analysis of plastering sand, R. Smith's pit:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained.	0.30	0.80	1.35	3.90	11.80	71.00	91.65	95.85	98.20

Per cent. of fineness 58.35
Real specific gravity 2.732
Apparent specific gravity 1.575
Weight in lbs. per cubic foot.... 98.412
Percentage of voids 42.3

Granular metric analysis of filtering sand, R. Smith's pit:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained.	0.65	3.05	7.95	36.60	60.60	90.90	97.20	98.50	99.35

Per cent. of fineness 45.02
Real specific gravity 2.687
Apparent specific gravity 1.539
Weight in lbs. per cubic foot 96.163
Percentage of voids 42.7

Haldimand County

There is a good sand beach near Port Maitland, on the shore of Lake Erie, at the mouth of the Grand river. The deposits are in the form of sand dunes extending for two miles along the lake shore and 300 to 500 feet inland. The deposit is from 12 to 15 feet thick and overlies the limestone. There are various grades of sands and gravels in the dunes. Near the surface the material is generally blown sand that could perhaps be used as an abrasive for cutting stones. Under one foot of this material the sand is coarser, and is used for building purposes. It passes gradually into a limestone gravel before the solid rock is reached. Dredging of gravel and sand is done in the river by a pumping dredge; Jos. Battle of Thorold operated such a dredge during 1916.

Numerous deposits of sand and gravel occur near the Grand river in the northwestern part of this county (fig. 22). They are mostly round Caledonia and seem to be ancient river terraces. The gravels are principally composed of pebbles, but contain a little shale. The sands are generally sharp and of good quality for building purposes.

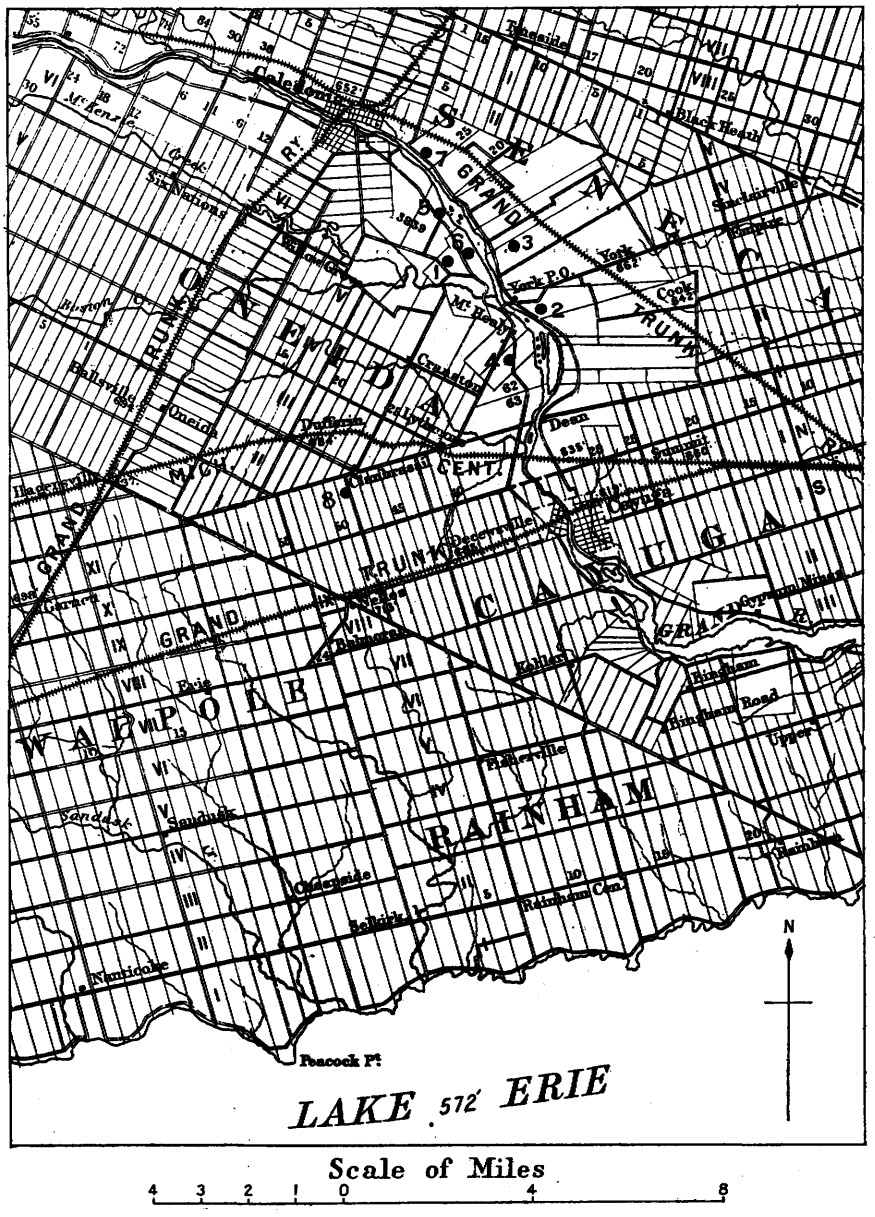


Fig. 22—Map showing sand and gravel pits along the Grand river, Haldimand county. The numbers refer to the list given in the text. No. 8 is the location of the Oneida Lime Co's. quarry.

The following list gives some information about the principal pits:

No.	Owner	Township	Size in feet	Product	Remarks
1	F. W. Foster, Caledonia.....	Oneida	60 by 60 by 7	Sand.....	Reserve: 4 acres, 2½ ft. of loam on top.
2	Isaac Gowland, York.....	Seneca	20 deep	Gravel	Idle; 5 ft. clay on top.
3	Robert Hamilton, Caledonia	Seneca	200 by 200 by 5	Gravel	Reserve: 10 acres, idle.
4	George Moore, Caledonia.....	Oneida	100 by 100 by 20	Gravel and sand	Only 1 ft. to be stripped.
5	Nicholas, Gideon, Caledonia	Oneida	.....	Sand	Not working.
6	Arthur Smith, Caledonia	Oneida (Tiffany Block)	80 by 80 by 10	Sand 150 yd. per annum	Reserve: 5 acres. Sold at 40 cents a yd.
7	David Young, Caledonia.....	Seneca	2 acres 10 ft. deep	Gravel.....	Not working.

Oneida Lime Co., Limited.—An interesting deposit is the one worked by this company in Cayuga township, near Nelles Corners. The headquarters of the company are in Buffalo. This company quarries Oriskany sandstone of Devonian age, and by crushing this material obtains a very pure white sand used for glass making. After washing, this sand contains sometimes as much as 99.50 per cent. of pure silica. The works have been operating six years. The quarry in 1917 measured 300 by 100 by 12 feet. There is an old quarry to the west of the present one of double the size.

The Oriskany sandstone appears to form a small basin overlying the Salina limestone beds of Silurian age and covered by the Onondaga limestone. At the quarry the section is as follows:

Brown soil	4 to 6 inches.
Coarse sandstone	4 "
White and fine sandstone	3 feet.
Coarse sandstone	4 inches.
Ferruginous sandstone	6 "
Quartzitic sandstone	6 feet.
Dolomitic limestone	

The rock varies in grain and nature in a vertical as well as in a horizontal direction. At some places, the sandstone can be crushed to sand between the fingers; at other places, it is much more like a quartzite.

The Oneida Lime Co., Ltd., owns about 150 acres. To the east of its property and on the same outcrop, there is another property, 200 acres in size, belonging to the Consolidated Plate Glass Co.

The material from the quarry is washed and crushed to a coarse sand, composed principally of small grains, but containing also some fragments up to 8 mm. in diameter. In this state the sand is suitable for use in steel plants. To produce glass sand, the crushed material is passed through an 8-mesh screen and the oversize is recrushed. There were about 25 employees working for the greater part of the year. Some material is shipped during winter months from storage bins. The output for 1916 was about 15,000 tons and sold at $1.50 to $1.70 a ton.

Granular metric analysis of glass-making sand, Grade No. 6, The Oneida Lime Co.:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained.	0.00	1.20	2.50	7.60	17.70	64.80	93.60	98.15	99.40

Per cent. of fineness	57.23	Apparent specific gravity	1.64
Coefficient of uniformity	75.90	Weight in lbs. per cubic foot	102.474
Real specific gravity	2.612	Percentage of voids	37.2

Two analyses made at the Babcock Testing Laboratory, Buffalo, of crushed sandstone from this quarry follow:

	Old Quarry.	New Quarry.
Moisture	0.00	0.00
Loss on ignition	0.93	0.13
Iron (metallic?)	1.63	1.48
Al_2O_3	trace	trace
CaO	1.55	0.71
MgO	0.30	trace
S	0.11	0.08
SiO_2 (by difference)	95.48	97.60
Total	100.00	100.00

It is probable that the iron considered as metallic is in the form of magnetite (Fe_3O_4).

Following is a chemical analysis of this sand, ready for glass works, by W. K. McNeill:—

	Per cent.		Per cent.
Silica	96.54	Alkalies	0.94
Alumina	0.96	Carbon dioxide	0.59
Ferric oxide	trace	Water	0.15
Ferrous oxide	nil		
Lime	0.90		100.08

The figures of the three analyses are very similar, and confirm the value of this material for chemical industries. This sand would be suitable for the manufacture of silica brick. Similar materials are used for such purposes in France. From a recent note of M. Philippon [1] the following results are taken:

(1) The crushing strength of the bricks after drying and burning is greater the more finely the quartz grains are pulverized.

(2) All the quartz tested will give strong bricks if it is sufficiently pulverized.

(3) The swelling or expansion on burning of the brick made of similar grains is greater when the grains are large. The expansion is practically nil for impalpable powders.

(4) The strength of the brick after drying and burning is greater as the amount of water introduced into the paste is increased.

(5) The strength of the brick after drying depends on the amount of lime added to the quartz. The strength of the brick after burning increases up to 1 per cent. of lime, remains constant between 1 and 2 per cent., and seems to decrease for more than 2 per cent.

(6) Every unit of lime added to the quartz reduces the melting point by about 20° C.

Bricks made from impalpable powder begin to harden at 800° C.

At 1,200° C. their crushing strength is about 2,700 lbs. per square inch; at 1,300° C. it is about 4,000 lbs. per square inch. Bricks made from coarser grains begin to harden only at 1,100° C. At 1,300° C. their crushing strength is only 1,000 lbs. per square inch.

The less fusible bricks are those containing the minimum of impalpable material. In a good brick the grains should not be larger than 8 mm. in diameter.

[1] La fabrication des briques de silice. Compte Rendus des séances de l'Académie des Sciences, Paris, Tome 165, No. 25, December 17th, 1917, pp. 1002-1005.

In practice silica bricks should be made from pulverized silica containing at least 96 per cent. SiO_2. Crushed Oriskany sandstone is of such a standard composition. In France silica bricks are made from a mixture of 30 per cent. impalpable powder, and 70 per cent. silica grains ⅛ mm. in diameter. The impalpable powder contains about 2 per cent. lime, the remainder being silica. The total amount of lime in the brick is thus not higher than 0.6 per cent. These bricks are burned at 1,300°C. in a tunnel kiln. They have a crushing strength of 2,800 to 3,500 lbs. per square inch. The average expansion on burning is 1.6 per cent. The absolute specific gravity is lower than 2.4, the apparent specific gravity being about 1.9. The melting point is near 1780°C. Such bricks have lasted for more than 200 runs in a Martin furnace. They are in general use in steel plants and foundries.

Physical properties of sand, grade No. 7, from Port Maitland beach, Haldimand county:

Granular metric analysis:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	0	0	0	traces	0.10	10.90	83.55	97.65	99.55

Per cent. of fineness	67.58	Apparent specific gravity	1.62
Coefficient of uniformity	86.85	Weight in lbs. per cubic foot ..	101.224
Real specific gravity	2.834	Percentage of voids	42.5

Haliburton County

The Irondale, Bancroft and Ottawa railway runs through the southwest corner of Haliburton following a series of lakes and the Irondale river, a tributary of the Burnt river. In this part of the county limestone hills rise often very steeply, but in the immediate neighbourhood of the shore lines there is an alluvial plain made of sand and silt. The sand is generally ferruginous, and contains limestone and feldspar fragments. The proportion of quartz is occasionally very small. The deposits extend sometimes for miles, although they are not wider than 300 yards. In some places the pebbles become more abundant, and the material could be used for building purposes, as ballast for railroads and for road work.

Snowdon Township

In the southwestern corner of Snowdon township, there is an area covered by an apron of sand 10 to 15 feet thick and sometimes 60 feet higher than the level of the Burnt river at Kinmount. The road marking the boundary between Haliburton and Peterborough runs for about three miles through this sandy terrace, under which appear gneissoid rocks with numerous veins of pegmatite. A similar apron of sand and gravel lies along the tracks of the Grand Trunk railway, Haliburton branch, principally near the station of Gelert. North of Gelert it is seen in several road and railway cuttings, the thickness of the deposits being at some places 40 feet.

Dysart Township

In the township of Dysart a large sand and gravel pit was excavated on lot 13, concession seven, west of the railway, the material being principally used for ballast and road work. The pit is of two parts, the first being 200 by 20 by 6 yards, the second 200 by 30 by 10 yards in size. The total material removed amounts to nearly 100,000 cubic yards. The pit is not worked at present, but a reserve of 100,000 cubic yards is still available. This pit is about one and a half miles south of the town of Haliburton. On lot 14, concession seven, south of the railway, there is a smaller pit, 200 by 100 by 30 feet in size, producing sand and gravel. The deposits round the lakes at Haliburton form a sand terrace about 40 feet above the water level. The sand is ferruginous, and may be used for road and building purposes. To the north of Haliburton, small local deposits resulting from the weathering of the underlying granitic gneiss are sometimes met. Such is the case about one mile and a half north of Haliburton along the road to Moose lake. A small deposit of ferruginous sand mixed with stones was worked here and used for re-filling the adjoining road. The deposit is about 90 feet above water level at Haliburton, and the excavation 75 by 30 by 4 feet in size.

Special reference should be made here to a particular industry developed in Haliburton by Bollender Bros. Crystalline limestone is quarried about one mile east of Haliburton, on the north shore of the river, on lot 19, concession eight, of Dysart. The rock is a white dolomitic limestone, very crystalline and containing in parts numerous grains of chondrodite altering to serpentine, and small flakes of a blue greenish phlogopite. Mr. Bollender gave us the following analysis of this material:

	Per cent.
$CaCo_3$	50
$MgCo_3$	5
Impurities	5

The excavation is at present 40 by 20 by 6 yards. The work started in 1914. The rock is quarried in lumps about 6 inches in diameter and sent to the mill where it is crushed to ⅛-inch and screened to five different grades. The product is used as poultry grit, as stone dust or agricultural lime, and for mixing with cement (aggregates, plastering, floors, artificial stone, etc.), for filtering basins, and for washing compounds. The tonnage shipped in 1917 amounted to 500 tons, the average price being $4 a ton for crushed material. Some part of this production goes to the western provinces. The several grades are screened as follows:

Below 60-mesh: Fine dust used for washing compounds.
From 60-mesh to 10-mesh: Agricultural lime, mixing with cement, etc.
From 10-mesh to 8-mesh: Grit for birds and young chickens.
From 8-mesh to 5-mesh: Grit for pigeons.
From 5-mesh to ⅛ in.: Poultry grit.

Halton County

There are no deposits of importance along the shore of Lake Ontario, in this county, but in the northeastern corner of the county, round Glen Williams and Georgetown, some sand and gravel are available.

North of Glen Williams there is a sandy hill about 75 feet high and 125 feet wide where it crosses the road. This hill extends for several hundred yards on either side of the road, and contains deposits of both sand and gravel. A sand pit has been opened on the side of the hill on the property of Jos. Beaumont of Glen Williams. Only a few loads were sold in the last few years. A small gravel pit has also been opened up from which material has been taken for road work.

With regard to gravel, the most important pits lie round Georgetown. Sand beds of small thickness occur occasionally in these deposits. The gravel is rather coarse near the top, and becomes finer in the central part of the bed. It is made up of pebbles of different size and shape, mostly limestone, but there are also some pebbles of sandstone, shale, granite, and quartz. These gravels make very good material for road purposes; certain grades are self-cementing. The gravel is generally sold at 25 cents a load of 1.5 cubic yards. The various pits are indicated in the following list:

Owner	Township, Con. and Lot	Size in feet	Output per year	Remarks
Jas. Arnott, Georgetown...	Esquesing tp. Con. VII., lot 17	.....	.....	6 ft. loam to strip.
J. A. Willoughby, Georgetown...	Esquesing tp. Con. VII., lot 17 (W½)	150 by 100 by 25.	2,400 yd.	0–5 ft. to strip. Reserve, 3 ac.
James Buck, Georgetown.,,	Esquesing tp., Con. VII., lot 18	100 by 40 by 20.	150 yd.	Reserve, ½ ac. Idle in 1917.
John Giffen, Georgetown...	Esquesing tp., Con. VIII.....	100 by 100 by 60.	.....	Alternate layers of gravel and sand.

The physical properties of sand from J. Beaumont's pit, Glen Williams, are shown by the granular metric analysis, as follows:

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	0.30	0.90	1.45	5.75	11.30	49.90	85.25	94.15	98.60

Per cent. of fineness 61.38
Coefficient of uniformity 73.95
Grade ..... No. 6
Real specific gravity 2.766
Apparent specific gravity 1.67
Weight in lbs. per cubic foot .. 104.348
Percentage of voids 39.6

Granular metric analysis of gravel from J. Buck's pit, Georgetown:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	51.55[1]	65.70	75.20	91.80	96.35	99.15	99.50	99.60	99.75

Per cent. of fineness, 13.5

[1] The 51.55 per cent. remaining on the 4-mesh sieve consists of 31.40 per cent. pebbles larger than one inch, and 20.15 per cent. smaller than one inch. Some pebbles are made of cemented grains.

Hastings County

Deposits of sand and gravel are scarce in this county. There are some deposits near Belleville, but along the Bay of Quinte there is practically no gravel, nor any sand east of Belleville, before reaching Quinte point, 14 miles from the city and 8 miles west of Deseronto. The greater part of the shore of the Bay of Quinte is marked by limestone outcrops. There is a deposit of gravel west of the Prince Edward bridge, largely used for the supply of Belleville.

John Creeper's Pit.—John Creeper, Belleville, owns some sand and gravel pits situated east of the road to Madoc, in the eleventh concession of Thurlow township, just one-quarter of a mile from the limit of Belleville. These pits supply a dozen different kinds of sand and gravel. Two pits are now working, the northern one producing principally gravel, the southern pit chiefly sand. The northern pit is at present 150 by 90 by 10 feet. The deposit is principally composed of limestone pebbles, which are generally flat and angular. It looks like the upper portion of a limestone formation crumbled to pieces. Different beds

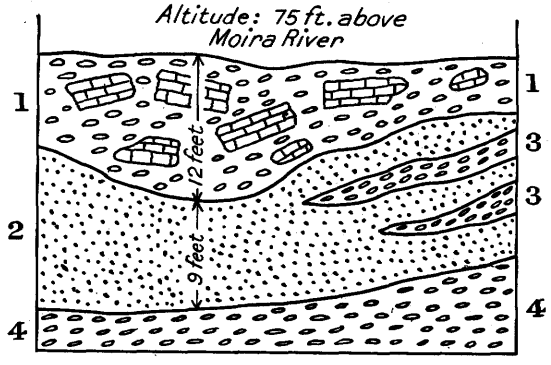


Fig. 23—Section of John Creeper's sand and gravel pit. (1) Gravel, with limestone boulders. (2) Sand. (3) Black limestone gravel layers. (4) Gravel.

are to be found in the gravel, some being more shaly and dark in colour, the others composed of limestone only. In one of the walls an anticline was very well marked. Very few granitic pebbles are to be found in the gravel, which consists mostly of material in place. The walls of the pit are vertical and hold very well. The gravel is used for road and concrete work.

The southern pit is located near the highest point of the hill, about 75 feet above the level of the Moira river, where the limestone outcrops. At present the size of the excavation is 600 by 120 by 25 feet, the longer dimension being east and west, while the depth increases to the east. The section is shown in the accompanying diagram (fig. 23). The upper part is composed of gravel with very large flat limestone boulders sometimes one yard long. Some of the pebbles are, however, of igneous rocks. The wall of the pit is about 25 feet high and stands perfectly straight. The gravel at the top is kept together by some calcareous sand and is used for making concrete. Beneath the gravel is a bed of sand eight feet thick, which is used for mortar.

Under the sand comes some black gravel which is believed to be of considerable depth. The sand is a mixture of quartz grains and calcareous material in the form of calcite and limestone grains. The calcareous nature of this sand is shown by the following chemical analysis by W. K. McNeill.

	Per cent.		Per cent.
Silica	55.46	Potash	2.04
Alumina	9.99	Soda	2.62
Ferric oxide	0.81	Carbon dioxide	11.04
Ferrous oxide	1.58	Water	0.43
Lime	14.88		
Magnesia	1.29	Total	100.14

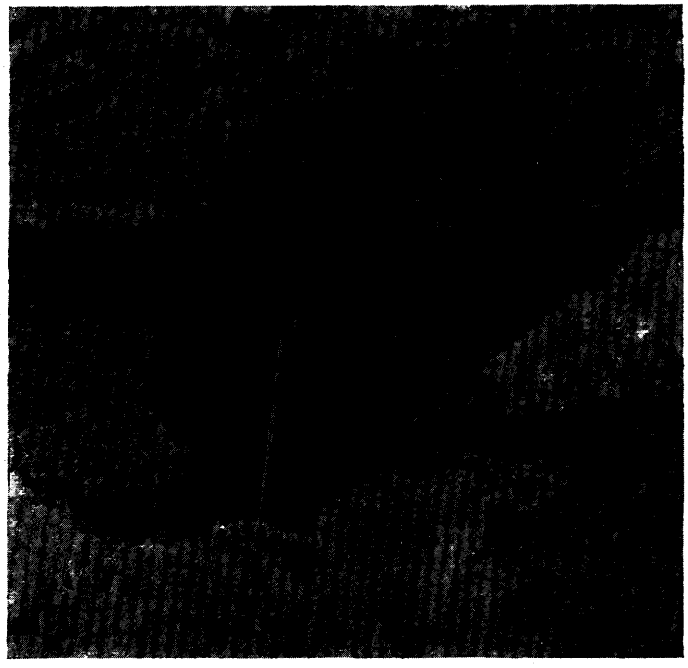


Fig. 24.—Shallow excavation in cemented material, J. Creeper's sand and gravel pit.

Norm calculated from the preceding analysis:

Calcite	25.10	Magnetite	1.16
Orthoclase	11.68	Enstatite	3.20
Albite	22.01	Grünerite	2.24
Anorthite	4.17	Quartz	28.02
Corundum	2.04	Water	0.43
		Total	100.05

The outstanding feature of this norm is the very low content of quartz. The feldspars seem to be more abundant than one would conclude from a casual examination of the material. The large percentage of calcite explains the autocementing properties of this sand.

and Georgetown, some sand and gravel are available.

The physical properties of the sand are shown by the granular metric analysis:

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	0.00	0.10	0.40	4.20	13.90	60.70	86.05	93.25	98.00

Per cent. of fineness 60.38
Coefficient of uniformity 72.15
Grade ..... No. 6
Real specific gravity 2.788
Apparent specific gravity 1.70
Weight in lbs. per cubic foot ...106.223
Percentage of voids 39.0

Granular metric analysis of gravel from Creeper's pit:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	49.80	63.85	69.50	79.10	85.55	94.45	97.55	98.55	99.30

Per cent. of fineness, 18.04.

Near Corbyville, on the eastern shore of the Moira river, on lot 6 in the fourth concession of Thurlow, a deposit of sand overlies the clay. There is about one foot of loam, then some ferruginous sand, and beneath sharp white sand. The sand is very pure, and could perhaps be used for glass-making. The property is owned by Wilson Reid.

Hungerford Township

In the township of Hungerford, deposits of sand and gravel are found in the neighbourhood of Tweed. At the northeastern end of Stoco lake, small sand deposits resulting from the weathering of granitic rocks outcropping in this area are found near the lake shore. Small sand beaches are also noticed in little bays of the lake. On lot 17, concession ten, a large sand ridge about 100 yards wide and 500 yards long extends in a southwest and northeast direction. It contains large and valuable reserves of sand for building purposes, and lies about 25 feet above the lake level. This ridge represents an old beach of Stoco lake.

On the south and western shores of Stoco lake, along the road running from Chapman to Tweed, there are several sand and gravel ridges, sometimes 100 feet above the present level of the lake. One of the ridges is located just north of Chapman, on lot 8, concession seven. A pit on this ridge supplies mostly sand, although there is also some gravel. The excavation is 60 by 20 by 10 yards. On lot 9, concession eight, a gravel pit 50 by 50 by 25 yards in size has been opened; it is located two miles south of Tweed, the gravel being mostly used for road work. Another pit on lot 10, concession nine, is one mile south of Tweed and also supplies road material. The excavation is 100 by 30 by 12 yards.

In the western part of Tweed, there is a gravel and sand ridge on the farm of W. H. Hicks. A pit 100 by 40 by 20 yards in size supplies coarse sand for building purposes and road gravel. About three miles west of Tweed there are two small gravel pits on Geo. Graham's farm, lot 3, concession eleven, township of Hungerford. Reserves are very large, but the output in 1917 was only 150 loads sold at 10 cents per load.

In the northern part of Hungerford township the country is composed of Archean rocks covered by a mantle of earth and boulders. At some places it becomes very sandy, and between Tweed and Actinolite, for instance, large areas have been covered by sand brought in by the Moira and Scootamatta rivers. Some parts of the river banks present fine sand beaches. There is in this part of Hastings a large reserve of available material, the sand being generally coarse and fit for building purposes. It contains as a rule a large amount of limestone and granitic detritus, calcite, feldspar and kaolinite being common components. This is probably the reason why crops do well on these sandy areas.

Elzevir Township

At Actinolite, in the township of Elzevir, there is a big gravel pit about 100 by 50 by 15 yards in size, the products being largely used for road work.

Between Actinolite and Queensboro, some terraces noticed along the railway are sandy, and great reserves of ferruginous sand derived from the alteration of the country rocks are available. At the lower levels more gravel is mixed with the sand, and some gravel pits have been opened in the deposits near mile 45 of the Bay of Quinte railway, close to Queensboro and Allan stations, the latter place being located in Madoc township.

Madoc Township

Similar deposits are found in the township of Madoc, at some bends of the river south of Bannockburn. The sand often contains a large amount of lime and iron, and is brown in colour. A terrace about 25 feet above the present level of the Moira river is indicated by a large deposit of sand, at least 10 feet thick, covering several acres and located on lot 24, concession five, Charles White's farm. This sand contains a large proportion of calcite grains. However, as a whole, the area around Bannockburn is rocky, and arenaceous deposits are scarce. Similar conditions prevail in Tudor and Limerick townships.

Dungannon Township

It is only near Turiff, in Dungannon township, that gravel and sandy material appear over the area made up of limestone and amphibolites. This locality is in the drainage area of the Ottawa river. The sand found here is the product of decay of the neighbouring massive rocks, and was sorted by the rivers and lakes of the country in the earlier stages of their history. It contains as a rule a large amount of lime and some silt. The stratification is often oblique. The occurrences are local, but near the Bay of Quinte railway sometimes extend over large areas. Good examples of such deposits are to be seen near Bancroft and L'Amable station. One pit is located 200 yards east of the York river at Bancroft,

on the south side of the road to Bronson, lot 63 of the gore of Faraday township. The excavation is 30 by 10 by 7 yards in size, and supplies sand and gravel. Other areas along the York river and its tributaries are covered by drift of a sandy nature, this being the case between Bronson and the bridge on the York river, along the road running east from Bancroft; and in the area northwest of Bancroft along the York river and Baptiste lake. In this northern part of Hastings, the Archean rocks appear mostly as rounded hills, the slopes near rivers and lakes being often covered by sand, gravel, silt or clay.

Huron County

The sand and gravel beach at Kincardine in Bruce county extends to the south in Huron county as far as Goderich. In the remainder of the county, sand is comparatively rare, but there are many gravel pits in the townships of Hay, Usborne and Stephen, near Crediton, Dashwood, Exeter, Hensall and Zurich. Most of these deposits are connected with the shore line of the ancient Lake Algonquin. Sometimes the bottom of the pit is of sand. The gravel is often variable in the same deposit. At the top it is generally very coarse, with some pebbles as large as 10 inches in diameter, but the regular gravel of this county is made of angular pebbles not larger than 3 inches. Finer grades such as pea gravel are found sometimes near the bottom. As to its composition, the gravel is mostly made up of limestone pebbles intermixed with sandy material. The coarse gravel is used for road making, and is sold at about 10 to 15 cents a yard, while finer cement gravel is sold at 25 to 30 cents a yard. Following is a list of the principal gravel pits in the region round Exeter and Crediton:

Owner	Township, Con. and Lot	Size in feet	Output	Remarks
Ed. Campbell. Exeter	Usborne, near N.E. corner, Con. VI	.....	.....	Not working.
John Cann, Exeter	Usborne, Con. V, lot 31	50 by 50 by 30	.....	Not working, sand and gravel.
Wm. Moody, Exeter	Usborne, Con. II	.....	.....	Large pit.
Wm. J. Robinson, Crediton	Stephen, Con. III. lots 4, 5	200 by 60 by 16	1,000 yd.	Reserve, 1 ac.
John Rollins, Crediton	Stephen, Con. V, lot 8	125 by 75 by 6	1,000 yd.	
Peter Whitlock, Hensall	Usborne, Con. V, lot 30	3 pits about 50 by 50 by 30	.....	
John Wood, Exeter	Usborne, Con. IV–V	600 by 300 by 12	1,500 yd.	Reserve, 8 ac., gravel and sand.

Granular metric analysis of sand in J. Cann's pit:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained,	8.85	33.10	48.10	66.45	72.85	87.80	96.50	98.45	99.35

Per cent. of fineness 32.06
Coefficient of uniformity 39.25
Grade ..... No. 2
Real specific gravity 2.718
Apparent specific gravity 1.85
Weight in lbs. per cubic foot ...115.60
Percentage of voids 31.90

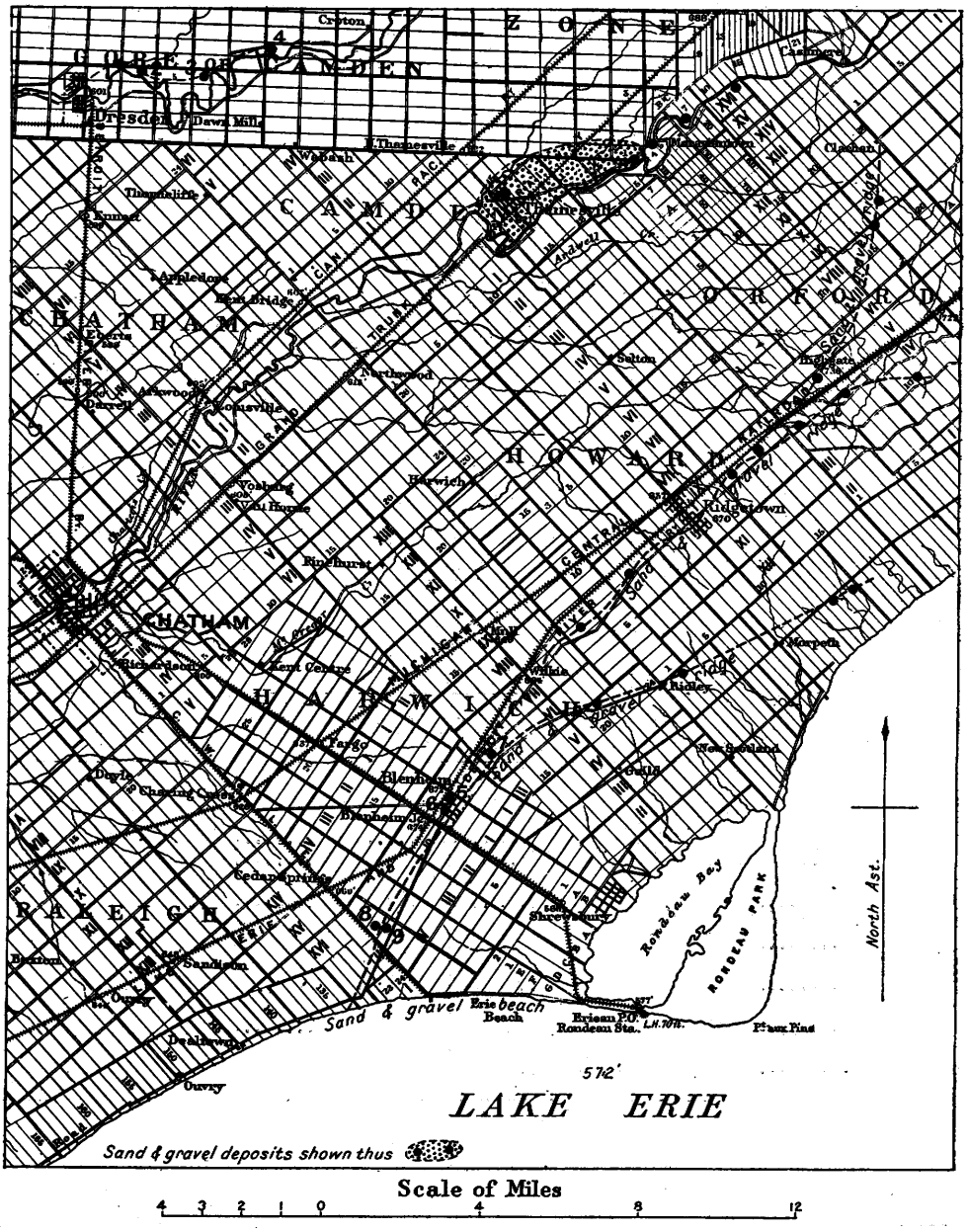


Fig. 25—Map of the eastern part of Kent county, indicating location of sand and gravel deposits. The numbers refer to the list given in the text.

Kent County[1]

In this county sand and gravel (fig. 25) are found as recent deposits along the Lake Erie shore, principally at the southwestern end of the county, in the township of Romney, and also in Harwich township, near Rondeau Park. A sandy and gravel beach 30 to 40 feet wide is met south of Cedar Springs and extends as far as Erieau and Rondeau Park. There is a clay dike north of the beach, parallel to the lake shore. At Erieau the beach is 100 yards wide and about 150 yards at the eastern end near the harbour. The sand is coarse; near the water there is a strip about 4 feet wide of limestone pebbles one and two inches in diameter. Dredging was done on this part of the shore, but has been discontinued.

Other recent deposits are found along the Thames river in Camden township and near the Sydenham river, in the Gore of Camden. The deposits along the Thames occur principally around Thamesville, and are due to floodings in this flat region. In this area, extending to the northeast as far as Moraviantown, the principal gravel pits are those owned by Arthur Tiffin and Mrs. Wm. Watts. The pit of Mrs. W. M. Sherman, in Thamesville, is a sand pit. The sand is pure and coarse. The gravels of this area are generally fine and made of limestone pebbles. The sand is sold at about 25 cents a yard, the gravel at 75 cents. At the top of these recent deposits of sand there is sometimes a small layer of moulding sand. Such is the case at Arthur Tiffin's pit, where at places this layer is two feet thick.

The recent deposits near the Sydenham river are located around Dresden. They are generally of coarse sand containing some pebbles, and are used for cement work. There is here also some moulding sand at the top of the deposits.

Herewith are particulars of the pits about Thamesville and Dresden:

No.	Owner	Township and Con. and Lot	Size in feet	Output	Remarks
1, 2	Rice, Geo. A. and Sons, Dresden	Gore of Camden, Con. III and IV, lot 5	60 by 60 by 8	140 yd.	3 ft. earth at the top, some moulding sand.
3	——Sharp, Dresden	Gore of Camden, Con. VI, lots 4 and 5	100 by 100 by 10	.....	South shore of river.
4	——Richards, Dresden	Gore of Camden	.....	.....	Not working.
	Arthur Tiffin, Thamesville	Camden, Con. X, lot 6	300 by 100 by 7	.....	2 ft. of soil on top.
	Mrs. Wm. Sherman, Thamesville	Camden	200 by 100 by 10	.....	2½ ft. to strip. Reserve 2 ac.
	Wm. Watts, Thamesville	Camden	300 by 75 by 8	.....	Large reserve.

Besides the recent deposits there is an extensive sand and gravel ridge running from Lake Erie, about south of Cedar Springs, in a northeasterly direction, and passing through Blenheim, Wilkie, Ridgetown, Highgate, and Clachan, thus extending over the townships of Harwich, Howard and Orford. East of Blenheim the ridge subdivides into two branches, the southern one passing through Ridley, Morpeth and Palmyra. The ridge is of variable width and depth; it has its largest

[1] For further details respecting road material in the county of Kent, see L. Reinecke's Report, op. cit., pp. 115-137.

width, 600 ft., at the southwestern end near the lake shore; the depth varies between 5 ft. and 60 ft. The material comprises different grades of sand and coarse gravel. In the following table are given some details of the principal pits visited.

No.	Owner	Township, Con. and Lot	Size in ft.	Output	Remarks
5	— Blenheim	Harwich, Con. I, lot 10.	150 by 75 by 7	.....	Sand pit.
6	Ross, Blenheim	Harwich, Con. I, lot 11.	100 by 60 by 6	.....	Gravel of fine grade.
7	Young, Blenheim.....	Harwich, Con. II, lot 10.	.....	.....	Worked out.
8	Wallaceburg, Chatham and Lake Erie Ry. Co.....	Raleigh, Con. II, lot 24	500 by 150 by 30	.....	Coarse and pea limestone gravel, sandstone and a little shale.
9	Townships of Raleigh and Harwich.....	Raleigh, Con. II, lot 24	75 by 75 by 30	.....	Fine gravel, some iron oxide.

Granular metric analysis of sand, Geo. Rice and Sons, Dresden:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained.	1.75	12.00	21.00	38.80	45.75	63.20	88.50	95.85	98.10

Per cent. of fineness 48.34
Coefficient of uniformity 42.75
Grade ..... No. 6
Real specific gravity 2.578
Apparent specific gravity 1.65
Weight in lbs. per cubic foot ...103.10
Percentage of voids: Calculated.. 36.0
Measured . 34.5

Granular metric analysis of sand from Arthur Tiffin's pit, Thamesville:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained.	2.40	4.45	5.85	9.70	12.50	34.10	82.65	91.45	95.95

Per cent. of fineness 62.33
Coefficient of uniformity 70.15
Grade ..... No. 6
Real specific gravity 2.748
Apparent specific gravity 1.66
Weight in lbs. per cubic foot... 103.72
Percentage of voids 39.60

Lambton County

A line of deposits (fig. 26) passing through Copleston, north of Petrolia, Wyoming, north of Watford, and bending then slowly to the north, while passing through the counties of Middlesex and Huron, runs about parallel with the present shore of Lake Huron at an average distance of ten miles. These deposits are probably connected with an old shore line of Lake Algonquin. Numerous pits have

been opened at the several places mentioned, as the deposit extends over a large area and contains great reserves of sand and gravel. The ridge is sometimes wider than 1,000 feet, and in this county alone from the Copleston area east, it runs for more than twenty miles. It supplies good building sand, cement gravel and road gravel. Gravel is the predominant material, and this consists principally of limestone; around Petrolia and Copleston there is very little slate among the pebbles, but in some places, as at Watford, the quantity of limestone becomes smaller, and most of the pebbles are shale in a state of alteration to clay and iron oxide. When used

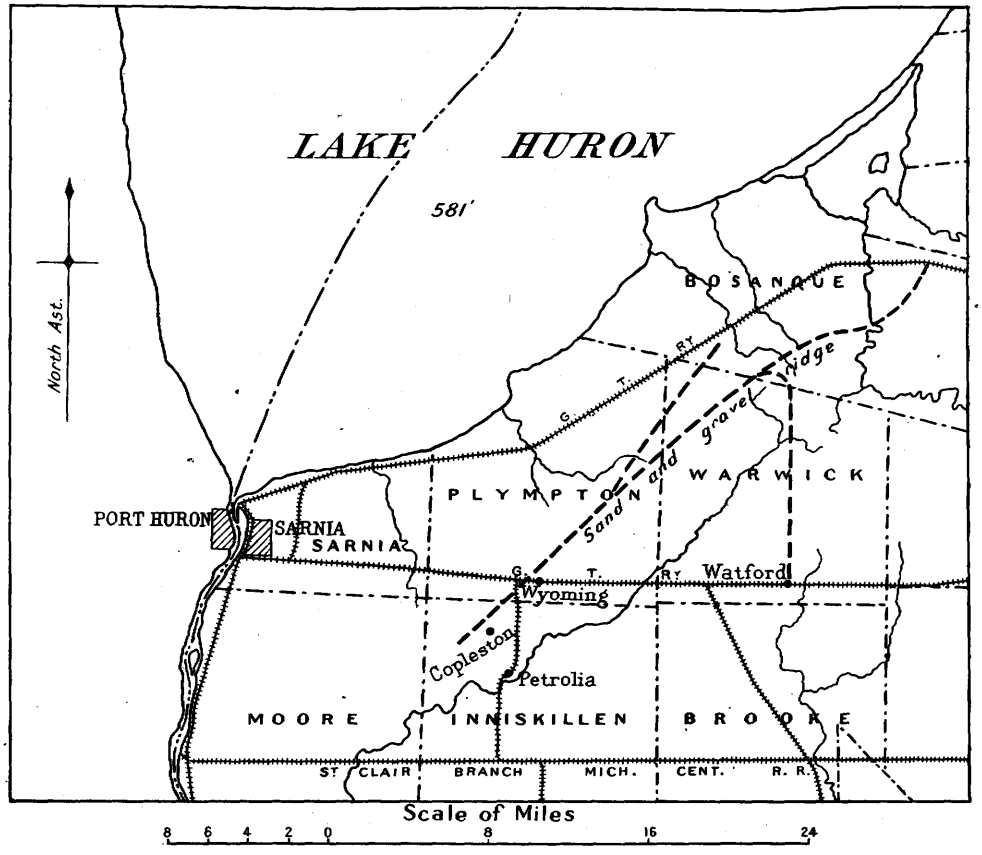


Fig. 26—Northern part of Lambton county, showing the location of the sand and gravel ridge passing near Copleston, Wyoming and Watford.

on roads such gravel produces a large amount of fine dust. The poor quality of such road gravel explains why it is sold at 16 cents a yard in the pits near Watford, while at Copleston the average price is 50 cents a yard. The working of the pits is very often done in a wasteful way, 3 or 4 feet generally remaining unworked at the bottom of the pit. The teamsters loading the gravel in a pit prefer to take the upper layers, as they are much more easily shovelled into their wagons; or they take only the very best material, that of inferior quality being disregarded and covered by loam and earth.

The following list gives some details about the deposits connected with the shore line of the ancient lake Algonquin:—

Owner	Township, Con. and Lot	Size in ft.	Output	Remarks
John W. Cann, Copleston	Enniskillen, Con. XIII, lot 7.	150 by 150 by 7	200yd.	Cement gravel, ferruginous at the bottom. Reserve 2 acres.
Enniskillen tp., Petrolia.	Enniskillen, Con. XIII.	300 by 150 by 10	1,000 yd.	Sand and gravel. Reserve 2 acres.
Estate, J. Kerr, Petrolia.	Enniskillen, Con. XIII, lot 9.	300 by 200 by 10	.....	Sand and cement gravel. Reserve 1.5 acre.
John Kerr, Petrolia	Enniskillen, Con. XIII, lot 13.	150 by 150 by 15	2,000 yd.	Sand and gravel. Reserve 0.5 acre.
Robert Kettle, Petrolia..	Enniskillen, Con. XIII, lots 7 & 9	Two pits, 60 by 60 by 10, 300 by 150 by 8.	500 yd.	Sand and gravel 23 ft. deep. Reserve 20 ac.
Wm. Kettle, Petrolia....	Enniskillen, Con. XIII.	325 by 100 by 12	500yd.	Sand and gravel. Reserve 10 acres.
Jno. McPhedran, Petrolia	Enniskillen, Con. XIII.	300 by 300 by 10	.....	Sand and gravel. Reserve small.
Robt. Whiting, Copleston.	Enniskillen, Con. XIII, lot 13.	400 by 150 by 8	1,000 yd.	Cement gravel. Reserve 1.5 acre.
Jno. Wooley, Petrolia....	Enniskillen, Con. XIII, lot 7.	500 by 125 by 6	.....	Gravel of variable grade, 12 ft. deep. Reserve 1.5 acre.
Richard Bryson, Wyoming	Plympton, Con. V, lot 18.	100 by 100 by 12	200yd.	Gravel and sand.
Thos. Conboy, Wyoming..	Plympton, Con. V, lot 17.	10 deep.....	.....	Gravel. Reserve 1.5 ac.
Corporation of Wyoming.	Plympton, Con. I, lot 16.	200 by 100 by 6	.....	Gravel.
G. T. R., Wyoming.....	Plympton, Con. I, lot 16.	400 by 200 by 10	.....	Gravel.
Lucas, Wyoming.....	Plympton, Con. V, lot 18.	200 by 100 by 10	750yd.	Cement and road gravel, and sand.
Isaac Mariett & Son, Wyoming.	Plympton, Con. V, lot 18.	400 by 125 by 7	.....	Not worked.
Stonehouse, Wyoming....	Plympton, Con. I, lot 15.	1 acre by 15 ft..	750yd.	Road gravel.
Robt. Fleming, Watford..	Warwick, Con. IV, lot 17.	600 by 150 by 4	250yd.	Cement gravel. Reserve 1 acre.
Robt. Lucas, Watford....	Brooke, Con. XII, lot 12.	300 by 150 by 12	300yd	Road gravel. Reserve 3 acres.

Granular metric analysis of sand from R. Kettle's pit, Copleston:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	0.0	1.30	2.80	6.15	8.95	43.80	86.10	93.85	98.40

Per cent. of fineness	62.07	Apparent specific gravity	1.62
Coefficient of uniformity	77.15	Weight in lbs. per cubic foot...	101.22
Grade	No. 6	Percentage of voids	40.8
Real specific gravity	2.738		

Granular metric analysis of gravel from R. Kettle's pit, Copleston:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	57.15	62.35	63.75	66.10	68.15	89.15	97.95	98.70	99.30

Per cent. of fineness, 21.93.

Other deposits of sand and gravel occur in the county of Lambton. Ten miles north of Wyoming, there is a gravel beach along the shore of Lake Huron. In the township of Euphemia, there are some pits round Aberfeldy and others near Cairo. The walls of these pits are made of alternate layers of gravel and sand. This material is sold at 75 cents a yard in the pit. There are only two pits working at present:—

Owner	Township, Con. and Lot	Size in feet	Output	Remarks
Samuel Turtle, Aberfeldy.....	Euphemia, Con. IV, lot 26.	200 by 100 by 12	600yd.	The gravel does not contain pebbles larger than 2 in. Reserve: 60 acs.
John L. Munroe, Cairo	Euphemia.	250 by 75 by 8	.....	Fine gravel and sand. Reserve: 1.5 acs.

Lanark County

There is some gravel near Smiths Falls which was extensively used by the railway companies for ballast. Near Perth, there is some sand and gravel.

The deposit used by the Canadian Northern Railway company, two miles north of Smiths Falls, in the township of Montague, extends over about 20 acres, with an average depth of 10 feet. It was worked by steam shovel, and about half of the gravel has been taken out.

The gravel pit owned by George Kerfoot, Smiths Falls, is in the township of Montague, lot 26, concession eight. It is about 3.5 miles north from Smiths Falls, near the tracks of the Canadian Pacific railway. The average depth of the pit is 10 feet, below which clay is found. The material is about two parts of gravel to one of sand. Two hundred cubic yards were taken out in 1916, and sold for delivery in town at $1.75 per cubic yard. There is an estimated reserve of three acres.

Leeds County

Deposits of sand and gravel in this county are scarce. Some sand and gravel used by the corporation of Brockville is obtained from the St. Lawrence river, about ten miles west of the city. It is supplied by J. H. Simpson, Lyn.

As to pit material, one deposit is owned by Geo. E. Sherwood, Prescott Road, Brockville, situated in Elizabethtown township, lot 3, concession one. The present excavation is 200 by 100 by 10 feet. The material consists principally of gravel, with some sand. The pebbles are angular, and are generally dolomitic limestones or metamorphosed rocks; this gravel is used for concrete work. The

sand contains a little loam, but by sifting a good sharp building sand is obtained. The output of 1916 was 500 cubic yards, sold at $1.25 a cubic yard for delivery in Brockville. The available reserve extends over six acres.

Jos. H. Morrison, Brockville, owns a deposit of sand and gravel near Lyn, in Elizabethtown township. The reserve extends over three acres, and the present pit is 25 feet deep. The output of 1916 was about 800 cubic yards, sold at $1.75 for delivery in Brockville.

Some moulding sand occurs in a sand pit two and a half miles west of Brockville. It is owned by T. H. Bresee and is situated on lot 20, concession one, Elizabethtown. The moulding sand extends here over a large area, covered by bushes. Trenches were dug at 4 feet depth and an average thickness of 2 feet of moulding sand was discovered. Three hundred tons of this sand are used in one year by foundries in Brockville and Smiths Falls, replacing an equal quantity of Albany moulding sand. Below is given a chemical analysis of this material by W. K. McNeill, Provincial Assayer.

Moulding sand, Bresee farm, near Brockville:—

	Per cent.		Per cent.
Silica	74.80	Soda	3.43
Alumina	11.25	Carbon dioxide	0.60
Ferric oxide	2.11	Water	0.62
Lime	2.92	Ferrous oxide	1.89
Magnesia	0.41		
Potash	2.20	Total	100.23

The alumina and alkalies are probably the result of the disintegration of feldspars, and the iron oxides are due to the alteration of ferro-magnesian minerals.

Norm calculated from the preceding analysis:—

Calcite		1.40
Orthoclase	2.79	
Albite	28.82	50.78 feldspars
Anorthite	9.17	
Magnetite		3.02
Wollastonite		0.58
Enstatite		1.00
Grünerite		1.72
Quartz		41.05
Water		0.62
Total		100.17

The large proportion of feldspars and quartz indicates that this sand is one of the final stages of the weathering of a granitic rock. The bonding power is due to a certain amount of kaolinite and ferric hydroxide not indicated in the norm.

At the opposite or southwestern end of the county, there is a deposit of sand on a granite hill, two miles north of Gananoque. A pit owned by Fred C. Gray, of Gananoque, is located on this hill, in lot 11, concession one of the township of Leeds. The size of the pit is about 120 by 120 by 15 ft. Most of this material is fine sand derived from granitic minerals, and some pebbles. There are two feet of moulding sand near the top. The total average output is 3,000 yards a year. It is sold at 25 cents a cubic yard at the pit and $1.25 for delivery in Gananoque. The reserve is 15 acres. There is a small gravel pit, about 200 yards southwest from the sandpit.

In the township of South Elmsley, in the northern corner of the county, there is some good gravel. One pit located in lot 10, concession three, is operated by James Shanks, Smiths Falls. The present excavation is 100 by 100 by 8 feet, the bottom being limestone. About 70 per cent. of the material is gravel, the remainder being sand. The gravel is coarse and is used for road-making. The pebbles vary between four inches and one quarter of an inch in diameter. They consist mostly of limestone, with some granitic and metamorphic rocks.

Granular metric analysis of sand from James Shanks' pit:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained ..	20.00	22.90	25.20	37.50	52.55	93.45	97.80	98.30	98.95

Per cent. of fineness	39.26	Apparent specific gravity	1.77
Coefficient of uniformity	55.95	Weight in lbs. per cubic foot ..	110.60
Grade	No. 5	Percentage of voids	35.10
Real specific gravity	2.729		

Granular metric analysis of coarse sand from Fred C. Gray's pit:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	0.40	1.20	1.85	5.55	18.45	75.05	93.50	97.30	98.90

Per cent. of fineness	56.42	Apparent specific gravity	1.67
Coefficient of uniformity	75.05	Weight in lbs. per cubic foot ..	104.35
Grade	No. 6	Percentage of voids	40.50
Real specific gravity	2.807		

Granular metric analysis of fine sand from Fred C. Gray's pit:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	0.00	0.00	0.00	traces	0.10	24.60	76.20	90.60	98.05

Per cent. of fineness	67.83	Apparent specific gravity	1.64
Coefficient of uniformity	76.10	Weight in lbs. per cubic foot ..	102.47
Grade	No. 6	Percentage of voids	41.80
Real specific gravity	2.822		

Lennox and Addington County

The area round Napanee in the townships of Richmond and Fredericksburg is made of slaty limestones of the Trenton formation. About ten miles south of Napanee this slaty limestone occurs as an escarpment along the shore of Lake Ontario. The weathering and disintegration of the rock produces a limestone gravel, made of discoid pebbles of greatly varying sizes, from a few millimetres up to one foot in diameter. The deposit of gravel is only two or three feet thick, and occurs very often on a width of ten yards along the escarpment. Some large boulders of gneiss and granite occur along the lake shore, and pebbles of this material are found in small quantity in the gravel. The gravel is used for road work in the vicinity of the lake shore.

On the Napanee River

Northeast of Napanee, the Napanee river runs through a valley containing numerous alluvial deposits of sand and gravel. This river comes from Frontenac county, enters the township of Camden, and passes through Colebrook, Yarker, Camden East, Newburgh, Strathcona and Napanee, this last town being in the township of Richmond. On both sides of the river slowly grading slopes are covered by alluvial deposits until 100 feet above the river level. At this line begins a nearly vertical escarpment of limestone. The sand is coarse and makes good material for building purposes. It contains pebbles of limestone, and of granitic or gneissoid rocks coming from the eastern pre-Cambrian area. Large boulders are also found in these deposits.

Good deposits of this kind occur east of the bridge on the Napanee river, about half-way between Napanee and Newburgh. A pit of 60 by 30 by 12 feet is opened south of the Napanee-Newburgh road in the township of Camden, on lot 5, concession one. It belongs to David Mowears, the deposit extending over three acres of his property. The sand layers show oblique stratification. The material is used for building purposes and for road work and is sold at 25 cents a load.

The largest sandpit south of the river was the one operated by R. C. Katon, township of Camden, lot 6, concession one, but it is not worked at present. Another pit south of the river belongs to M. Emptey, township of Camden, lots 8 and 9, concession one.

On the northern shore of the Napanee river, east of Strathcona, and about one mile west of Newburgh station, there is a large alluvial deposit of sand and gravel with some silt. It has been used for a length of 500 yards by the Canadian Northern railway for ballast. The width of the pit is from 60 to 75 yards, and the average depth 10 yards. The material removed amounts thus to nearly 500 by 70 by 10 = 350,000 cubic yards. Large reserves are still available. The material is more silty and not so suitable for building purposes as the one found on the south shore.

Another large pit is located 200 yards east of the Newburgh graveyard, between the Napanee-Yarker road and the river. Sand and gravel are found in this pit, the material being of good quality. It is worked on a length of 150 yards in a direction parallel to the river, an average width of 25 yards, and an average depth of six yards. The upper part is as a rule of sharp sand, with very few pebbles; the lower part is gravel, the two parts being sometimes separated by a thin layer of clay. The whole deposit shows oblique stratification.

In Camden East, Sidney Williams opened a sand pit on the north shore of the river. The material is used for building purposes. This pit is 125 yards long and 8 yards deep, and is located between the C.N.R. tracks and the graveyard.

The area along the C.N.R. between Camden East and Tamworth is mostly covered with limestone boulders and some granitic material. In the cuttings between Enterprise and Tamworth, several local deposits of gravel produced by the disintegration of the underlying rocks are noticeable.

Sheffield Township

In the township of Sheffield, some deposits occur in the area around Tamworth. North of the station of Erinsville, about two miles west of Tamworth, a gravel and sand ridge occurs on the west shore of Beaver lake. One pit of 150 by 75 by 30 feet has been opened by P. McCann, in the township of Sheffield, on lot 8, concession three. Most of this material is the product of decomposition of granite, metamorphic schists, and limestone. Large pebbles and boulders of these rocks are found in the deposit. The sand is coarse and suitable for building purposes, but the market is small and very little is taken out in a year; the selling price is 15 cents per load. Another gravel pit, belonging to Mr. Anderson, Erinsville, is located on the north shore of the C.N.R. Little work has been done in it lately.

About one mile and a quarter west of Erinsville, near the boundary between the counties of Lennox and Addington and Hastings, there is a very large gravel pit belonging to the C.N.R. and used for ballast supply. The pit is not worked at present, but the excavation is 300 by 100 by 20 yards in size, representing a removal of 600,000 cubic yards. The reserve contains at least 1,200,000 cubic yards. The pit is located on lot 5, concession two, Sheffield, north of the C.N.R. tracks. The gravel exhibits oblique stratification. On top of the ridge the material is a little silty.

The area between Beaver lake and White lake is near the contact of granitic and sedimentary rocks. It is covered by numerous drumloid hills made of sand and gravel. Similar hills occur east of Beaver lake, and in one of them is situated a pit owned by H. Cunningham, Tamworth. It produces sand and gravel; the former coarse, the latter made up of pebbles of various rocks, rather angular in shape. The excavation is small: 30 by 15 by 4 feet, but there are large reserves available. The material is used for road work and building purposes, road gravel being sold at 10 cents per load.

Similar deposits occur in the township of Kaladar, near Addington and Kaladar.

Lincoln County

In this county the shore line of the glacial lake Iroquois extends from Queenston, at the east, to Grimsby, at the west, passing through St. David, Homer, St. Catharines, Jordan, and Beamsville. It lies between the Niagara escarpment and the Lake Ontario shore, but is not marked by a continuous line of sand and gravel deposits. Only some small bars occur here and there along this line, as at Homer and St. Catharines, but they are without economic importance.

White sandstone, which may be suitable for making glass or ferro-silicon, has been found under the red Medina sandstone on the Niagara escarpment. Outcrops of this white sandstone may be seen along the Michigan Central railway northeast of St. David. It consists of layers about 10 inches thick, alternating with small bands of shale. Above the railway the white rock outcrops for about 15 feet underlying, in succession upwards, 8 feet of red sandstone, 3 feet of bluish calcareous shale, and the dolomitic limestone of the top. Assuming that the white sandstone runs one mile in length along the railway with a probable thickness of

12 feet, each yard under the plateau would represent a reserve of 2,000 by 4 = 8,000 cubic yards. Below is given a chemical analysis of this white sandstone by W. K. McNeill:—

White sandstone, Queenston Quarry Co., St. David:—

	Per cent.
Silica	93.36
Alumina	2.54
Ferric oxide	0.75
Ferrous oxide	1.13
Lime	0.90
Alkalies	0.83
Magnesia	0.37
Carbon dioxide	0.22
Water	0.23
Total	100.33

Norm calculated from the preceding analysis:—

Calcite	0.50	
Orthoclase	2.78	8.98 feldspars
Albite	3.14	
Anorthite	3.06	
Corundum	0.31	
Enstatite	0.90	
Grünerite	1.45	
Magnetite	1.16	
Quartz	86.88	
Water	0.23	
Total	100.41	

The proportion of quartz in this rock is very high, contrasting with the small amount of feldspars and of iron-bearing minerals.

Middlesex County

Deposits of gravel are very abundant in this county; sand also occurs, but in smaller amount. The principal locations are: London, Thorndale, Dorchester, Lucan, and Parkhill. In the last locality the deposits belong to the old shore line of lake Algonquin; in the other localities they are connected with the history of the Thames river and its tributaries.

In the city of London large quantities of gravel are taken from the north branch of the river; most of this gravel is washed from the gravel banks west of Adelaide street. On the south branch there are only small deposits, and on the main stream there is nothing of interest above the cove, west of the G.T.R. bridge. The principal deposits in the river and pits of sand and gravel are marked on a map of London (fig. 27). The pits are numerous; practically the whole north-western part of the city is on gravel, while in the eastern and northeastern parts the sub-soil is all sand. Sewer excavations at 20 feet in depth in Egerton street have shown the sand at the bottom. The upper parts are generally of good sharp building sand, while the deeper parts become finer and approach quicksand. The gravels vary in size of pebbles from one pit to another, affording supplies of road and cement gravel. The pebbles are mostly of limestone fragments intermixed with some igneous and metamorphic rocks. This material is delivered in various wards at prices varying from 50 cents to $1.25 a cubic yard. The city of London used in 1916 about 50,000 cubic yards of gravel. These figures were obtained from H. A. Brazier, city engineer.

Near Thorndale the gravel pits supply gravel of similar kind. About 80 per cent. is limestone, the pebbles being sometimes as large as four inches in diameter. This material is used for road building and is sold at 20 cents per cubic yard. Southwest of Thorndale there is an area of several square miles covered by such gravel.

At Dorchester, in the southeastern part of the county, the gravel is mixed with coarse and sharp sand, one-half of the material being gravel, the other half sand. Fifty per cent. of the pebbles are limestone. The deposit extends on both sides of the Thames river. There are several deposits of this kind between Dorchester and Sandpit, near London.

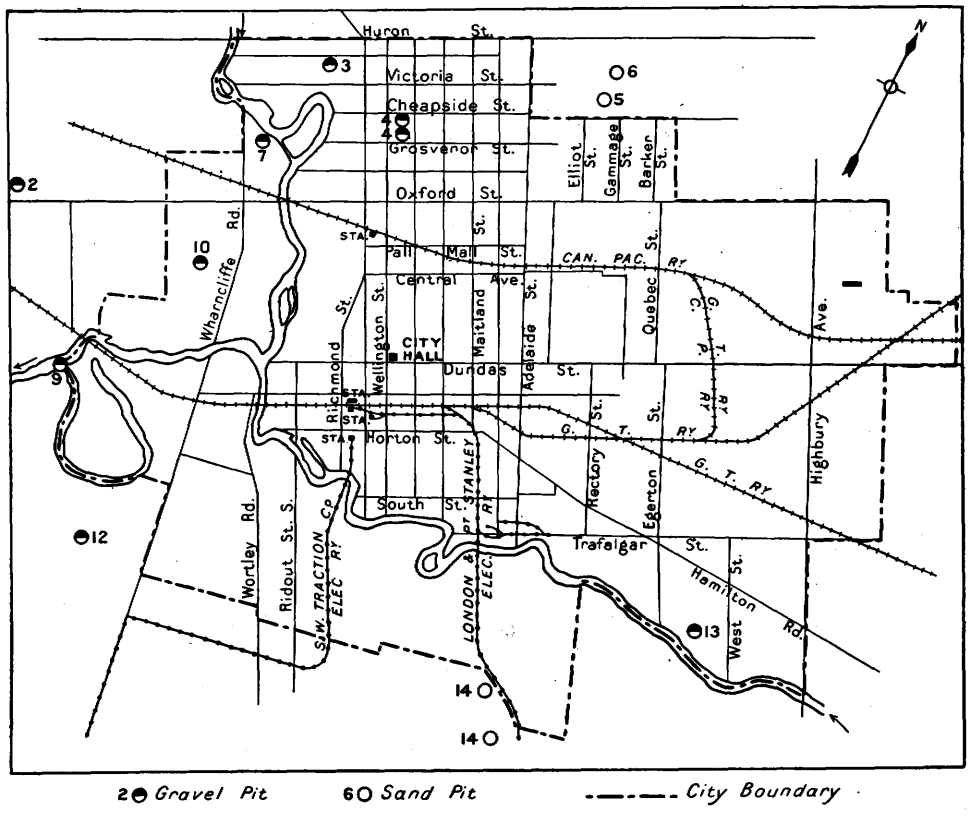


Fig. 27—City of London, Ont., with location of sand and gravel deposits. Scale: one mile to the inch. The numbers refer to the list given in the text.

In the township of Biddulph, in the north of the county, there are some gravel pits round Lucan and Clandeboye. The material is made of pebbles generally under 5 inches and coarser near the top.

The fine grade of the gravel found near the bottom of the pits is sometimes auto-cementing, and has some value as a cement gravel.

The deposits in the neighbourhood of Parkhill are numerous. They are located in the townships of West Williams, East Williams, and McGillivray. As to the quality, the ridge contains road and concrete gravel, the first being sold at 10 cents, the second at 25 cents a yard at the pit. The average depth of the deposits approaches 10 feet.

The following list gives some details about the principal pits in Middlesex county:—

No.	Owner	Location	Size in feet	Remarks
1	——, London....	North Branch of the Thames, between Oxford and Adelaide Sts., London.....	.....	River gravel.
2	——, London....	Near Jewish Cemetery, north side of Oxford St., London...	150 by 75 by 10	Gravel pit. Double of actual area in reserve.
3	——, London....	Angle of Regent and Talbot Sts., London	150 by 60 by 4	Road gravel pit.
4	——, London....	Block between Cheapside, Wellington, Grosvenor, Waterloo Sts., London	20 deep	Gravel pit; quite exhausted
5	Builders' Supply Co., London	South of Eastern end of Victoria St., London.....	300 by 150 by 15	Sand pit.
6	Boss, Lower London	North of eastern end Victoria St., London	100 by 100 by 15	Sand pit.
7	——, London....	Near river; angle of Beaufort St. and Wharncliffe Road,	300 by 150 by 12	Two gravel pits. Similar
8	M. Stincombe, London	London	150 by 150 by 12 75 by 75 by 10	area in reserve. Gravel hill.
9	——, London....	Island at mouth of cove, Thames main branch, London.....	250 by 50	Gravel.
10	——, London....	Paul St., London	.....	Gravel.
11	——, London....	Outside and west of city; along Pipe Line Road.....	.....	Gravel pits.
12	——, London....	West of Alexandra Ave. London	.....	Gravel pit.
13	——, London....	Southeastern part Egerton St., London	.....	Gravel pits.
14	——, London....	Near Base Line, Westminster tp., W. of London & Port Stanley Ry.	.....	Two sand pits.
15	Mrs. Henderson, Thorndale	Nissouri, W. tp., Con. I, lot 15.	500 by 150 by 10	Road gravel. Res., 4 acres.
16	Walter Bryan, Thorndale	Nissouri, W. tp,, Con. I, lot 16.	100 by 100 by 15	Road gravel. Res., 2 acres.
17	Henry Baskerville, Thorndale	Nissouri, W. tp., Con. III, lot 5.	300 by 300 by 10	Road gravel. Res., 2 acres.
18	Raywood Bott, Thorndale	Nissouri, W. tp., Con. V, lot 2..	100 by 100 by 15	Two gravel pits. Ridge, 500
19	Wm. Smith, Thorndale	Nissouri, W. tp., Con. IV, lot 3.	100 by 100 by 15 150 by 150 by 12	yd. long and 100 yd. wide. Road and cement gravel. Reserve, 25 acres.
20	Geo. Showler, Dorchester	Dorchester, N. tp., Con. III, lot 4	300 by 150 by 6	Gravel and sand.
21	Michael Armitage, Lucan	Biddulph tp., Con. IV	Small	Gravel pit.
22	Geo. Hodgins, Lucan	Biddulph tp., Con. IV.....	Small	Gravel pit.
23	John S. Park, Lucan	Biddulph tp., Con. II, lot 30....	300 by 200 by 20	Road and cement gravel. Reserve, 4 acres.
24	T. Appleton, Parkhill.....	McGillivray tp., Con. XIX, lot 10	100 by 100 by 12	Road and cement gravel.
25	Lewis H. Durr, Parkhill.....	McGillivray tp., Con. XVIII....	300 by 200 by 6	Cement gravel. Reserve, 2.5 acres.
26	John Grieves, Parkhill.....	East Williams tp., Con. VIII...	300 by 300 by 4	Cement gravel.
27	—— Hartle, Parkhill.....	McGillivray tp., Con. XVIII..	200 by 50 by 10	Road and cement gravel.
28	Wm. Smithers, Parkhill.....	McGillivray tp., Con. XIX, lot 10	250 by 40 by 12	Gravel and sand. Reserve, 3 acres.
29	Wesley Harris, Kerrwood	Adelaide tp., Con. IV, lot 1	200 by 150 by 20	Sand and gravel. Exhausted.
30	Waltham, Kerwood.	Adelaide tp., Con. IV, lot 2.....	300 by 300 by 20	Sand and gravel. Exhausted.
31	Rivers, Kerwood..	Adelaide tp., Con. III, lot. 1....	200 by 75 by 15	Road and cement gravel. Reserve, 1 acre. Output, 1,000 cu. yd.
32	Chambers, Kerrwood	Adelaide tp., Con. III, lot. 2....	225 by 175 by 30	Road gravel. Res., 10 acres.

Granular metric analysis of sand, Builders' Supply Co. pit:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained.	0.50	4.55	10.50	29.15	45.55	92.55	99.90	100.00	100.00

Percent. of fineness	46.37	Apparent specific gravity	1.65
Coefficient of uniformity	63.40	Weight in lbs. per cubic foot	103.10
Grade	No. 5	Percentage of voids	39.3
Real specific gravity	2.718		

Granular metric analysis of gravel from fourth pit in list:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained.	96.25[1]	99.45	99.85	100.00	100.00	100.00	100.00	100.00	100.00

Per cent. of fineness, 0.49.

Muskoka District

In this district, where the rock formations are principally granitic, the gravels and sands are due to the weathering and to the glacial erosion of the rocks. In the southern part of the district along the Grand Trunk railway tracks, a fine, yellow and loamy sand appears as the result of the weathering. It is associated with gravel, of which large quantities are available round Bracebridge and Gravenhurst. Near the last-mentioned place, in the township of Muskoka, the deposits have been partially worked by the railway company. At Bracebridge, in Draper township, the two principal pits are located in the thirteenth concession, southeast of the town.

Ollivero's pit, on lot 4, is an excavation of 150 by 150 by 20 feet, with lenticular formations of sand and gravel. The material is sold at 10 to 20 cents a cubic yard.

John Watson's pit, on lot 5, is about 100 by 100 by 15 feet in size. It contains sand, cement, and road gravel, and also some big boulders near the top. The output in 1916 was about 150 cubic yards, and the selling price was about 10 cents a yard.

Granular metric analysis of sand from John Watson's pit, Bracebridge:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained.	0.40	3.50	9.50	29.45	46.45	75.90	90.55	95.05	98.40

Per cent. of fineness	50.09	Apparent specific gravity	1.65
Coefficient of uniformity	46.45	Weight in lbs. per cubic foot	103.10
Grade	No. 5	Percentage of voids: Calculated	39.80
Real specific gravity	2.744	Measured.	35.70

[1] Of the 96.25 per cent. remaining on the 4-mesh sieve, 66.10 were pebbles larger than one inch.

More to the north, round Huntsville, in Chaffey township, several deposits of sand and gravel occur near the lake and river shores. At the locks of the Muskoka river, lot 13, concession twelve of Brunel township, there are large deposits extending about one mile south of the locks, on both sides of the river. The ridge is highest on the west side near the locks, where the deposit is 50 yards thick and 5,000 yards wide. The material is made up of sand of various grades and is used for building purposes and for road work.

At Fairyport, on the south shore of Fairy lake, lot 19, concession thirteen, there is a small sand beach and some sand banks about 30 feet above the lake level. Similar deposits occur in the neighbouring bay at Hollinshead's.

On the north shore of Peninsula lake some sand occurs in concession one of Chaffey township, between Deerhurst and Grassmere.

On the southwestern shore of Mary lake there are sand and gravel deposits around Port Sydney, in the township of Stephenson.

The northeastern shore of Lake Vernon is marked by some deposits of sand, gravel and clay, principally south of the mouth of the East river and also opposite May island.

All these arenaceous deposits in the Lake of Bays district are remnants of a former stage of the physical history of this area, when it was occupied by one large lake, the actual hills being small scattered islands.

Norfolk County

There is some sand and gravel available on the Lake Erie beach at Port Dover, west of the lighthouse overlying a substratum of clay, which rises in the form of cliffs along the beach. Near the shore are deposits of pea gravel, of blue and white limestone, also igneous and metamorphic rocks. The pebbles are less than half an inch in diameter, and are angular in shape. Beyond the gravel comes a zone of white or yellow, and farther up, near the clay cliffs, a red garnetiferous sand. Sometimes heavy winters with much wind and ice bring large deposits of gravel to the beach, this material being carted away in the spring. On this account there is often no gravel left on the beach in the summer. The gravel is sold at 15 cents a yard on the spot and $1.65 for delivery in town. There are large reserves of building sand to be found on the beach. Its only defect is a small proportion of vegetable matter.

In the corporation of Simcoe a deposit of sand about 10 acres in size has been worked by Arthur Coats. The size of the present excavation is 100 by 150 feet, with a depth varying from 6 to 20 feet. The upper part consists of two feet of soil, below this come 6 feet of good sharp sand, and then about 12 feet fine white sand. The sharp sand is sold at about $1.00 a cubic yard, for delivery in town.

There are valuable reserves of gravel between Simcoe and Watford, in the township of Townsend, but they are not being worked at present. To the south of Simcoe, there is a gravel pit in Charlotteville township, on lot 24, concession nine, belonging to Mr. Weston and Mrs. Wright. The excavation is 100 ft. by 500 feet by 8 feet. The material, coarse at the top, becomes finer near the bottom, and is made up principally of angular limestone pebbles. There is an approximate reserve of one acre of similar material. A bucket elevator, screens and bins represent the equipment in this pit.

To the southeast of Simcoe, in the township of Woodhouse, Mr. Decew owns a sand and gravel pit on lot 1, concession five, the present excavation being 120 by 120 by 10 feet, with an equal area in reserve. The output in 1916 was 2,000 yards, which sold at 50 cents per yard. A certain proportion of the sandy soil at the top of this deposit could be used as a pipe moulding sand.

Granular metric analysis of white beach sand, Port Dover:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained.	0	0	tr	tr	tr	53.80	97.10	99.25	99.45

Per cent. of fineness	61.16	Apparent specific gravity	1.70
Coefficient of uniformity	97.10	Weight in lbs. per cubic foot	106.22
Grade	No. 6	Percentage of voids	43.60
Real specific gravity	3.017		

Granular metric analysis of red beach sand, Port Dover:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained.	0	0	0	tr	tr	8.60	83.60	98.70	100.00

Per cent. of fineness	67.68	Apparent specific gravity	2.29
Coefficient of uniformity	90.10	Weight in lbs. per cubic foot	143.09
Grade	No. 7	Percentage of voids	44.40
Real specific gravity	4.123		

Northumberland County

The shore line of ancient Lake Iroquois crosses this county in a direction parallel to the shore line of Lake Ontario. Gravel and sand deposits are closely connected with the old shore line near Baltimore, Colborne, Brighton and Trenton. In the southeastern corner of the county, near Trenton, there are several beach levels with their related gravel and sand bars.

The gravel pits of the Baltimore and Cobourg Gravel Road Co. of Baltimore are situated one mile south of Baltimore, in the township of Hamilton, on lot 7, concession two. The principal pit is 150 by 150 by 15 feet in size, the material being gravel with a very small proportion of sand. The pebbles are 70 per cent. limestone, the remainder being metamorphic rocks. The upper part of the pit contains large boulders. There is a reserve of 3 acres of this material near the pit. The shore of Lake Ontario at Cobourg consists of sand of the same kind as the Port Hope sand. To the east of the town, the proportion of pebbles increases, and the shore line is marked out by gravel. Between Grafton and Colborne the country becomes sandy, and between Colborne and Brighton there are numerous sandy hills about one mile north from the shore of Lake Ontario. Small sand pits are located in these deposits.

Near Trenton large deposits of sand and gravel are worked in the Trenton mountain (fig. 28), a large hill west of the Trent river and south of the C. P. R. bridge, in Murray township, lots 4 and 5, concession one. The openings are on the side of the mountain, and afford a good section from north to south. The wall is about 150 feet high. At the top there is a layer of gravel from one to six feet thick; next, a sand layer about 15 feet in thickness, and under it about 80 feet of gravel of different sizes. There are some small layers of sand in this gravel; the stratification is horizontal in the main part of the section, but near

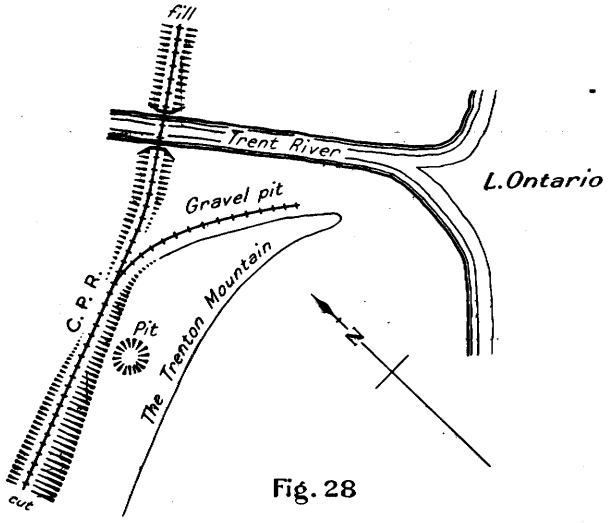


Fig. 28—Location of the Trenton Mountain, Trenton.

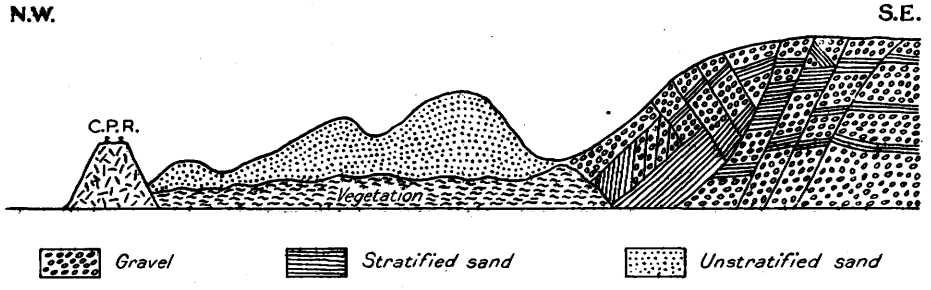


Fig. 29—Diagram of section through the Trenton Mountain.

the northern end there has been some sliding, and several faults separate parts with different dips (fig. 29).

To the north, the formation becomes more sandy; the sand is mostly coarse and sharp, although there are some layers composed of a fine material with a large amount of silt. The coarse sand contains a good proportion of limestone grains, and shows some auto-cementing properties. The gravel is composed mostly of limestone pebbles, but includes also some metamorphic rocks and shales. The ridge of which the Trenton mountain is a part is about 150 yards wide to the south; it runs in a northwesterly direction, nearly parallel to the C. P. Ry. tracks.

A large cutting has been made for the railway roadbed in an east and west direction. Near the central part of this cutting, the ridge has a width of 500 yards. Several pits have been opened on top of the ridge.

Granular metric analysis of sharp sand at Trenton mountain:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained.	14.50	19.25	22.45	34.75	53.45	97.15	99.50	99.70	99.90

Per cent. of fineness 39.9
Coefficient of uniformity 62.40
Grade ..... No. 5
Real specific gravity 2.908
Apparent specific gravity 1.67
Weight in lbs. per cubic foot .. 104.35
Percentage of voids 42.50

Granular metric analysis of fine silty sand at the Trenton mountain:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained.	0.00	0.00	0.10	1.50	4.00	9.95	11.30	13.20	33.40

Per cent. of fineness 91.8
Coefficient of uniformity 86.80
Grade ..... No. 9

Ontario County

Recent deposits of gravel and sand occur in small bays of Lake Ontario, near Whitby and Dunbarton. At Whitby the beach has been drawn on since 1913 to provide building materials for the Provincial Hospital for the Insane. The digging is carried on for eight months a year, with a weekly output of 175 cubic yards. The material is crushed and screened and gives sand, pea gravel with pebbles smaller than three-quarters of an inch, concrete gravel with pebbles from three-quarters of an inch to two inches, and road gravel, larger than two inches, the last being the remnant left from screening. The pebbles are principally of limestone, with a little granite, gneiss, quartzite, sandstone and about two per cent. of shale, the latter very objectionable. The sand is fine, and may be used for mortar, but is not quite sharp enough, and the presence of the shale dust also reduces its quality. Up to June, 1917, the beach had been excavated for a length of 700 feet, a width of 100 feet and a depth of 6 feet. The work is done with a steam shovel (fig. 30) and the yearly output is about 6,000 cubic yards. In the operations most of the western part of the beach has been removed.

There remains some material on the eastern shore of the bay and along the lake shore to the east. The formations near Whitby are mostly clay. Well-borings have discovered quicksand at 14 feet depth in some places, at 25 feet in others. Gravel was struck at a depth of 40 feet about one mile north of Whitby.

Sand pits belonging to Mr. Bonnell and to Mr. Broughton are located east of Whitby, the first at 1½ miles, the second at one-half mile. They supply good sharp sand for building purposes.

There is also a good gravel pit belonging to John Rice, located two miles north of Whitby.

At Dunbarton, the Lakeshore Sand and Gravel Co. is working on the material located in Frenchman bay, for the third season. The daily output is about 400 cubic yards, all brought by boat to Toronto: work is carried on in this plant for five days a week, and eight months a year, making a grand total of 68,000 cubic yards as the yearly output. Three kinds of material, sand, fine and coarse gravels are produced and used for building.

At Pickering on the G. T. Ry. all the sand and gravel used—about 200 cubic yards per year—is taken out of the creek after the spring floods.

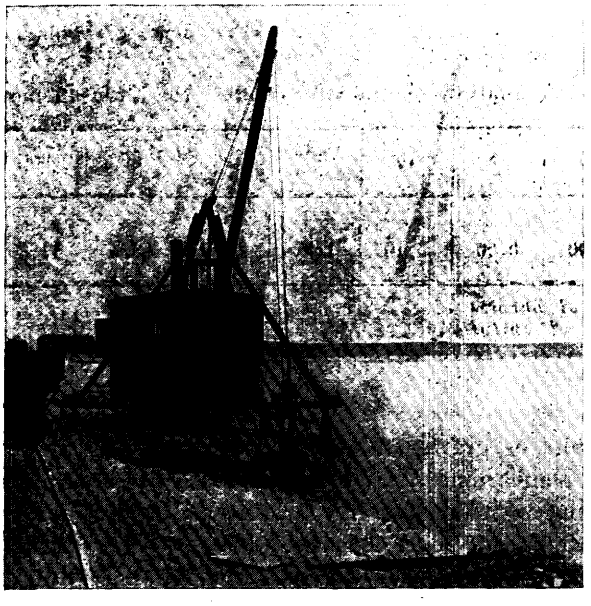


Fig. 30—Steam shovel dredging gravel from Lake Ontario, Whitby.

Going north from the shore of Lake Ontario, the recent deposits become thinner, and the country north of the G. T. Ry. is made up mostly of Iroquois clay. Still farther to the north, one approaches the Iroquois sand and gravel ridge along which the Canadian Northern railway was built. This ridge runs in a northeasterly direction to the township of Pickering, passing through concessions one to five. At its western end near Cherrywood it is only three miles from Lake Ontario, but to the east, near Kinsale, it is seven miles north of the lake. The ridge then runs into the township of Whitby West and bends to the south-east, passing through concessions five, four and three, its general direction being from east to west through Whitby East in concession three. Near Taunton it is five miles north of the lake.

Sand and gravel deposits are quite continuous in this ridge through the whole of Ontario county. Numerous pits, most of them gravel pits, have been opened. The character of the gravel is quite uniform along the ridge in this county: the pebbles are subangular to rounded in shape, consisting of about 70 per cent. limestone and 30 per cent. granite and metamorphic rocks. At some places, as in

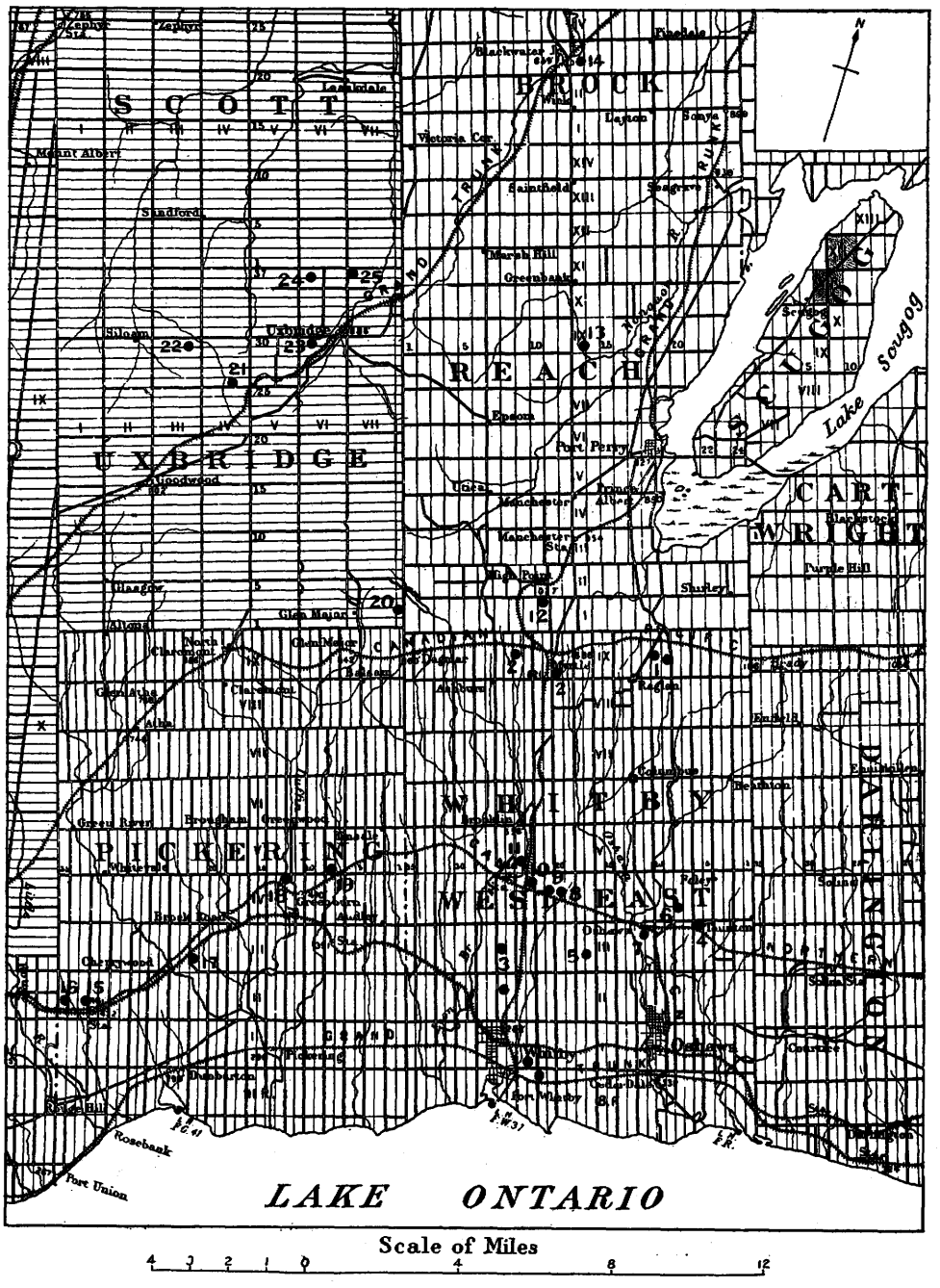


Fig 31—Map of part of Ontario county, showing the location of principal sand and gravel deposits. The numbers refer to the list given in the text.

concessions three and four, Pickering township, near Brock Road, the sand deposits are rather extensive and of great thickness. This material is shipped to Toronto by rail for building purposes. The Iroquois ridge through Ontario county averages more than 300 feet in width. Very large reserves are still available, at least 30,000 by 100 by 2=6,000,000 cubic yards.

North of the Iroquois ridge the region is covered with glacial drift and numerous large boulders. There are many drumlin hills characteristic of the glacial topography. The whole country between the C. N. Ry. and the C. P. Ry. lines is made up of sand; well-borings have shown this formation to extend to a depth of 100 feet before the clay is reached. This sandy formation extends north of the C. P. Ry., as shown in the deep cuttings between Myrtle and High Point. There are large deposits of sand and gravel near Myrtle, Port Perry and Uxbridge. Some moulding sand from a point a little west of the station was used ten years ago by a foundry in Port Perry. One mile south of Uxbridge there is a sandy ridge with numerous pits scattered along it. At the highest point of the ridge some fine white "blow" sand is carried about by the wind, covering the fields and injuring the crops.

To summarize, the eastern part of Ontario county, including the townships of Whitby, Reach, Brock, Thorah, Mara and Rama, has a fair reserve of gravel and sand. There are very few pits in Scugog township. The western row of townships, Pickering, Uxbridge and Scott, have also fairly good reserves of sand suitable for building purposes, and of gravels for ballast and construction work.

The following list gives some details respecting the principal pits in Ontario county (fig. 31):—

No.	Owner	Township, Con. and Lot	Size in ft.	Remarks
1	—— Raglan	Whitby, Con. IX, lot 11–12		Road gravel.
2	—— Myrtle	Whitby, Con. IX, lot 20–25	Depth 40	Sand and gravel.
3	Geo. Hurt, Whitby	Whitby, Con. III, lot 26	75 by 75 by 25	Gravel.
4	S. Burgoyne, Oshawa	Whitby, Con. III, lot 6	200 by 75 by 10	Road gravel.
5	Tp. of Whitby and Town of Oshawa	Whitby, Con. III, lot 17		Road gravel.
6	Cement Brick Co., Oshawa	Whitby, Con. IV, lot 9	300 by 100 by 10	Road and concrete gravel.
7	Canadian Northern Ry	Whitby, Con. III, lot 12	1,300 by 120 by 6	Ballast.
8	Canadian Northern Ry	Whitby, Con. IV, lot 20	1,200 by 200 by 15	Ballast.
9	Tp. of Whitby	Whitby, Con. IV, 20–21	500 by 70 by 10	Road and concrete gravel.
10	G. T. Ry	Whitby, Con. IV, lot 23	1,200 by 250 by 15	Ballast.
11	G.T. Ry	Whitby, Con. V, lot 24	1,000 by 300 by 12	Ballast.
12		Reach, Con. I and II, lot 10	Depth 40	Gravel.
13	Corporation of Port Perry	Reach, Con. X, lot 13		Sand and gravel.
14	Godson Contracting Co., Toronto	Brock, Con. III, lot 13		Gravel, crushed and screened.
15	C. N. Ry. and C. P. Ry.	Pickering, Con. II, lot 32	400 by 75 by 10	Gravel.
16	C. N. Ry	Pickering, Con. II, lot 34	700 by 400 by 10	Ballast.
17	Toronto Builders' Supplies Ltd., Toronto	Pickering, Con. III, lot 22	Very deep	Sand.
18	F. L. Green, Greenwood	Pickering, Con. IV, lot 13	300 by 150 by 10	Road gravel.
19	Godson Contracting Co., Toronto	Pickering, Con. V, lot 8		Gravel.
20		Uxbridge, Con. VIII, lot 2		Sand.
21		Uxbridge, Con. IV, lot 26		Sand.
22	C. Hockley, Uxbridge	Uxbridge, Con. III, lot 30		Gravel.
23	Chapman, Uxbridge	Uxbridge, Con. VI, lot 30		Gravel.
24	H. Alford, Uxbridge	Uxbridge, Con. VI, lot 36		Road gravel.
25	H. Gall, Uxbridge	Uxbridge, Con. VII, lot 37		Gravel.

Granular metric analysis of screened sand, Whitby bay:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained.	0.00	7.95	16.35	35.55	50.20	88.10	97.30	98.60	99.00

Per cent. of fineness 45.22
Coefficient of uniformity 52.55
Grade ..... No. 5
Real specific gravity 2.824
Apparent specific gravity 1.706
Weight in lbs. per cubic foot .. 106.60
Percentage of voids 39.6

Granular metric analysis of sand, Landshore Sand & Gravel Co., Frenchman's bay:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained.	0.30	3.10	6.40	16.80	25.70	60.00	93.25	98.40	99.15

Per cent. of fineness 55.2
Coefficient of uniformity 67.55
Grade ..... No. 6
Real specific gravity 2.855
Apparent specific gravity 1.693
Weight in lbs. per cubic foot ... 105.785
Percentage of voids 40.7

Granular metric analysis of fine sand, Landshore Sand & Gravel Co., Frenchman's bay:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained.	41.55	88.25	98.85	100.00	100.00	100.00	100.00	100.00	100.00

Per cent. of fineness 7.93
Coefficient of uniformity 88.25
Grade ..... No. 1

Oxford County

Large deposits of gravel occur along the Grand Trunk railway between Dorchester in Middlesex county and Beachville in Oxford county. These deposits were extensively worked by the railway for ballast, principally in the neighbourhood of Ingersoll. One of the excavations was two miles long, 75 feet wide and about 20 feet deep. Large excavations of this kind are located north of the railway between Ingersoll and Beachville. There still remain large reserves available.

Around Woodstock there are some deposits of gravel and sand. South of the town there is a sand ridge containing very large reserves. The gravel is generally made up of limestone, with some igneous and metamorphic rocks. The pebbles are as a rule under 2 inches in diameter. The material is sold at an average of 70 cents a cubic yard for delivery in town.

Different grades of sand are found here; they are mostly used for building purposes. Following is a list of the principal pits in the vicinity of Woodstock:

Owner	Location	Size in ft.	Output	Remarks
——Butterfield, Woodstock	Southern part of Woodstock.	40 by 30 by 12	100 yd.	10 ft. sand and little gravel.
C. E. Rapson, Woodstock..	Woodstock.....	20 deep	.....	Sand and cement gravel.
C. E. Rapson, Woodstock ..	Blandford tp., Con. II, lot 17.	60 by 60 by 15	.....	Sand and gravel. Reserve 10 ac.
——Silcox, Woodstock.....	Blandford tp. Con. II, lot 14.	.....	.....	Large reserves of sand and gravel.
——Blair, Woodstock	Blandford tp., Con. II, lot 13.	.....	.....	Large reserves of sand and gravel.
Silvester Keys, Woodstock.	East Oxford tp., Con. III.	.....	.....	Big ridge, about 35 acs. of gravel.

Granular metric analysis of sand from Butterfield's pit, Woodstock:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained.	1.00	3.75	5.20	12.65	25.45	73.15	88.35	93.20	97.25

Per cent. of fineness	55.55	Apparent specific gravity	1.642
Coefficient of uniformity	62.90	Weight in lbs. per cubic foot...	102.60
Grade	No. 6	Percentage of voids	42.2
Real specific gravity	2.838		

Peel County

There is not much material available in the southern part of this county near the shore of Lake Ontario. In the township of Chinguacousy there are some deposits round Brampton and along the Credit river, and in the northern township of Caledon, some large gravel deposits are found in the Credit river valley near Cataract.

At Brampton, the pits contain mostly sand and gravel, the thickness of the respective layers varying from one pit to another. At the top there are often one or two feet of loam, then 2 to 15 feet sand, and below this again gravel of various grades. There is a little pea gravel, but as a rule the pebbles are rather large and made up of sandstone, limestone, granite and some metamorphic rocks. The pits are deep and the walls stand up well, the gravel showing some auto-cementing power. The principal deposits here form part of a ridge running north and south from lot 5 to lot 12, in concessions one and two, in the eastern part of Chinguacousy.

In the same township deposits along the Credit river are worked near Huttonville, principally for small gravel. This material is sold, as in Brampton, for 25 to 40 cents a yard at the pit.

Large pits were opened near Cataract in the Credit river valley. The gravel is coarse and made up mostly of sandstone, shaly sandstone, igneous and metamorphic rocks. The pits are located on the east bank of the river and mostly

in the concave bends. This gravel was probably brought down by the river during the formation of the valley. The walls of the pits are about 70 feet high. The deposits are extensively worked by steam shovels, the material being used as ballast and road gravel.

The following list gives some details about the pits met with in Peel County:

Owner	Township, Con. and Lot	Size in ft.	Output	Remarks
John Parr, Brampton	Chinguacousy, Con. 2E, lot 5.	30 by 60 by 30	.....	Several other small pits, gravel and sand.
W. B. Markle, Brampton..	Chinguacousy, Con. 2E, lot 6.	150 by 30 by 30	.....	Sand and gravel.
Town of Brampton.....	Chinguacousy, Con. 2E, lot 12	300 by 300 by 30	.....	Road gravel.
Ackroyd, Stanley Mills ..	Chinguacousy, Con. 5E. lot 10	100 by 60 by 15	.....	Pea gravel and sharp sand
John Reid, Huttonville....	Chinguacousy, Con. 4W, lot 5	.....	.....	Small reserves of gravel
J. W. Chesney, Huttonville	Chinguacousy, Con. 5W, lot 5	150 by 100 by 10	Small...	Bucket elevator and screener.
A. Laidlaw, Norval	Chinguacousy, Con. VI, lot 7	.....	.....	Gravel.
.....	Chinguacousy, Con. V, lot 7	.....	.....	Sand.
A. Laidlaw, Norval	Chinguacousy, Con. VI, lot 10	150 by 100 by 5	150 yd..	Cement gravel, mostly limestone pebbles and sand.
Hydro-Electric Com., Toronto	Caledon, Con. III, lot 14 (Cataract)	300 ft. along the Credit R. 70 ft. high.	.....	Coarse gravel.
Canadian Pacific Railway.	Caledon, Con. III, lot 14	500 ft. along the Credit R. 65 ft. high.	.....	Gravel.

Granular metric analysis of sand from John Parr's pit, Brampton:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained.	1.05	5.85	8.95	36.35	67.05	86.75	94.95	96.85	98.35

Per cent. of fineness 44.87
Coefficient of uniformity 58.10
Grade ..... No. 5
Real specific gravity 2.763
Apparent specific gravity 1.623
Weight in lbs. per cubic foot .. 101.41
Percentage of voids 41.3

Granular metric analysis of gravel from Markle's pit, Brampton:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained.	38.25	58.65	67.35	80.45	87.65	96.30	98.45	98.90	99.55

Per cent. of fineness 19.4
Coefficient of uniformity 58.65
Grade ..... No. 1

Perth County

A great number of deposits are to be found in the southern part of this county near Stratford and St. Marys, in the form of gravel ridges (fig. 32).

To the east of Stratford in the township of North Easthope, two ridges run in a direction from east to west through lots 43 and 44 of concession one. The material is a coarse road gravel, mostly of limestone. It is sold at about 40 cents a yard.

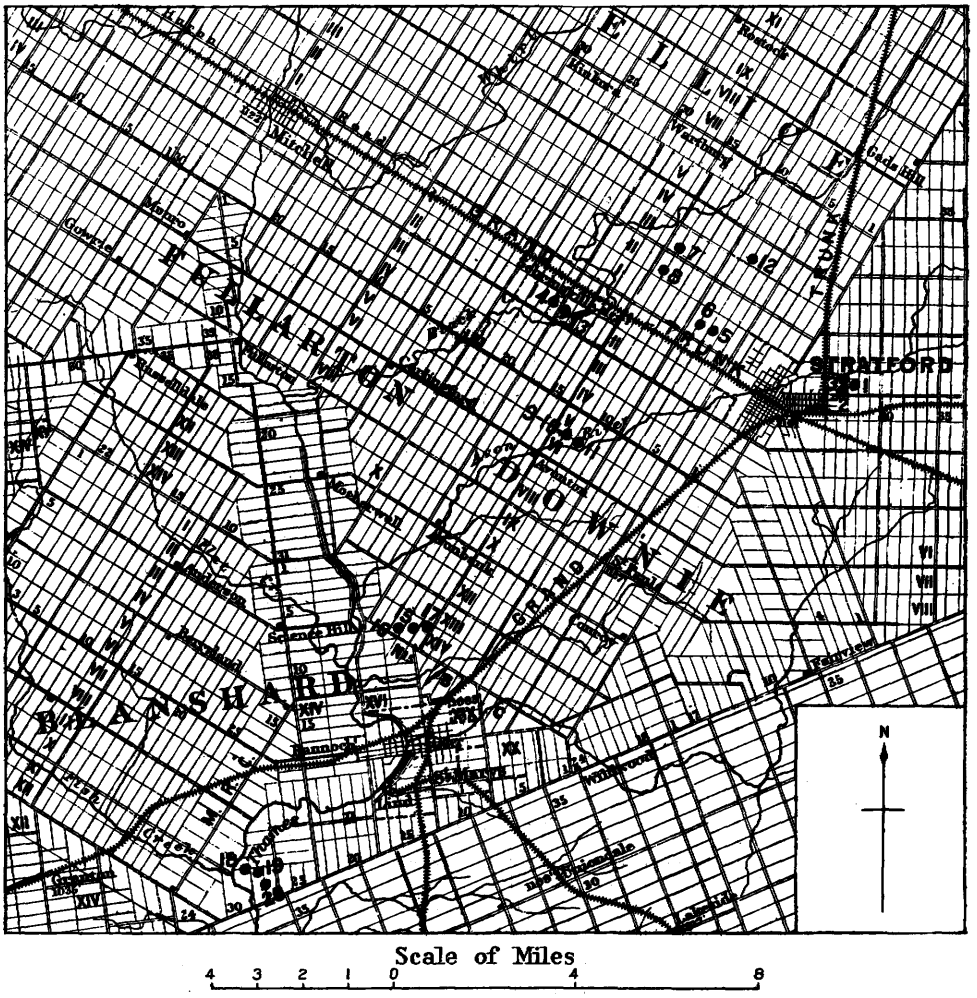


Fig. 32—Map indicating the location of sand and gravel pits in the vicinity of Stratford and St. Marys. Numbers refer to the list in the text.

West of Stratford and about 400 yards north of the Huron road there is a similar ridge running approximately parallel to the road, and at least three miles long. It passes through lots 8 to 12 in concession one of Ellice township and then bends southwards into the township of Downie. A small pit is to be found on the southern side of the Huron road where the ridge crosses the latter. Other ridges are to be seen to the north in Ellice, and some parts of the county are completely overlaid by gravel.

Deposits of gravel of several grades used for road and cement purposes, occur south of Sebringville, on the shore of Black creek. They are probably due to floodings of this creek. The material sometimes contains a little sand. The cement gravel is sold at 50 cents a yard, the road gravel at 12½ cents, and the sand at 50 cents. The pebbles are mostly limestone, but there is a fair proportion of sandstone, as well as some gneiss and granite fragments.

Another gravel ridge extends through concession five, of Downie township, a little northeast of Avonton, on both sides of the Avon river.

In the southern part of Downie, there is a very large ridge containing sand and gravel of fine quality, extending through lots 14, 15, 16 in concession fourteen, and passing into Blanshard township. The sand is sold at 40 cents a yard, the gravel at 35 cents. Much of this material is used in St. Marys for building purposes.

South of St. Marys in concession eight, several large pits are located in lots 28 and 29 on a ridge running north and south. Hills on this ridge indicate where the material is very abundant. They are made up of coarse gravel on top, and cement gravel at the bottom. Stratification is oblique. The pebbles are mostly of limestone, with some sandstone, granite and gneiss. The material is sold at low prices, about 60 cents to $1.00 a cord (12 to 20 cents a yard) for cement gravel and 50 cents a cord (10 cents a yard) for road gravel.

GRAVEL AND SAND PITS IN PERTH COUNTY

No.	Owner	Township, Con. and Lot	Size in feet	Output	Remarks
1	John Sebben, Stratford	N. Easthope, Con. I, lot 43	10 deep		Road gravel and 3 ft. sand.
2	Henry Kirby, Stratford	N. Easthope, Con. I, lot 44		500 yd.	Road gravel.
3	Henry Kirby, Stratford	N. Easthope, Con. I, lot 44	100 by 100 by 20		Road gravel. Reserve, 4 ac.
4	Wm. McKay, Stratford	Downie	125 by 125 by 20	900 yd.	Road and cement gravel. Coarse sand.
5	Mrs. M. Roadhouse, Stratford	Ellice, Con. I, lot 8.	100 by 125 by 6		Cement gravel.
6	J. R. Schenck, Stratford	Ellice, Con. I, lot 9.	75 by 75 by 6		Gravel.
7	Chas. Finnegan, Stratford	Ellice, Con. III, lot 14	450 by 300 by 25	600 yd.	Gravel. Reserve 10 acres.
8	Wilmot Frazer, Stratford.	Ellice, Con. II, lot 14	Small pit		Gravel.
9	James Mills Stratford	Downie, Con. V, lot 12	150 by 75 by 15	400 yd.	Gravel. Reserve, 750 by 75 by 15 ft.
10	John Munroe, Stratford	Downie, Con. V, lot 12	500 by 150 by 10		Gravel.
11	Thos. Aitcheson, Stratford	Downie. Con. V, lot 11	150 by 100 by 20		Gravel.
12	Wm. Malloy. Stratford	Ellice, Con. IV, lot 8	300 by 300 by 25	2,500 yd.	Cement and road gravel and sand. Reserve, 50 ac.
13	Geo. S. Litt, Sebringville	Downie, Con. II, lot 18	309 ft. along Black Cr. 15 ft. high	350 yd.	Cement and road gravel, sand.
14	Dillman K. Erb, Sebringville	Downie, Con. II, lot 19	400 by 100 by 20	300 yd.	Cement and road gravel.
15	Edward Betridge	Downie, Con. XIV, lot 15	75 by 40 by 8	150 yd.	Road and cement, gravel and sand.
16	Gourley	Downie, Con. XIV, lot 16			Gravel.
17	Wm. White, St. Marys	Downie, Con. XIV, lot 14	100 by 150 by 20	1,000 yd.	Gravel and sand. Reserve, 20 ac.
18	Jas. Harris, St. Marys	Con. VIII, lot 29	450 by 450 by 25	4,000 yd.	Road and cement gravel.
19	Robert Fewster, St. Marys	Con. VIII, lot 28	300 by 150 by 20	750 yd.	Road and cement gravel.
20	Malcolm Conn, St. Marys	Con. VIII, lot 28	150 by 150 by 10		Gravel and sand.

Granular metric analysis of sand from Sebben's pit, Stratford:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained,..	0.0	0.0	0.10	0.30	0.85	24.35	79.35	92.45	98.85

Per cent. of fineness 67.08
Coefficient of uniformity 78.50
Grade ..... No. 6
Real specific gravity 2.938
Apparent specific gravity 1.524
Weight in lbs. per cubic foot ... 95.225
Percentage of voids 48.1

Granular metric analysis of cement gravel from Edward Betridge's pit, Downie tp.:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	47.60	61.65	68.60	80.55	87.50	95.85	97.50	97.90	98.45

Per cent. of fineness 16.04
Coefficient of uniformity 61.65
Grade ..... No. 1

Granular metric analysis of gravel from M. Harris' pit, St. Marys:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	54.15	64.75	69.80	80.55	87.85	97.10	99.00	99.45	99.80

Per cent. of fineness 16.4
Coefficient of uniformity 64.75
Grade ..... No. 1

Peterborough County

The pits examined in this county are all situated in the city of Peterborough and vicinity. There are some other deposits in the southern part of the county.

The deposits near the city of Peterborough are composed of sand and gravel in alternating layers. The corporation pit, which is located at the north end of the city on the west shore of the Otonabee river, shows on top three yards of fine gravel, underneath which are three feet of sharp sand, then three feet of sandy gravel, then two yards of coarse gravel, and at the bottom large boulders. The excavation, which is about 300 by 60 by 40 feet in size, is part of a ridge, which contains much suitable material; but houses have been built on it so as to render a large proportion of the deposit unavailable.

Just north of the corporation pit there is another pit 250 by 60 by 60 feet in size, which is owned by Mr. Stothart, and shows a similar section. In both pits the gravel contains 75 per cent. limestone, the remainder being granite and metamorphic rocks.

There are several other pits, among which is the Brown pit, 1,000 by 60 by 30 ft. in size, located on the same ridge running parallel to the Otonabee river. This ridge is parallel with the Lakefield road for about one mile, and then turns west at a point about three miles north of the centre of Peterborough.

At the southern end of the city, near the cemetery, J. T. O'Connell owns a sand pit about 200 by 120 by 10 ft. in size, containing layers of coarse sand and pea gravel. The present output of this pit is very small.

Granular metric analysis of sand from T. O'Connell's pit, Peterborough:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	2.55	6.05	11.90	44.30	72.85	92.55	95.55	97.15	98.90

Per cent. of fineness 42.02
Coefficient of uniformity 60.95
Grade ..... No. 4
Real specific gravity 2.805
Apparent specific gravity 1.611
Percentage of voids 42.5
Weight in lbs. per cubic foot ... 100.66

Prescott County

Sand is dug from the shores of the Ottawa river at the northern limit of this county. It is similar in character to the material obtained in the vicinity of the city of Ottawa.

In the neighbourhood of Vankleek Hill there are some gravel and sand deposits. The gravel is composed principally of limestone pebbles. In certain layers the gravel is fine and intermixed with sharp sand in such a proportion that good concrete is obtained in mixing cement with this gravel in the ratio 1 to 7. The reserves of sand and gravel near Vankleek Hill are very large. Details of the principal pits of this region are given below:—

Owner	Township, Con. and Lot	Size in ft.	Output	Remarks
Corporation of Vankleek Hill....	Hawkesbury, W., Con. VI, lot 11...	75 by 75 by 5	.....	Gravel.
D. A. McPhee, Vankleek Hill.....	Hawkesbury, W., Con. VI, lot 10...	400 by 75 by 6	.....	Fine pea gravel. Reserve, 15 ac.
A. J. Cross, Vankleek Hill	Hawkesbury, W., Con. IV, lot 18...	100 by 100 by 15	100 yd.	Sand and cement gravel. Reserve, 1.5 ac.
——Duff, Vankleek Hill,....	Hawkesbury, W., Con. IV, lot 16...	.....	.....	Sand.

Granular metric analysis of sharp sand from A. J. Cross' pit, Vankleek Hill:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	0	0.20	1.75	27.90	65.20	91.30	97.05	98.35	99.15

Per cent. of fineness 46.57
Coefficient of uniformity 63.45
Grade ..... No. 4
Real specific gravity 2.685
Apparent specific gravity 1.514
Weight in lbs. per cubic foot ... 94.60
Percentage of voids 43.6

Prince Edward County

The most extensive deposit of sand in this county, and one of the largest in southern Ontario, is the sandbar south of Wellington. The bar has a direction N.40°W., and is located between Lake Ontario on the west and Yeo lake on the east, making a small strip of ground which is wider to the south. It starts south of Wellington and extends for five miles to Owen Point (fig. 33).

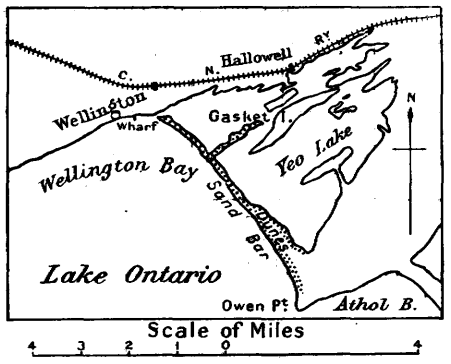


Fig. 33—Sketch indicating the location of the sandbar between Wellington and Owen Point.

At its northern end, that part of the bar above the lake level is only about 25 yards wide. An east-west section in this part is shown in fig 34. On the western side gravel and sand are continuously deposited. The sand is rather sharp, while the gravel is composed of limestone pebbles of varying sizes and a small proportion of granitic material.

The bar remains only 25 yards wide for two miles, then it widens and sand dunes appear in the centre of the bar (fig. 35).

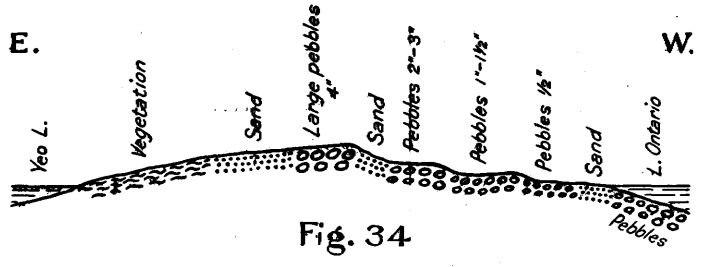


Fig. 34—Section of the northern end of the Wellington sandbar.

The dunes are composed of very white fine sand, while the sand near the shore is coarser and sharper, and contains more ferro-magnesian minerals. The dunes are higher farther south where the bar is wider. About four miles south of Wellington, the dunes have advanced eastwards so as to cover a large area of agricultural ground. Sixty years ago they were close to the shore of Lake Ontario; to-day in the vicinity of Sandbanks they have advanced 500 yards from the shore, and form a ridge extending north and south with an approximate width of 500 yards (fig. 36).

The highest point of this ridge is about 150 feet above the water level.

The amount of sand available is very large. Taking a length of five miles and an average width of 260 yards, the reserve would cover an area of 2,288,000 square yards. With an average height of 20 yards, the total volume may be estimated at 45,760,000 cubic yards.

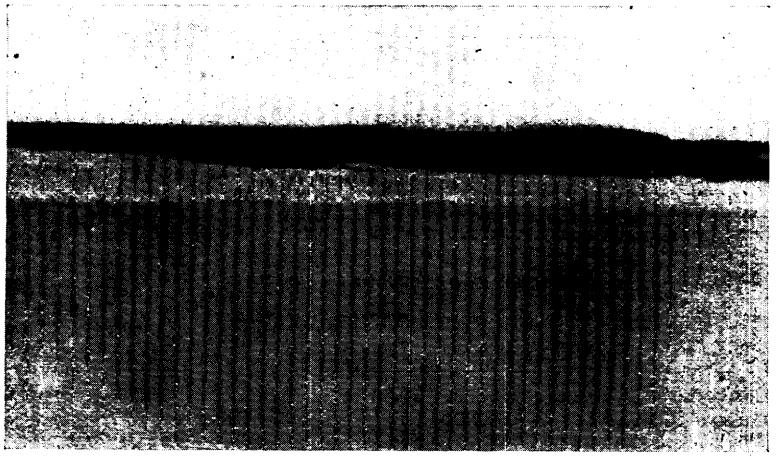


Fig. 35—Sand beach, two miles south of Wellington.

The dune sand is in general too fine for building purposes, but it has been suggested that some parts could probably be used for making ordinary bottle glass. A microscopical examination of samples taken at different parts of the bar shows that it is composed principally of glassy quartz particles, some of which are covered by rust. Among the other minerals observed were calcite,

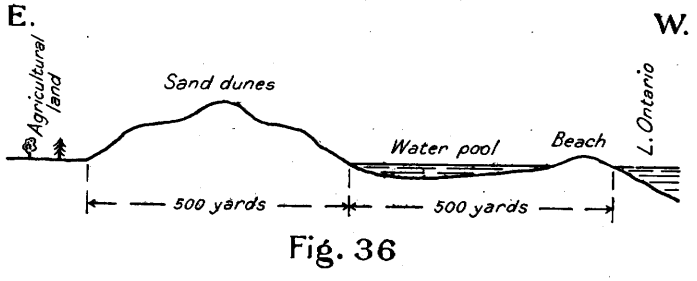


Fig. 36

Fig. 36—Section of the southern end of the Wellington sandbar.

orthoclase, plagioclase, magnetite, rutile, garnet, hornblende and tourmaline. In the shore sand, the proportion of quartz is larger north of the bar than to the south, where garnet and magnetite become more abundant and give to the sand a darker colour. The dune sand is finer grained, and the proportion of heavy ferro-magnesian minerals it contains is lower than in the beach sand, although the coloured minerals account for 5 to 10 per cent. of the whole mass.

In its natural state, this sand seems unsuitable for glass on account of the ferro-magnesian minerals present, but a large amount of the iron-bearing minerals may be extracted by a magnetic separator. Magnetite, garnet, hornblende and

tourmaline are the principal minerals found among the extracted particles. The average proportion of the separated material, in four experiments, amounted to 6.72 per cent.

Chemical analysis of the dune sand of the Wellington bar (1) in its natural state and (2) after magnetic separation gave the following results:

	(1) Per cent.	(2) Per cent.
Silica	59.60	61.69
Alumina	8.52	10.25
Ferric oxide	2.46	0.80
Ferrous oxide	1.64	0.95
Lime	12.61	12.38
Magnesia	1.86	1.33
Potash	2.02	1.62
Soda	2.58	2.72
Water	0.29	0.31
Carbon dioxide	8.36	8.20
Total	99.94	100.25

Norms calculated from the preceding analyses:—

	(1) Per cent.		(2) Per cent.	
Calcite	19.00		18.60	
Orthoclase 11.68			9.45	
Albite 22.01	39.25		23.06	42.24 feldspars
Anorthite 5.56			9.73	
Magnetite	3.71		1.16	
Corundum	....		0.51	
Wollastonite	1.74		....	
Enstatite	4.60		3.30	
Grünerite	0.92		1.19	
Quartz	30.42		33.00	
Water	0.29		0.31	
Total	99.93		100.31	

These figures show that this sand is composed of very mixed materials: feldspars, quartz and calcite are the principal constituents, but the proportion of pure quartz is rather small. The magnetic separation process applied to this sand only separates some magnetite and iron-bearing silicates, and the general composition of the sand is not much improved. For glass-making, the requirements are generally 98 to 99 per cent. of silica, and only traces of iron oxides. These requirements are not met by the sand of Prince Edward county dunes.

Granular metric analysis of sand from central portion of the Wellington dunes:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	0.0	0.0	0.0	0.0	0.0	0.25	63.75	94.45	100.00

Per cent. of fineness	71.28	Apparent specific gravity	1.575
Coefficient of uniformity	94.20	Weight in lbs. per cubic foot	98.41
Grade	No. 7	Percentage of voids	46.3
Real specific gravity	2.937		

N.B.—The material remaining on the 200-mesh and passing the 100-mesh is darker than that remaining on the 100-mesh; this is again darker than the material remaining on the 80-mesh.

Granular metric analysis of sand from eastern slope of the dunes:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	0.0	0.0	0.0	0.0	0.05	3.10	85.60	98.70	99.80

Per cent. of fineness	68.08	Apparent specific gravity	1.558
Coefficient of uniformity	95.6	Weight in lbs. per cubic foot	97.35
Grade	No. 7	Percentage of voids	44.8
Real specific gravity	2.823		

N.B.—The small particles contain most of the dark minerals.

Renfrew County

Between Eganville and Golden Lake this country is underlain by granitic rocks covered with forest, the rock at some places being concealed by lenses of brown sand. Similar occurrences exist between Golden Lake and Pembroke. The sand is very often intermixed with pebbles, and grades into gravel. This material has been extensively used by the G. T. Ry. as ballast. West and south of Pembroke the greater part of the area for about two miles is sandy. There is generally some loam at the top, and under it a coarse sharp, brown sand mixed with pebbles, underlain by white sharp sand. It should be noticed that the percentage of limestone pebbles is smaller than usual in the gravel deposits, there being frequently 50 per cent. of granite and metamorphic rocks.

There is an extensive sandy area near Haley on the C. P. Ry. line, and near Olmsted lake. From 6 to 10 miles northwest from Arnprior, there is a sand and gravel beach along the Ottawa river near Castleford and Sandpoint. The sandy formation here covers the limestone outcrops near the river to a height of 50 feet above the present water level.

Arnprior also gets some sand and gravel from pits located in the northwestern end of Carleton county.

SAND AND GRAVEL PITS EXAMINED IN RENFREW COUNTY.

Owner	Location	Size in feet	Remarks
Wm. Markus,Ltd. Pembroke	1 mile S.-W. of Pembroke.	500 by 250 by 40	Brown sand and gravel near top; white sand near bottom.
Johnson Griffith, Pembroke	1 mile S.-E. of Pembroke.	100 by 100 by 8	Concrete gravel. Reserves, 4 acres.
James Stewart, Arnprior....	3 miles S. of Arnprior...	.....	Road gravel.

Granular metric analysis of brown sand from pit of W. Markus, Ltd., Pembroke:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained ...	32.85	39.20	42.50	54.10	69.30	93.85	97.95	98.75	99.60

Per cent. of fineness 30.2
Coefficient of uniformity 39.75
Grade ..... No. 5
Real specific gravity 2.746
Apparent specific gravity 1.687
Weight in lbs. per cubic foot ... 105.40
Percentage of voids 38.5

Russell County

The principal deposits in this county are located at Bear Brook, Bowesville, Brisson, Casselman, Cumberland, and Leonard. The deposits around Casselman, in the township of Cambridge, were visited. These consist of deposits of building sand, moulding sand and gravel, but no extensive work has been done in recent years. The whole district around Casselman is rather sandy, but there is no large market for ordinary sand and gravel in the neighbourhood.

On the other hand, the moulding sand of this region has not been worked, although there are large reserves northwest of Casselman. These moulding sand deposits are well shown on the north side of the G. T. Ry. line between a point about two miles west from Casselman, and the station of South Indian. It occurs as fine grained material in a layer one or two feet thick under the loam.

PITS EXAMINED IN RUSSELL COUNTY.

Owner	Township, Con. and Lot	Size in feet	Remarks
Ad. Rainville, Casselman.....	Cambridge, Con. VI and VII, lot 15	100 by 100 by 30	Principally sand and a little gravel. Reserve, 1.5 acre.
A. F. Durivage, Casselman.....	Cambridge, Con.VIII, lot 7.....	200 by 100 by 6	Sand.
Dieudonne Forgues, Casselman.....	Cambridge.....	90 by 60 by 8	Cement gravel.

Granular metric analysis of sand from Ad. Rainville's pit, Casselman:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	0	tr.	0.15	5.05	26.30	72.00	92.50	96.45	99.05

Per cent. of fineness 56.5
Coefficient of uniformity 66.95
Grade ..... No. 5
Real specific gravity 2.795
Apparent specific gravity 1.589
Weight in lbs. per cubic foot ... 99.29
Percentage of voids 43.2

Simcoe County

The greater part of this county was covered by the waters of the ancient Lake Algonquin. About three-fifths of the whole area is now covered by surface deposits due to the action of this lake. Several shore lines may be followed through the county. The principal one, known as Algonquin Lake shoreline (fig. 37) enters the southeastern corner of the county through the township of Gwillimbury west and runs in a north-northeasterly direction about parallel to the boundary of the county and the western shore of Lake Simcoe.

At a point about two and a half miles from Big Bay point, the shoreline turns west, passing near Allandale, Colwell and Angus, where it turns again south as far as Beeton, in Tecumseth township. From this point it runs in a more or less straight line about N.40°W. through the townships of Tecumseth, Adjala, Tosorontio, and Nottawasaga, and crosses the county boundary to enter Collingwood township in Grey county. Between Lake Simcoe and the Georgian Bay there are some large islands of Lake Algonquin marked by their old shorelines. In the whole of Simcoe county the Algonquin shore line is between 750 and 775 ft. above sea level.

The preceding facts are of interest for the location of sand and gravel surface deposits. Practically the whole district south of the ancient shoreline consists of good farming lands. Such is the case for the greater part of the townships of Gwillimbury West, Tecumseth, Adjala, Innisfil, and Essa. Good farming land is also found in the northern part of Simcoe county, in the townships of Oro, Vespra and Tiny, which existed during Algonquin times as large islands.

The remainder of the county was covered by Lake Algonquin, and shows to-day extensive deposits of sand, gravel, and clay. This is the case in the greater part of Medonte, Orillia, Tay, Flos, Sunnidale, and Tosorontio townships. It should also be noticed that other shorelines higher than the Algonquin line are marked locally by sand and gravel deposits.

The most abundant deposit of Lake Algonquin is a brownish red or reddish brown sand, too fine in size to be of economical value, as shown by the granular metric analysis. It can be well seen in the cuttings of the Nottawasaga river in Tecumseth and Essa townships. The upper part of the section is this reddish sand; under it comes some finer white sand approaching quick sand, and at the bottom of the valley there is some silty, impermeable clay. Borings for water at Camp Borden, in Essa township, showed a similar section: under the clay the borings struck a formation of sand and gravel containing water coming from Lake Simcoe, altitude 718 feet, and well filtered during its underground course. In some borings made at Camp Borden 45 feet of sand were found below the 630 feet altitude and over the clay.

To get a general view of these surface deposits, a trip was begun from Coldwater, in Medonte township, taking the C.P.Ry. in a southwesterly direction. Near Coldwater there is some sand. Gravel excavations and cuttings occur near Eady station; the brown ferruginous sand is very abundant near Carley station, where it extends over miles of the country. It can be followed for ten miles along the C.P.Ry. tracks, being sometimes mixed with pebbles and used for ballast. This sand formation is also very characteristic near Craighurst, in the southwest corner of Medonte township. It runs also over Vespra township; the sand shows a

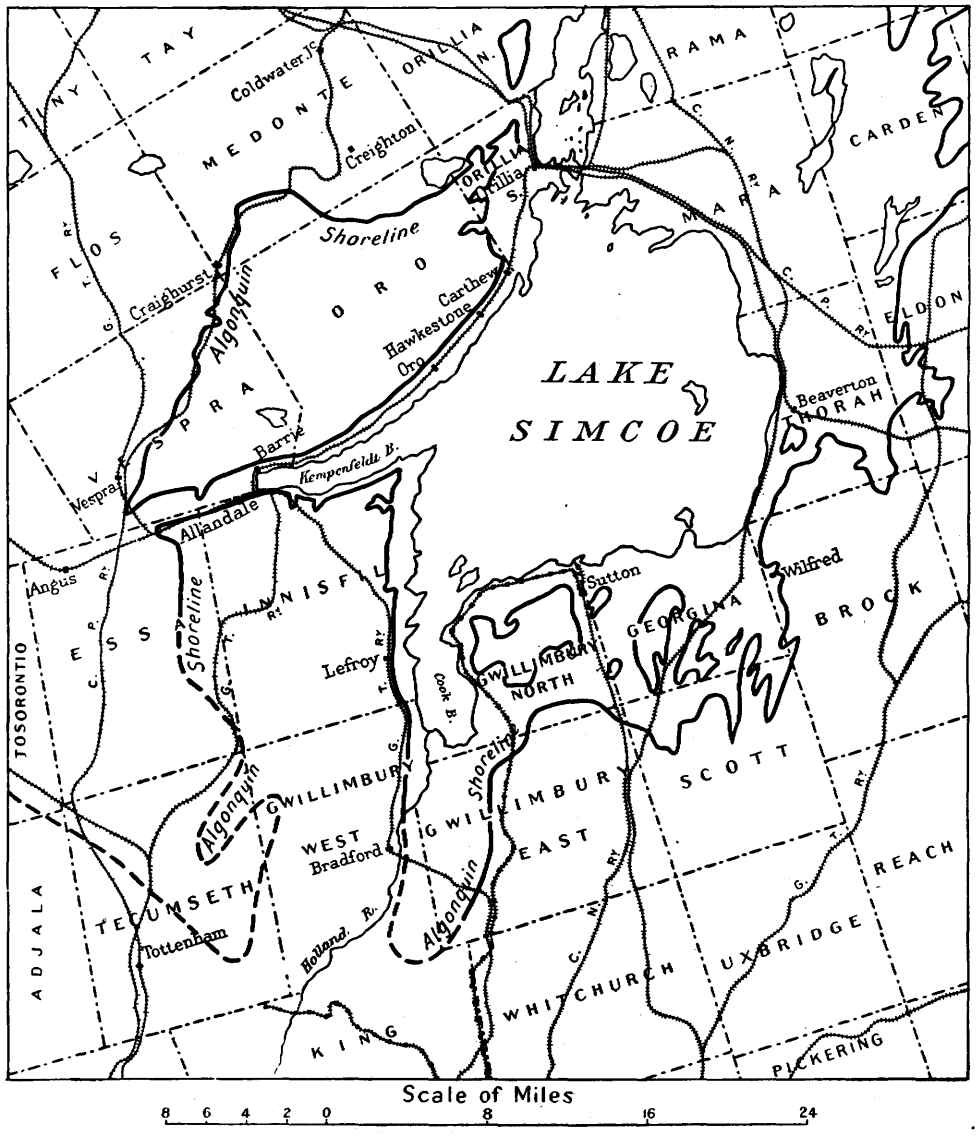


Fig. 27—Map of Lake Simcoe showing portions of the counties of Simcoe, York and Ontario. The approximate location of the shore line of ancient Lake Algonquin is indicated by a heavy line.

thickness of more than 100 feet in a big ravine, north of Midhurst station. South of Vespra township there is the ancient channel between a large island and Lake Algonquin shore; here the pebbles become more abundant, and large deposits of gravel occur southeast of Utopia station, near the boundary of Essa township. The region around and west of Angus is very sandy; the greatest part of this surface sand is a fine dune sand.

Sand dunes form a ridge near the southern boundary line between Sunnidale and Tosorontio townships. An extensive area covering parts of Essa, Tosorontio, Adjala and Tecumseth townships is part of a large bay of ancient Lake Algonquin. This bay has been completely filled by sand, and at present forms a country made up of large pine plains and extensive barren sandy grounds. It is in this region that Camp Borden is located.

Near Orillia, there are large deposits of sand and gravel between the present shore of Lake Couchiching and the shore line of a large ancient island of Lake Algonquin. This line runs about parallel to the western shores of Lake Simcoe and Lake Couchiching from Barrie to the northern end of Lake Couchiching. Lake Simcoe is, in fact, a remaining part of the channel between this large island and the shore of Lake Algonquin. Similar formations are found near Barrie and Allandale.

The region near Collingwood, in the northwest corner of Simcoe county, is a good example of recent detrital formation. Collingwood is on Nottawasaga Bay, near the southern point of Georgian Bay. To the east of the town, there is a gravel area still in formation, as can be seen along the creeks. The bottom of these creeks is made of shaly Ordovician limestone, covered by very angular pebbles of the same material. In summer time many of the creeks are dry, but during the winter the lake and the creeks carry this gravel over the adjoining area about six miles in an east-west direction and one mile in a north-south direction. The depth is variable and generally not more than four feet. The gravel is not of first-class quality, and only small pits have been opened in it. Going east the gravel turns gradually into sand. On the beach, six miles from Collingwood, the sand still contains some gravel, but farther east it becomes a characteristic beach sand extending ten to twelve miles along the shore to the mouth of the Nottawasaga river. The sand contains some magnetite and garnet grains, and is used for building purposes. The beach, not covered by vegetation, is at present 30 to 50 feet wide. It was from 150 to 200 feet some years ago, when the level of the lake was much lower.

Granular metric analysis of sand near the surface, Camp Borden:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	0.0	0.0	0.0	0.0	tr.	1.70	23.60	57.80	96.00

Per cent. of fineness	80.1	Apparent specific gravity	1.527
Coefficient of uniformity	72.40	Weight in lbs. per cubic foot	95.41
Grade	No. 8	Percentage of voids	48.3
Real specific gravity	2.958		

Granular metric analysis of silty sand, Camp Borden:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	0.0	0.0	0.0	0.0	tr.	1.25	2.00	5.70	41.50

Per cent. of fineness 94.39
Coefficient of uniformity 94.30
Grade ..... No. 9

Granular metric analysis of sand from Nottawasaga bay, seven miles east of Collingwood:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	0.0	0.0	0.0	tr.	tr.	13.80	82.95	98.10	99.95

Per cent. of fineness 67.24
Coefficient of uniformity 84.30
Grade ..... No. 7
Real specific gravity 2.864
Apparent specific gravity 1.633
Weight in lbs. per cubic foot ... 102.04
Percentage of voids 42.9

Stormont County

Deposits of sand and gravel are abundant in this county (fig. 38) as shown by the numerous excavations. These pits are mostly not very large, although they have a great quantity of material in reserve; the demand, however, is small. The deposits are generally in the form of irregular lenses of sand and gravel intermixed; the sand is rather sharp and is sometimes black in colour from the presence of the limestone grains. The gravel is generally sandy, 60 to 90 per cent. of the pebbles being composed of limestone, the remainder being granitic material. The size is variable, but the average is a fine gravel, large pebbles and boulders occuring only on top of the deposits. These materials are sold at various prices, but on the average the pit owners ask 50 cents a yard for building sand or cement gravel, and 25 cents a yard for road gravel. The writer visited a number of pits located near the southern boundary of the county, and others on both sides of the New York and Ottawa railway. A list of the principal excavations follows:—

No.	Owner	Township, Con. and Lot	Size in ft.	Output	Remarks
1	Ephraim Aube, Berwick	Finch, Con. VII, lot 18	120 by 50 by 10	200yd.	Nearly all building sand.
2	Henri Canneer, Berwick	Finch, Con. V, lot 20.	40 by 25 by 8	100yd.	Road gravel. Reserve, 0.5 ac.
3	Alfred Casselman, Berwick	Finch, Con. VI, lot 17.	125 by 125 by 8	100yd.	Road and cement gravel and sand. Reserve, 1.5 ac.
4	Guy Empey, Finch	Finch, Con. IV, lots 15, 16	{30 by 60 by 5} {100 by 40 by 6}	.....	Two gravel pits. Reserve, 5 ac.
5	Michael Godard, Crysler	Finch, Con. IX, lot 20	500 by 125 by 12	300yd.	Gravel and sand. Reserve, 10 ac.
6	Wesley Hume, Northfield	Finch, Con. V, lot 19.	100 by 25 by 12	.....	Road gravel. Reserve, 1 ac.
7	Ronald McMillan, Finch	Finch, Con. IV, lot 19,	150 by 100 by 7	300yd.	Road and cement gravel. Reserve, 2 ac.
8	Wm. Bowles, Newington	Osnabruck, Con. VIII, lot 28.	175 by 100 by 8	.....	Sharp sand and pea gravel. Reserve, 2 ac.
9	J. Joint, Newington	Osnabruck, Con. VIII.	150 by 100 by 4	.....	Road gravel. Reserve, 2 ac.
10	Jas. Winter	Osnabruck, Con. VIII,	150 by 100 by 9	.....	Sand and gravel. Reserve, 7 ac.
11	Albert Aimable, Moulinette	Cornwall	.....	.....	Gravel.
12	Thos. Cleary, Mille Roches	Cornwall, Con. I, lot 28	120 by 60 by 10	300yd.	Sand and gravel. Reserve, 1.5 ac.
13	Alexander Day. Mille Roches	Cornwall, Con. III...	60 by 60 by 8	.....	Road and cement gravel; sand.
14	Hugh McGillis, Harrison Corners	Cornwall	120 by 120 by 7	.....	Coarse gravel. Large reserves.
15	Herbert Mattice, Wales	Cornwall, Con. II, lot 34	125 by 125 by 20	.....	Gravel and sand of various grades. Reserve, 2 ac.
16	Wm. Murphy, Wales	Cornwall, Con. II, R. 5, lot 36.	500 by 100 by 9	.....	Gravel. Reserve, 8 ac.
17	Geo. Murray, Cornwall	Cornwall, Con. VI, lot 31	150 by 100 by 12	.....	Coarse gravel.
18	Howard Winters, Mille Roches	Cornwall, Con. III, lot 24	500 by 250 by 15	250yd.	Fine gravel. Reserve, 7 ac.
19	Cory Woods, Moulinette	Cornwall	.....	.....	Gravel.

Granular metric analysis of sand from Michael Godard's pit, Crysler:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	0.0	0.0	0.10	0.30	0.50	8.90	42.05	65.20	90.40

Per cent. of fineness 76.95
Coefficient of uniformity 56.30
Grade ..... No. 7
Real specific gravity 2.753
Apparent specific gravity 1.568
Weight in lbs. per cubic foot .. 97.975
Percentage of voids 43.04

Granular metric analysis of fine sand from H. Mattice's pit, Moulinette:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	0.0	0.0	0.0	tr.	tr.	0.10	0.50	7.45	61.25

Per cent. of fineness 92.3
Coefficient of uniformity 92.55
Grade ..... No. 9
Real specific gravity 3.168
Apparent specific gravity 1.434
Weight in lbs. per cubic foot .. 89.60
Percentage of voids 54.7

Victoria County

The shoreline of the glacial lake Algonquin passes through the townships of Dalton, Carden, Bexley, Fenelon, Somerville, and Eldon. The usual deposits of sand and gravel occur along this line, for instance, near Argyle, Kirkfield, Baddow, and Fenelon Falls.

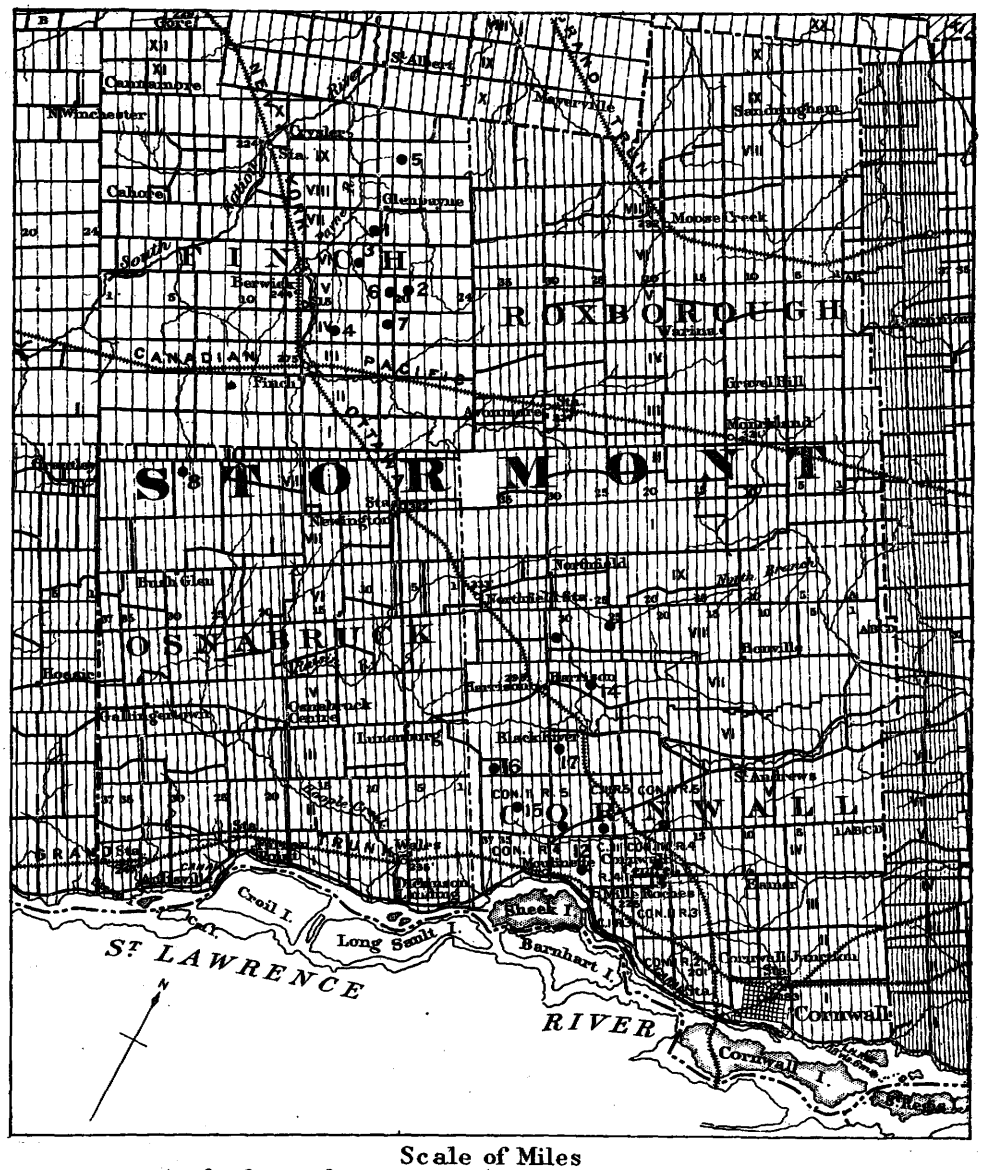


Fig. 38—Map of Stormont county, showing the principal sand and gravel pits. Numbers refer to the list given in the text.

In the township of Fenelon there are extensive deposits of sand of different grades on the McCormick hills, about three miles west from Fenelon Falls. The material is sharp, and contains a large amount of limestone grains. This deposit covers about 400 acres.

The area east of Fenelon Falls along Sturgeon lake, in the townships of Fenelon and Verulam, is part of the ancient channel connecting Algonquin lake and Iroquois lake. This channel is known as Algonquin river and follows the chain of lakes in this district and the Trent valley. Numerous fluviatile deposits of sand and gravel occur along this line.

North of Burnt River, in Somerville township, the country is very sandy, and consists principally of calcareous sand originating from the weathering of the underlying limestones. The deposits extend to the south of Burnt River, where there is also some limestone gravel.

This line of deposits also occurs in Verulam township, where there are numerous beds of sand and gravel. Along the Bobcaygeon-Lindsay road several pits have been opened.

In the township of Ops a ridge of gravel west of Lindsay runs in a northeast-southwest direction and passes through lots 18, 19, 20 and 21 of concession 4. It is about one and a half miles from the town of Lindsay, and several pits have been opened upon it. The depth is generally about 10 feet. About 70 per cent. of the gravel is composed of limestone pebbles. The large stones found on top of the deposits are used for foundation work. Some sand with bonding power sufficient to make good moulding sand was found on top of this ridge.

SAND AND GRAVEL PITS IN VICTORIA COUNTY.

Owner	Township, Con. and Lot	Size in feet.	Remarks
Wm. Weese, Lindsay	Ops, Con. IV, lot 18S	150 by 60 by 10	Gravel. Reserve, 10 ac.
Patrick McGuire, Lindsay	Ops, Con. IV, lot 18N		Gravel.
Miller, Lindsay	Ops, Con. IV, lot 19		Gravel.
Patrick Murphy, Lindsay	Ops, Con. IV, lot 20		Gravel.
Lindsay Corporation, Lindsay	Ops, Con. V, lot 23		Road gravel
Grand Trunk Ry	Fenelon		Gravel.
G. H. Brandon, Fenelon Falls	Fenelon		Sand.
Fenelon Council	Fenelon, McCormick Hills	200 by 40 by 15	Sand.
R. Hawkins, Woodville	Eldon, Con. III, lot 17		Sand and gravel.
Alex. Morrison, Kinmount	Somerville, near Kinmount.		Sand.
Somerville Township	Somerville, Con. I, lot 22		Gravel.
Thos. Hodgson, Burnt River	Somerville, Con. V, lot 12	100 by 30 by 8	Sand and gravel.
John Rich, Bobcaygeon	Verulam	100 by 75 by 10	Sand and gravel. Reserve, 1 acre.
Thos. Kettle, Bobcaygeon	Verulam		Sand and gravel.
C. D. Logan, Bobcaygeon	Verulam		Sand and gravel.
R. W. Wilson, Omemee	Emily		Gravel.
McConnell, Omemee	Emily		Gravel.
Frank Duwell	Fenelon, McCormick Hills.	500 by125 by 10	Sand.

Granular metric analysis of sand from F. Duwell's pit, McCormick hills:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	2.10	9.60	16.55	37.70	52.85	82.05	93.50	96.25	98.35

Per cent. of fineness 45.67
Coefficient of uniformity 44.35
Grade ..... No. 5
Real specific gravity 2.837
Apparent specific gravity 1.664
Weight in lbs. per cubic foot .. 103.973
Percentage of voids 41.3

Granular metric analysis of gravel from W. Weese's pit, Lindsay:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	57.20	66.60	73.95	87.30	92.30	96.75	98.15	98.70	99.30

Per cent. of fineness 14.42
Coefficient of uniformity 66.60
Grade ..... No. 1



Fig. 39—Sand and Supplies, Ltd., Ayr.
View of the pit and bucket elevator.

Waterloo County

In the vicinity of Kitchener, Preston, Galt and Ayr the county is hilly, and there are several gravel ridges, a few of which have been worked. The most important pits are those of Sand and Supplies, Ltd., of Toronto, near Ayr. This

concern owns a large pit situated in a ridge of hills one and a half miles northeast of Ayr (fig. 39). The excavation covers at present a surface of 600 by 250 feet, the depth varying between 15 and 60 feet. The upper 15 feet of the high wall are gravel; under it there are sands of varying character, sometimes mingled with pebbles. At certain places 4 feet of clay occur near the top. The excavating is done by a digger elevator with buckets and screeners, producing materials of different grades. A car of 80,000 lb. capacity is filled in nearly 20 minutes.

Granular metric analysis of sand from Sand and Supplies Co., Ltd., Toronto (Ayr pit):—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	0.0	0.30	1.10	8.40	22.80	78.30	96.90	98.95	99.60

Per cent. of fineness	54.85	Apparent specific gravity	1.634
Coefficient of uniformity	74.10	Weight in lbs. per cubic foot	102.099
Grade	No. 6	Percentage of voids	41.4
Real specific gravity	2.791		

Welland County

Sand deposits are still in formation along the beaches of Lake Erie between Port Colborne and the mouth of the Niagara river. The material is worked on a large scale and is used for building purposes in Canada and in the United States.

Welland county lies completely south of the Niagara escarpment, on a plateau at an altitude of about 550 feet. On this plateau there are several buried channels and valleys, representing ancient connecting lines between Lake Erie and Lake Ontario. These valleys, like the present Niagara valley, were cut through the Niagara limestones and Medina shales. They are now completely filled with drift, sand, and gravel. The most important gravel pits of this county are located in these buried valleys. In such pits, irregular, oblique stratification is not rare. Gravel and sandbeds alternate, some parts of the valley being completely occupied by sand, others containing more gravel. The sand comprises a variety of grades, some parts being good sharp building material. The gravels are mostly of small limestone pebbles, with a little sandstone; the average gravel is a good auto-cementing material for concrete work. Deposits of this kind have been worked around Fonthill, Stamford, and Niagara Falls.

The concerns working in Welland county are mostly large and well equipped, this being the case both for those dredging sand out of Lake Erie and those working gravel pits. The material is sold at about 50 cents a yard. Some moulding sand is found on top of the buried valleys.

SAND AND GRAVEL PRODUCERS, WELLAND COUNTY

Owner	Location	Size in feet.	Output.	Remarks
Confederation Sand and Gravel Co., St. Catharines	Mouth of Niagara R.		100,000 yd.	Sand dredged out of Lake Ontario
Empire Limestone Co., Buffalo	Lake Erie shore		100,000 yd.	Sand dredged out of Lake Erie..
Conlon, St. Catharines	Fonthill	180 by 90 by 40 100 by 120 by 40		Two pits. Sand and gravel.
Clifton Sand and Gravel Co., Toronto.	Stamford	450 by 600 by 75		Sand. Reserve, 50 acres.
Ontario Sand Co., Niagara Falls	Stamford tp.	300 by 400 by 15	12,000 yd.	Gravel and sand. Reserve, 39 acs.
Stamford Sand Co., Niagara Falls	Stamford tp	500 by 300 by 75		Sand and gravel.
Standard Gravel Co., Niagara Falls	Stamford tp	200 by 200 by 15	Daily output in 1917, 100 yds.	Sand and gravel. Reserve, 6 ac.

Granular metric analysis of sand from the Ontario Sand Co.'s pit, Niagara Falls:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained....	13.0	20.45	25.50	49.60	68.85	90.05	94.95	96.25	97.75

Per cent. of fineness	38.2	Apparent specific gravity	1.743
Coefficient of uniformity	43.35	Weight in lbs. per cubic foot	108.910
Grade	No. 4	Percentage of voids	38.8
Real specific gravity	2.847		

Granular metric analysis of gravel from the Standard Gravel Co.'s pit, Niagara Falls:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained ...	35.35	45.75	50.85	61.65	70.75	93.40	98.20	98.85	99.35

Per cent. of fineness	27.3
Coefficient of uniformity	45.75
Grade	No. 1

Wellington County

The pits examined in this county were near Guelph and Erin. In the southern part of Guelph there is a ridge about 100 feet west of the Waterloo road, containing road and cement gravel, moulding sand, brick sand, and building sand. This deposit extends over a large area, and important reserves are still available. In one of the pits there were about 20 feet of sand on top, over the gravel; and borings have shown

this gravel to be 80 feet in thickness, overlying the limestone. The sand, which shows oblique stratification, is of good quality for making mortar and for other building purposes. In some places there are 4 feet of moulding sand. This material is valuable, and is sold at $2.50 a yard, while gravel and ordinary sand sell at $1.50 per yard, delivered in Guelph.

The amount of gravel and sand found in the neighbourhood of Erin is very large, and some important concerns are now in operation. The gravel, which usually contains 60 per cent. pebbles and 40 per cent. sand, is screened to provide different grades. The large pebbles are sometimes crushed to produce finer material.

SAND AND GRAVEL PRODUCERS IN WELLINGTON COUNTY.

Owner	Location	Size in feet	Output	Remarks
Agnes Haggerty, Guelph	Waterloo Rd., Guelph	15 by 10 by 12	.....	Gravel pit opened in 1916.
A. McCannell, Guelph	Waterloo Rd	150 by 150 by 20 150 by 75 by 15	2,000 yd.	Gravel pit. Sand pit. Reserves, 40 acres.
Dr. Gear, Erin	Erin tp., Con. X, lot 15	75 by 60 by 12	350 yd.	Gravel and sand sold at 10c. per yd. at the pit.
Rocsand Co., Erin	Erin tp., Con. X, lot 16	500 by 350 by 20	Daily output in 1917, 300 cu. yd.	Gravel and sand, steam shovel and screening plant. Reserve, 20 acres.
C. P. Ry., Erin	Erin tp., Con. X, lot 16	1,000 by 200 by 15	.....	Ballast.
Construction and Paving Co., of Ont., Toronto.	Erin tp., Con. XI, lot 15	300 by 100 by 18	8,500 yd.	Gravel and sand.
J. Hamilton, Erin	Erin tp., Con. X, lot 15	Depth,35ft.gravel	Not worked	Gravel and sand. Reserves, 40 acres.

Granular metric analysis of sand from Rocsand Company's pit, Erin:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	0.35	2.65	5.95	18.65	41.20	92.45	97.20	98.05	98.80

Per cent. of fineness 49.4
Coefficient of uniformity 73.80
Grade ..... No. 5
Real specific gravity 2.935
Apparent specific gravity 1.636
Weight in lbs. per cubic foot .. 102.22
Percentage of voids 44.2

Granular metric analysis of gravel from Rocsand Co., Erin:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	57.85	67.40	72.10	81.10	88.90	97.85	99.30	99.50	99.70

Per cent. of fineness 15.14
Coefficient of uniformity 67.40
Grade ..... No. 1

Wentworth County

This county, with Hamilton as its principal city, is crossed by the shoreline of ancient Lake Iroquois (fig. 40). This shoreline is located at an average of about two and a half miles inland from the present shore of Lake Ontario, and lies close to and parallel with the Niagara escarpment. Several deposits of sand and gravel occur along this line, and are valuable sources of supply for Hamilton.

In the region south of Bartonville, in the townships of Saltfleet and Barton, moulding sand occurs as a surface deposit, and this material is used in the foundries of Hamilton and of Ontario in general. All grades of moulding sand, from very fine brass sand to coarse pipe sand, have been found in this region.

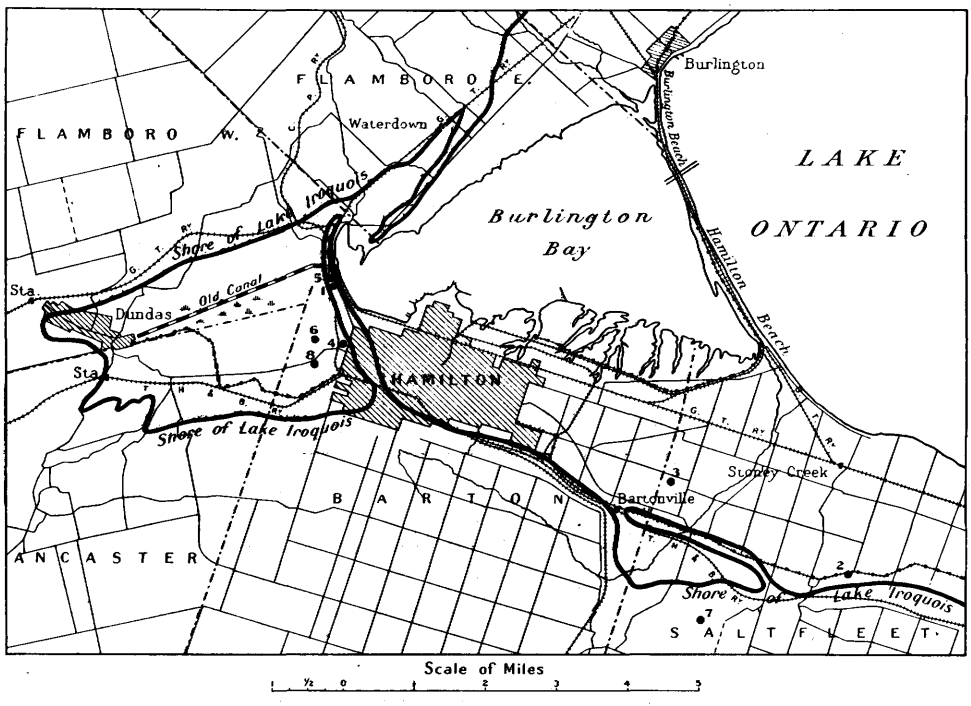


Fig. 40—Map of Hamilton and vicinity, showing location of the principal sand and gravel deposits, also the shore line of ancient Lake Iroquois. Numbers refer to the list given in the text.

There are also very large deposits west of Hamilton, on the area covered by the ancient bay that terminated Lake Iroquois to the west. These deposits, which at some places consist of alternate layers of clay, sand, and gravel, have been largely worked by brick plants.

Some layers of gravel are cemented by calcite; others consist of sandy gravel, from which by crushing the larger boulders and screening, the following products are obtained: coarse gravel, medium gravel, crushed stone for roadwork, pea gravel for concrete, medium sand, brick sand, and core sand. At the Armstrong Supply Co.'s pit at Hamilton, for instance, there are about 160 feet of gravel and sand before the water level is reached. The screening diagram of this concern indicates how the material is prepared for the market (fig. 41).

A large sandbar extends east of Hamilton in a north-south direction across Burlington bay, connecting Hamilton and Burlington. The southern part is known as Hamilton beach, the northern as Burlington beach. This bar is covered by cottages, railways, etc., and forms an important natural bridge. It is controlled by the Burlington Beach Commission. A little sand has been taken out of the lake in the neighbourhood. The average material sells at prices ranging from 70 cents to one dollar a yard at the pit. Moulding sand is sold at about one dollar per ton.

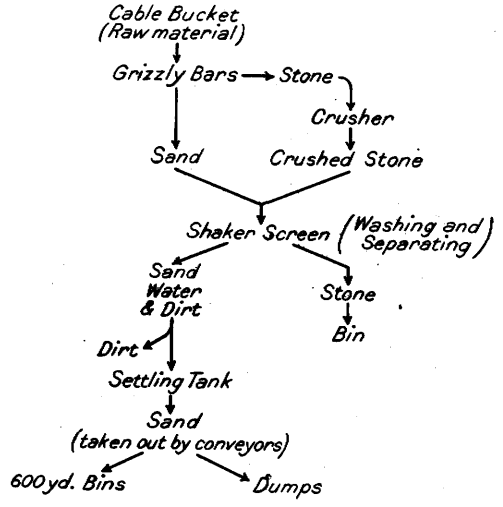


Fig. 41—Screening diagram of Armstrong Supply Co., Hamilton.

SAND AND GRAVEL PRODUCERS, WENTWORTH COUNTY.

No.	Owner	Location	Size in ft.	Output	Remarks.
1	Armstrong Supply Co., Hamilton.....	Western end of Burlington bay	Depth of pit, 80 ft.	.....	Sand and gravel. Reserves, 18 ac.
2	W. Barnes, Hamilton.....	Stoney Creek	.....	.....	Gravel and some moulding sand.
3	Barton Sand & Gravel Co., Bartonville ..	Barton tp., Con. III, lot 1	30 deep	8,000 yd.	Sand & gravel. Plant of 400 yds daily capacity. Reserve, 12 ac. (fig. 42)
4	Geo. Frid Brick Co., Hamilton.....	Northwest of Hamilton	50 by 50 by 30	20yd. per day	Sand and gravel. (fig. 43)
5	Hamilton Sand and Gravel Co., Hamilton.	Junction Cut, Hamilton	350 by 150 by 40	60 yd. per day (10,000 yds)	Gravel and sand. (fig. 44)
6	Ollmann Bros., Hamilton.....	Northwest end of Hamilton, near Dundas Road	500 by 300 by 40	2,000 yd..	Sand and gravel. Reserve, 8 ac.
7	O. Quigley, Hamilton	Saltfleet tp., Con. IV and V, lot 30.....	Depth, 6 ft.	10,000 yd..	Moulding sand. Reserve, 75 ac.
8	R. Tope, Hamilton ..	Dundas Rd., Barton tp. Con. II, lot 20	100 by 50 by 30	.....	Gravel (fig. 45)

Chemical analysis of pipe moulding sand, O. Quigley, Hamilton:—

	Per cent.
Silica (SiO_2)	80.42
Iron (Fe)	0.05
Iron oxide (Fe_2O_3)	5.423
Magnesia (MgO)	1.48
Alumina (Al_2O_3)	5.10
Lime (CaO)	3.12
Carbon dioxide (CO_2)	4.05
Total	99.643



Fig. 42—Barton Sand and Gravel Co's. pit, Bartonville.

Chemical analysis of machinery moulding sand, Quigley pit, Hamilton:—

(Analysis by W. K. McNeill, Provincial Assayer.)

	Per cent.
Silica	74.42
Alumina	10.37
Ferric oxide	2.61
Ferrous oxide	2.22
Lime	2.76
Magnesia	1.08
Potash	1.72
Soda	2.36
Water	1.65
Carbon dioxide	1.00
Total	100.19

The bonding power of this material is due to the high percentage of alumina and iron oxides.

Norm calculated from the preceding analysis:—

Calcite		2.30	
Orthoclase	10.01	37.15	feldspars
Albite	19.91		
Anorthite	7.23		
Corundum		2.04	
Magnetite		3.71	
Enstatite		2.70	
Grünerite		1.98	
Quartz		48.60	
Water		1.00	
Total		99.48	

The corundum and magnetite indicate the presence of kaolinite or clay mixed with iron oxides, the cause of the moulding qualities of the sand.

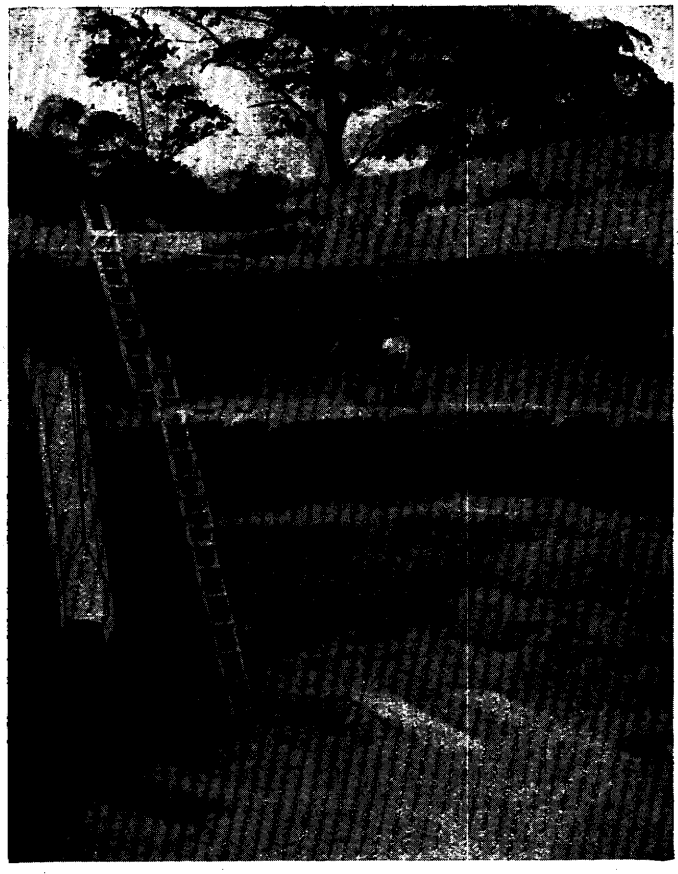


Fig. 43—Frid gravel pit, Hamilton.

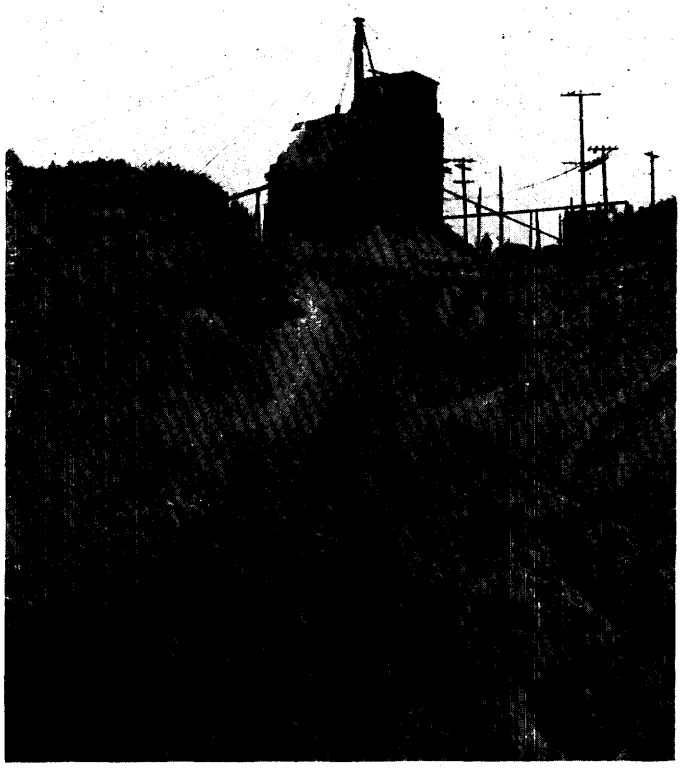


Fig. 44—Hamilton Sand and Gravel Co's. pit and screening plant.



Fig. 45—Tope gravel pit, Hamilton.

Granular metric analysis of washed sand from Armstrong Supply Co., Hamilton:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	0.05	4.95	10.00	24.30	32.05	68.05	94.00	98.60	99.10

Per cent. of fineness 52.10
Coefficient of uniformity 61.95
Grade ..... No. 6
Real specific gravity 2.841
Apparent specific gravity 1.645
Weight in lbs. per cubic foot .. 102.786
Percentage of voids 42.1

Granular metric analysis of sharp sand from Hamilton Sand and Gravel Co., Hamilton:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	0.20	0.70	1.45	4.05	11.75	71.75	97.55	99.25	99.60

Per cent. of fineness 57.08
Coefficient of uniformity 85.80
Grade ..... No. 6
Real specific gravity 2.933
Apparent specific gravity 1.511
Weight in lbs. per cubic foot .. 94.413
Percentage of voids 48.4

Granular metric analysis of pea gravel, from Armstrong Supply Co., Hamilton:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	89.60	99.85	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Per cent. of fineness 1.17
Coefficient of uniformity 99.85
Grade ..... No. 1

York County

The shorelines of Lake Algonquin and Lake Iroquois which pass across this county are rich in deposits of gravel and sand. From an economic standpoint, the deposits of the Lake Iroquois beach are the more important, on account of their proximity to the city of Toronto. The whole area between the Iroquois shoreline and Lake Ontario is covered by Iroquois beach materials, principally sand (fig. 46).

The greater part of Toronto lies on Iroquois sand, and while some large pits are still working inside the city limits, most of them are nearing exhaustion, as the surrounding buildings prevent the extension of the worked area.

On the southern side of Bloor street west, about 250 yards west of Dundas street, there is an outcrop of sand, 10 feet above the street level. Under the soil there are 3.5 feet of moulding sand, then a small gravel bed, and under it ordinary Iroquois building sand.

West of Toronto, and about two miles east of the Humber river, there are some small gravel and sand pits.

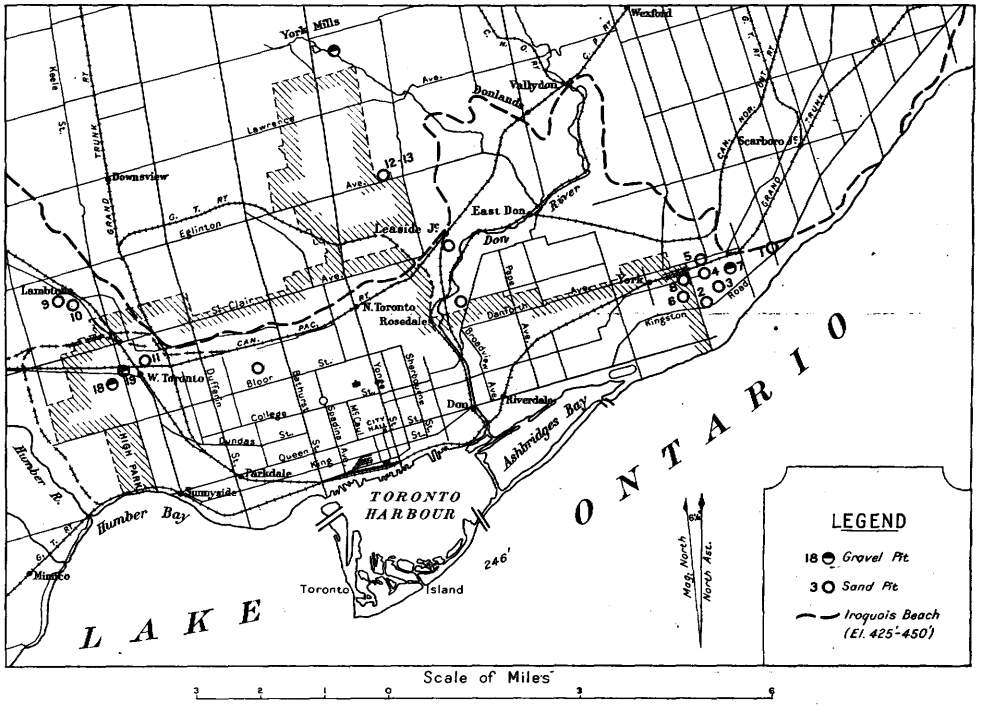


Fig. 46—Toronto and vicinity, showing location of principal sand and gravel pits. The numbers refer to the list given in the text.

Most of the sand and gravel supply of Toronto comes from the suburbs and from the surrounding district. Large sand and gravel bars were formed during Iroquois times east and west of the present city limits; the eastern bar, which is the more important, passes through York and Birch Cliff, while the western bar passes near West Toronto station and Lambton Mills. These bars were built up in the same way as Toronto Island is now being formed. This recent bar is not worked, the island being used as a summer resort.

In the Iroquois bars there are numerous pits of sandy gravel, which when screened produces four sizes.

(1) Sand used for polishing glass and marble; grains passing the 4-mesh screen.

(2) Gravel for roofing; pebbles passing the 2-mesh screen.

(3) Gravel for reinforced floors and concrete work; pebbles three-quarters of an inch in diameter.

(4) Gravel for road and general foundation work, pebbles between 1 inch and 3 inches.

The gravel bar is underlain by Iroquois sand. Where the Iroquois sand is the top deposit, the upper parts are generally brown, exhibiting bonding power, and at certain places this sand is a moulding sand or a core sand.

The pits are numerous on the north side of Kingston road, and some pits (York Sand and Gravel Limited) produce as much as 100,000 tons a year, half of this material being sand. The mortar sand sells at 25 to 40 cents a yard, sharp sand at about 40 cents, and screened gravel at $1.00 at the pit. As one team can make only two trips a day from the pit to Yonge street, the transportation costs are very high, so that pea gravel costs as much as $2.30 a yard, delivered at Yonge street.

One gravel pit was worked in Summerville, about ten miles west of Toronto. The gravel was brought to the city by motor trucks of 4.5 cubic yards load, making 5 trips daily. This considerably reduced the cost of transport, the cost of an ordinary team being about $6.75 per day.

The run of gravel of the Iroquois bar formation is used by the York Sandstone Brick Co. for making sand-lime bricks. The sandy gravel is screened to eliminate the large stones, and then mixed with 6 to 9 per cent. of slacked lime. This mixture is passed through a Chilean mill crusher, and then into moulding presses, from which the bricks are loaded on wagons, run into big tanks, and submitted for twelve hours to a steam pressure of 125 to 135 pounds. After this time, the bricks are white and hard. It is claimed that these bricks become harder as they advance in age, this phenomenon being probably due to the chemical action of the carbon dioxide of the atmosphere.

Northeast of Toronto, there are some gravel and sand formations near Leaside Junction, where recent gravel is found in the bed of the Don river; also near Aurora, where moulding sand which has been used in the foundry at Aurora, and building sand occurs over a large area. The area between Aurora and Bond lake is very sandy, and contains large reserves. At Maple, four miles west of Yonge street, in lots 22 and 23, concession three of Vaughan township, there are two operators, supplying large quantities of building sand and gravel to Toronto. This material is sold at about 70 to 80 cents a ton in Toronto, of which 55 cents is consumed in freight charges.

SAND AND GRAVEL PRODUCERS, YORK COUNTY.

No.	Owner	Location	Size	Output.	Remarks
1	Allen Bros., Toronto	Birch Cliff, Scarboro tp.	5 acres, 25 ft. gravel, 8 ft. sand	1,500 yd.	Sand & gravel. Screen moved by horse-gear.
2	Bourne & Son, Toronto	Scarboro tp., Kingston Rd			Sand and gravel.
3	E. Ashton, 1352 Queen St. E., Toronto	Scarboro tp., Victoria Park Rd.			4 kinds of sand and gravel.
4	York Sand and Gravel Co., Toronto	Scarboro tp, south of G.T.Ry.	Gravel, 25 ft. deep. Iroquois sand more than 100 ft. deep	95,000 tons	Pit run gravel, screened gravel, mortar, sand and brick sand. Steam shovel of 1,200 tons daily capacity.
5	York Sandstone Brick Co., Toronto	Scarboro tp., South of G.T.Ry.			Sand and gravel for sand-lime brick making.
6	John Foley, 196 Pickering St., Toronto.	Toronto City, east of Pickering St. and north of Kingston Rd	8 ft gravel		Gravel and Iroquois sand.
7	Jackson, 183 Pickering St., Toronto	Toronto City, east of Victoria Park Rd.		Small	Gravel.
8	J. McTague, Malvern Road, Toronto	East Toronto, north of Kingston Rd. and east of Pickering St.	8 ft. gravel	4 yd. a day	Gravel and sand.
9	Maher, Wm., Weston	Weston Rd., Mt. Dennis	35 ft. deep	40 yd. a day	Principally sand.
10	Thompson, Porter, 26 Porter Ave., Mt. Dennis	Mt. Dennis			Sand and gravel.
11	Lochrie, Keele St. and Westminster Ave., Toronto	Toronto			Sharp sand.
12	H. L. Johnson, 56 Soudan Ave., Toronto.	North of Eglinton, Ave. and 1 mile east of Yonge St.			Sand and a little gravel.
13	A. J. Rayner, 244 Broadway Ave., Toronto	North Toronto			Sand.
14	Jos. Billing.	Aurora, 1 mile west of Yonge St.			Moulding sand.
15	The Empire Sand and Gravel Co., Maple .	100 yds northeast of Maple station	750 ft. long, 30 ft. deep.		Building sand and gravel.
16	Maple Sand, Gravel and Brick Co., 178 Spadina Av., Toronto	500 yards north of Maple station	100 ft. deep.	40,000 tons	Sand and gravel. Reserve, 80 acres. Steam shovel and steam screen.
17	Frank Pringle, 309 Indian Grove, Toronto	Summerville, 10 miles west of West Toronto	16 ft. deep		Gravel. Reserve, 25 acres. Motor trucks used in transportation.
18	Niagara Power Plant	West Toronto	8 ft. deep.		
19	Home Smith Co., Toronto	Keele St., W. Toronto			Gravel.
20		Toronto, Shaw St.			Interglacial sand and gravel.

Granular metric analysis of Iroquois sand, near corner of Gerrard Street and Greenwood Avenue, Toronto:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	0.0	0.03	0.09	0.24	0.39	8.49	71.99	89.49	98.09

Per cent. of fineness	70.13	Apparent specific gravity	1.414
Coefficient of uniformity	81.00	Weight in lbs. per cubic foot	88.352
Grade	No. 7	Percentage of voids	52.1
Real specific gravity	2.953		

Granular metric analysis of sand from lake shore, Toronto Island:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	0.0	0.0	0.0	0.40	4.75	76.85	98.50	99.60	100.00

Per cent. of fineness	57.77	Apparent specific gravity	1.721
Coefficient of uniformity	93.75	Weight in lbs. per cubic foot	107.535
Grade	No. 6	Percentage of voids	44.3
Real specific gravity	3.093		

Granular metric analysis of sharp sand from interglacial beds, Shaw street, Toronto:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	0.0	1.25	2.35	5.80	12.65	67.30	92.85	96.65	98.70

Per cent. of fineness	58.05	Apparent specific gravity	1.585
Coefficient of uniformity	80.20	Weight in lbs. per cubic foot	99.037
Grade	No. 6	Percentage of voids	44.3
Real specific gravity	2.844		

Granular metric analysis of coarse sand, Bourne and Son, Toronto:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	0.0	0.0	tr.	0.30	0.70	9.55	62.90	84.35	95.60

Per cent. of fineness	71.84	Apparent specific gravity	1.654
Coefficient of uniformity	74.80	Weight in lbs. per cubic foot	103.349
Grade	No. 7	Percentage of voids	44.8
Real specific gravity	2.997		

Granular metric analysis of sand, upper part, Aurora deposit:—

Mesh	4	8	10	20	28	58	80	100	200
Per cent. retained...	0.0	0.0	0.0	0.0	tr.	tr.	0.20	2.30	31.35

Per cent. of fineness 96.24
Coefficient of uniformity 97.70
Grade ..... No. 9
Real specific gravity 3.230
Apparent specific gravity 1.581
Weight in lbs. per cubic foot .. 98.787
Percentage of voids 51.05

Granular metric analysis of sand, central part, Aurora deposit:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	0.0	0.0	tr.	tr.	tr.	0.30	10.10	28.60	58.60

Per cent. of fineness 89.16
Coefficient of uniformity 71.40
Grade ..... No. 9
Real specific gravity 3.036
Apparent specific gravity 1.667
Weight in lbs. per cubit foot .. 104.161
Percentage of voids 45.1

Granular metric analysis of gravel, Allen Bros., Birch Cliff:—

Mesh	4	8	10	20	28	48	80	100	200
Per cent. retained...	0.35	40.25	64.50	86.70	93.05	96.75	97.45	97.95	98.85

Per cent. of fineness 24.90
Coefficient of uniformity 64.15
Grade ..... No. 2

APPENDIX

Introduction

The following brief report on certain northern Ontario sand and gravel deposits, with the exception of the part dealing with granular metric analyses, was compiled by Prof. A. L. Parsons, of Toronto University, from the notes taken by Professor Ledoux during that part of the field season of 1918 prior to his decease on August 7th.

Granular metric analyses of thirty different samples of sand and gravel, as shown in the table accompanying this appendix, were carried out by H. E. Davis, who is in charge of testing road materials for the Ontario Department of Public Highways. P. A. Jackson, of the Bureau of Mines staff, assisted in the tests. Mr. Davis reports as follows in regard to the methods used:

Specific Gravity of Sand.—The specific gravity was determined by the use of Le Chatelier's specific gravity apparatus, consisting of a flask having a large bulb at the bottom tapering up to a narrow bulb which has a narrow neck of about ¼ inch. The flask is filled with water up to a mark on the lower section of the flask, the distance between this mark and the lower point on the graduations on the upper part of the flask is 20 cc., the narrow neck being graduated into tenths of cubic centimeters. A sample weighing 60 grams was then slowly introduced into the mouth of the flask and the displaced volume recorded.

$$\text{Specific gravity} = \frac{\text{Weight of sand}}{\text{Displaced volume}}$$

Tyler Standard Screens.—For some considerable time there has been a demand for standard testing screens with accurately measured openings that increase or decrease through the series of screens in a fixed ratio. The manufacturer of this screen has established, as a minimum standard, the 200-mesh commercial sieve which has been made of wire .0021 of an inch and having openings of .0029 inch. The scale ratio between the different sizes of screen opening has been taken as 1.414 or the square root of 2, as recommended for ore dressing. Taking .0029 inch, which is the opening of the 200-mesh screen, as the base, the diameter of each successive opening is exactly 1.414 times the opening in the previous screen. It also makes the area or surface of each successive opening on the scale just double that of the next finer or half that of the next coarser screen. In other words, the diameters of the successive sizes are in a ratio of 1.414 while the areas of the successive openings have a constant ratio of 2.

Methods used in conducting Granular Metric Analysis of Sand.—Having thoroughly mixed the samples submitted for test, a quantity of the sand[1] was weighed out and placed on the coarsest screen under which were placed in order the finer screens. The nest of screens was then submitted to a mechanical agitation for about 10 minutes. Screens were then removed and the sand on the coarsest was weighed and recorded. To this was added the sand on the next coarsest screen and the total weight recorded, giving the cumulative weight retained on each screen. To express this in total per cent. retained on any one screen the following formula is used:—

$$\frac{W}{W'} \times 100 = \text{per cent. retained on screen.}$$

where W = total weight of sand before agitation.
and W' = cumulative weight of sand retained on screen.

[1] Sand, as distinguished from gravel, is defined as that part which passes through a ¼-inch screen.

GRANULAR METRIC ANALYSES OF SAND CONTENT OF CERTAIN SAND AND GRAVEL DEPOSITS IN NORTHERN ONTARIO.

District	Description and location of deposits	Laboratory No.	Per cent. retained on Tyler standard screens								Real specific gravity	Per cent. of fineness
			8	10	20	28	48	80	100	200		
Parry Sound...	Parton pit, Parry Sound	15	9.3	17.9	50.7	77.3	96.0	99.9	100.0	100.0	2.69	31.1
" " ...	Beach sand, northwest of Kill Bear point, near Parry Sound.....	16	.....	.....	2.3	27.5	48.2	99.8	99.9	99.9	2.62	52.8
Nipissing.....	Beach sand, Lake Nipissing, 3 miles south of North Bay.....	17	.....	.....	.....	.....	11.2	92.0	99.0	99.9	2.69	62.2
"	Bordeleau gravel and sand pit, 2 miles east of Sturgeon Falls	18	13.5	19.7	34.8	46.4	74.6	90.9	95.6	98.4	2.74	40.8
"	Lakeview Park, North Bay, gravel on beach, in front of cottage of Judge Leach.....	19	2.2	28.9	98.0	99.7	99.7	99.8	99.8	99.8	2.62	21.5
"	Beach sand, Lake Nipissing, south of Sturgeon Falls	20	1.8	4.4	20.3	60.4	98.6	99.1	99.4	99.6	2.61	39.5
"	Gravel pit, Tomiko, mileage 25, T. & N. O. railway	†29	10.9	19.0	47.5	71.7	92.6	97.1	98.2	99.0	2.70	33.0
	Gravel pit, Rabbit Creek, mileage 58.5, T. & N. O railway	*28	21.6	39.2	68.5	81.7	93.0	96.4	97.9	99.3	2.70	25.3
Timiskaming...	Sand, Martineau bay, Lake Timiskaming.	30	.....	.1	2.7	16.6	97.9	99.8	99.9	99.9	2.67	47.9
" ...	Sand, Chambers-Ferland pit, Cobalt....	27	.1	.2	2.3	7.3	40.8	70.1	84.2	95.8	2.67	62.4
" ...	Sand near Nellie Lake station	2	.....	.....	.05	.1	3.5	36.1	69.4	93.2	2.68	74.7
" ...	Nellie Lake pit, T. & N. O. railway, sandy gravel	4	.....	.05	2.7	17.5	72.7	94.0	99.1	99.8	2.65	51.8
" ...	Nellie Lake ballast pit, fine gravel at bottom of pit	*7	18.5	35.2	78.2	96.8	99.4	99.5	99.5	99.5	2.67	21.7
" ...	Fine sand, Cochrane.....	9	.....	.....	.....	.1	.4	3.0	12.0	55.3	2.73	91.1
" ...	Gravel from ballast pit, 2 miles south of Cochrane	5	19.9	34.9	63.7	79.6	91.9	95.0	95.9	96.8	2.67	27.8
" ...	Sand at south end of ballast pit, 2 miles south of Cochrane	11	.1	.3	3.9	19.9	82.8	97.7	99.3	99.6	2.67	49.5
" ...	Sand, road west of Timmins	24	.....	.1	.15	.2	.4	8.4	39.1	82.3	2.64	83.7
" ...	Sand, east of Timmins	21	1.0	2.1	6.3	14.6	58.7	89.9	96.7	99.5	2.69	53.9
" ...	Gravel, east of Timmins	25	9.6	15.2	33.2	53.2	91.1	98.5	99.3	99.4	2.65	37.6
" ...	Coarse sand, east of Timmins	26	.9	2.7	10.2	22.1	71.5	95.0	98.1	99.3	2.65	50.0

GRANULAR METRIC ANALYSES OF SAND CONTENT OF CERTAIN SAND AND GRAVEL DEPOSITS IN NORTHERN ONTARIO.—*Continued.*

District	Description and location of deposits	Laboratory No.	Per cent. retained on Tyler standard screens								Real specific gravity	Per cent. of fineness
			8	10	20	28	48	80	100	200		
Timiskaming..	Drinkwater pit, Porcupine branch, T. & N O. railway	22	.8	1.2	2.0	3.5	20.0	56.7	82.2	94.5	2.63	67.4
" ...	Barber Bay, pit near the track, Porcupine branch, T. & N. O. railway	*23	24.9	38.1	60.7	75.9	92.9	96.9	98.0	99.9	2.69	26.6
" ...	Town of Cochrane gravel pit, located 1 mile north of town	*3	6.4	13.5	41.7	64.3	93.3	98.8	99.8	99.8	2.61	35.3
" ...	Sand from pit, 1 mile north of Cochrane near pumping station	8	.05	.07	.1	.2	6.1	52.0	82.8	97.5	2.65	70.1
" ...	Buskego, Canadian National Railway, mileage 9, west of Cochrane	6	4.1	8.7	28.6	49.0	90.4	96.7	97.7	98.5	2.65	40.8
" ...	Coarse sand, Buskego pit, west of Cochrane	1	·3	.5	2.1	7.3	68.6	95.2	97.9	98.6	2.70	53.7
" ...	Gravel pit, 1 mile south of mileage 57, near Moonbeam, Can. Nat. Ry.	13	10.3	27.3	72.0	90.4	99.7	99.9	99.9	99.9	2.69	25.1
Algoma.....	Gravel hill, 4 miles west of Hearst, Can Nat. Ry.	*10	9.0	22.6	64.2	79.4	88.9	92.9	94.7	97.0	2.62	31.4
"	Coarse sand, 4 miles west of Hearst	12	.....	.2	18.4	65.1	95.7	98.8	99.4	99.9	2.55	40.3
"	Moulding sand on top of hill 4 miles west of Hearst	14	.....	.....	.1	.2	.7	1.2	3.4	18.9	2.69	96.9

*Material suitable for concrete work.

†Quartz and feldspar grains from disintegrated gneiss predominate.

Parry Sound District

The district as a whole is very rocky, the outcrops being mostly granite, gneiss and other related pre-Cambrian rocks. The glacial Lake Nipissing once extended over this whole region, the smaller lakes at present scattered through the district being the remnants of the large lake after the water level had been lowered.

Deposits of gravel, sand and clay were laid at various depths in these waters and some of them are still found on the slopes of the hills.

Several deposits may be noticed in the vicinity of the town of Parry Sound. One mile north of the town there is a ridge of sand and gravel running north 45° east, mostly on the west side of the road. The graveyard is located on part of it.



Argue's sand pit, Parry Sound.

The length of the ridge is about 800 yards and the width 200 yards. Several pits located on the properties of Messrs. Argue, Parton and Reece Hall have been opened in this ridge.

Argue's pit is located just north of the cemetery, on the west side of the road, the excavation being 75 by 36 by 12 yards. The material is mostly sand, well suited for building purposes, the deposit showing oblique stratification. The north portion of it contains more pebbles and grades into a gravel. Some large boulders are found. As a rule the pebbles are granite and gneiss, although sometimes an odd pebble of limestone is found. The sand is coarse and contains quartz as its principal constituent. Feldspars and dark ferro-magnesian mineral grains are also abundant.

The deposit lies about 100 feet above the level of the Seguin river or 700 feet above sea level. This material is sold at about 40 cents a load at the pit. The reserve is 125,000 cubic yards approximately.

Parton's pit lies 500 yards to the north, on the east side of the road, in lot 28, Con. II, of McDougall township. Both sand and gravel occur, with gravel predominating in some parts. The present excavation is 40 by 20 by 10 yards in size, the reserves being 20 acres in area, mostly all gravel. If the average depth is calculated at ten yards, the available material would total 48,400 by 20 = 968,000 cubic yards. The output in 1917 was about 2,000 cubic yards, this material being sold at 15 cents for road gravel and at 25 cents for average cement gravel. The gravel is of good quality, most of the pebbles being of granite and other pre-Cambrian rocks, and very few of limestone. The deposit lies at an altitude of about 740 feet[1] above sea level.

Reece Hall's pit is located east of Parton's, and a little south of Mill lake. The excavation measures 60 by 12 by 10 yards, and lies at about the same level as the Parton pit. The east side of this gravel pit shows rock outcrops.

Four miles north of Parry Sound, on the east side of the northern road, there is a small sand and gravel pit 30 by 15 by 3 yards in size, located on a ridge crossing the road in an east and west direction. The pit belongs to John Draper.

One mile north of Waubamick station, on the C. N. Ry. line, there is a large pit containing mixtures of sand, clay and gravel. The material is used as ballast for the railway, and the present excavation is 400 by 150 by 12 yards, corresponding to a removal of 720,000 cubic yards. The pit has been idle for several years, but is to be worked again. The necessary equipment, including steam shovels, has been provided, and the railway company intends to take out during the summer of 1918 approximately 60,000 cubic yards. This deposit lies 850 feet[1] above seal level.

Another pit on the same large deposit of sand and gravel, but farther east, will be opened about one mile northeast from Waubamick station. This material is to be used principally for filling work.

The deposits around Waubamick lake were probably formed in an old bay or tributary of Long lake. The deposits near Parry Sound graveyard were formed by Mill lake, while the ridge on which J. Draper's pit is located is connected with a former stage of the history of Portage lake.

On the shore of Georgian bay and on the numerous islands located in Parry Sound the deposits of sand and gravel are few in number and as a rule of small extent. Between 2-Mile point and 3-Mile point there is a small sand beach about 75 yards long, the result of weathering of the rocks of Parry island. There are two little sand beaches about 30 yards wide near the lighthouse at 3-Mile point on Parry island. At Kill Bear point, about 200 yards east of the lighthouse, there is a sand beach about 100 yards long.

Northwest of Kill Bear point there is a large sandy beach extending around the bay in Con. VIII, McDougall township, for about 1,500 yards, but in no place wider than 200 yards. The sand contains numerous clear transparent quartz grains, some feldspar and brown ferro-magnesian minerals. There is only a narrow strip near the shore not covered by vegetation.

[1] Aneroid determination.

Sandy island, located in Georgian bay, about three miles from Parry island, is composed entirely of sand, with some large pebbles along the southeastern shore and smaller pebbles along the northern shore. This island has an area of about 1,000 acres, and is covered with wood, but contains a large reserve of sand resulting from the weathering of granitic and gneissoid rocks. The average elevation of the island is not more than 60 feet above Georgian bay. Black mineral grains and vegetable matter are intermixed with the sand. All round the island the water is very shallow for about 500 yards from the shore. Large quantities of material are recoverable by dredging. The sand at Sandy island is of a finer size than the sand of Kill Bear point, where it is coarse and whiter. The upper part of the Sandy island deposit looks white when dry, but it contains ferruginous elements, and as soon as digging is done black and brown sand are found. This island belongs to Walter L. Haight, Parry Sound.

There is a sandpit along the Canadian Pacific railway tracks near Shawanaga station, and also between Parry Sound and Byng Inlet, along the shore of Georgian bay. Small pockets of sand overlaid by mud are found in the bay opposite Franklin island, on Shebeshekong beach. Further north the islands in Georgian bay are more and more rocky.

Along the road through the bush from Parry Sound to Rose Point small deposits of angular gravel occur, resulting from the disintegration of underlying diabases, pegmatites and gneisses. Large quantities of poor sand were excavated for ballast at Depot Harbour on Parry island, in the cuttings of the Grand Trunk railway, near James bay junction and at Otter lake. This material is very often ferruginous, brown in colour and contains a certain amount of silt and angular fragments of the underlying rocks.

Near Whitehall and Sprucedale, in concessions X and XI of McMurrich township, local deposits of sand and gravel are not uncommon. East of Whitehall station, a large excavation, 15 feet deep, was made along the G. T. railway tracks for ballast supply. The sand is very often brown, due to vegetable matter from resinous trees which it contains.

There are also some deposits and excavations between Sprucedale and Scotia Junction. The country between Scotia Junction and Kearney along the G. T. railway is very sandy, and several railway cuts pass through deposits 25 feet in thickness. The adjoining territory in Bethune township is covered by a sandy soil, which has been used to some extent for railway ballast.

Near Ravensworth, the last station on the G. T. railway in Parry Sound district, the altitude rises to 1,400 feet, and small local sand pockets are found at this level. An excavation 800 by 100 by 37 yards has been made along the tracks for supplying ballast.

Between Scotia Junction and Burks Falls there is a great alluvial plain made mostly of sand and silt. Near Emsdale, at Burk's Falls, and at other local occurrences, the quality of this material is better, and it has been worked for sand or road gravel. The proportion of clay is, as a rule, too great, and on the roads this material is soon reduced to dust.

About one mile northwest of Burks Falls there is a sandy ridge at an altitude of 680 feet above sea level. The ridge is made of sharp sand, except at the

surface of the deposit, where it is mixed with clay and pebbles. At Carss station there is also some sandy material lying 675 feet above sea level (aneroid measurement).

At mile 172, on the G. T. railway, near Burks Falls, a gravel ridge crosses the line and is seen in the cuttings with boulder clay and sand, having a total depth of 10 yards. It is also met on the shores of a tributary of the Maganatawan river. This material was used for ballast.

Seven miles east of Burks Falls the fine sand beach on the southern shore of Pickerel lake is capable of supplying thousands of tons of clean washed sand.

In Burks Falls, half-way between the station and the mill, there is a gravel pit 30 yards long and 15 yards deep, containing large boulders of gneiss, banded quartzite, etc., and some clay. In the centre of the town, there is a large gravel pit belonging to the municipality. The present excavation is 75 by 20 by 8 yards in size, and the pit supplies both sand and gravel. The stratification is oblique.

In the township of Ryerson there are two pits about nine miles west of Burk's Falls.

In the township of Armour the following pits were noticed:

1. Chas. Freer's pit.
2. A. Hego's pit at Barriedale, supplying gravel.
3. D. J. Van Meer's gravel pit (clean material sold at 25 cents a load).
4. John Hughes' pit.
5. G. T. railway gravel pit, on lot 14, Con. XIII. The present excavation is 300 by 30 by 15 yards in size. The gravel is of good quality for railway work.
6. Knight Bros.' gravel pit. This material is used for roadwork.

In the northeastern corner of Parry Sound district there are large areas of sand near Trout Creek station, between Powassan and Burks Falls. Near Powassan there is a sandpit 200 by 15 by 5 yards in size along the east side of the G. T. railway tracks. Outcrops of gravel are met in the cuttings of the railway between Powassan and Callander.

The area south of lake Nipissing is a plateau lying about 125 feet above the water level of the lake. It consists of rounded rocky hills, often showing glacial striae and at some places it is covered by residual or maraine deposits of unassorted sand and gravel. The southern shore of lake Nipissing itself is mostly a sand beach, the material being of various grades in different localities. The finest beach sand in some places has been driven two miles inland by the wind. There are also some scattered deposits of gravel along the shore of lake Nipissing.

Nipissing District

Going from North Bay along the Temiskaming and Northern Ontario railway sandy material is shown in a cut about 3.5 miles north. This appears to be derived from the weathering of the underlying rock.

Near Trout Mills (mileage 7.5) there is an old pit about 300 by 30 by 10 yards in size. The material was largely used for fills on the railway, as it was rather dusty for ballast. Very little was taken out in 1917.

At mile 25 is a pit 250 by 15 by 5 yards, extending in a N.E. and S.W. direction. Toward the S.W. end the thickness of the deposit is not so great as at the N.E. end.

The material is a clean gravel, while at the N.E. end it is a coarse sand well suited for building. In size the material ranges from sand to boulders one to two feet in diameter, and the rocks from which it is derived are granite, gneiss, conglomerate, diabase, quartzite, and other rocks, principally intrusive. The pit lies north of a small lake, and this deposit probably represents the shoreline of the lake when it was at a higher level. For the past two years the pit has not been worked.

Near Tomiko station is a large abandoned pit, about five yards deep, from which filling and ballast were obtained for the building of the railroad.

At Rabbit Creek, mileage 58.5, is a pit on the east side of the railway, about 500 by 100 by 10 yards, from which ballast of good quality has been secured. Boulders are not numerous. The bulk of the material consists of gravel ranging in size from ¼ inch to 3 inches in diameter, and the pit is worked intermittently by steam shovel. The upper portion of the deposit consists of sand. At the east end of the pit bed rock is encountered, and rock outcrops are shown to the north of the pit.

North of Doherty station and just south of Twin lake, is another large gravel pit from which ballast was obtained for a revision of the line near Doherty.

About one mile northeast of Cassidy station is a pit 800 by 25 by 7 yards in size. This is a coarse gravel, with numerous boulders ranging from six inches to one foot in diameter. The pebbles are predominantly granite and gneiss. Large reserves are still available.

Timiskaming District

Between Haileybury and New Liskeard the shore of lake Timiskaming and the adjoining slopes are covered with clay. Near the shore several masses of rocks of the Cobalt series outcrop in dome-like hills. Sometimes a little sand is found on the surface in a layer one to two feet in thickness overlying the clay, but these deposits are local. After stormy weather a certain quantity of sand and gravel is deposited on the lake shore. The fragments are angular and small. The predominant rock in the gravel is a light-coloured limestone of Silurian age containing numerous fossils.

Along the lake shore south of Haileybury toward North Cobalt the composition of the gravel changes and pre-Cambrian rocks are more prominent. There are large reserves of this surface material, and it has been used for building operations.

Around Martineau bay of L. Timiskaming is a deposit of sand well suited for building purposes. The sand extends along the slopes of the adjoining hill and can be seen on both sides of the old Mission road. Large quantities of clean sand are available, which could be transported by scows to points on the lake.

MAIN LINE, T. AND N. O. RAILWAY

Cobalt and Vicinity.—Near the North Cobalt school-house a small deposit of sand has been worked. This is mixed with gravel and is only about a foot in thickness.

The sand pit of the Chambers-Ferland mine near mile 104 is an excavation 80 by 40 by 5 yards. Most of the available material has been removed. It is principally light-coloured sand, which contains patches of gravel.

To the west of mile 104 on the T. & N. O. Ry a gravel pit parallels the railroad on the ridge near the cemetery. The size of the excavation is 75 by 10 by 3 yards. The gravel is varied in composition, consisting principally of rocks of the Cobalt series and granite. A little further west is another excavation about half as large containing a good amount of small gravel. This is screened for use in concrete work.

About 2½ to 3 miles west of West Cobalt the soil becomes more sandy and contains a large proportion of pebbles. Near the powder factory it is a gravel. Small pits have been opened along the road for road building.

In lot 10, Concessions IV and V, township of Coleman, is a pit about a mile long, 50 yards wide and 15 yards deep. The material is principally a mixture of sand and gravel, but at some places clay is visible in the walls. The pebbles rarely are more than one foot in diameter, but occasional boulders as much as 3 feet in diameter were seen. Basic igneous rocks are prominent, though granite and gneiss are abundant. Large reserves are still available.

Nellie Lake.—Nellie Lake station, township of Calvert, is in the midst of a sandy plain, which extends about 500 yards east and about 1,500 yards west. Since the fire of 1916 this plain has been covered with partially burned forest. Just east of the station is a small kettle lake, the level of which is about 60 feet lower than the station. The altitude of the station is about 1,000 feet, but about 500 yards east of this point and about 150 feet above the level of the plain there is a sand ridge consisting of a series of hills ranging from 300 to 500 yards in length, with a width of from 200 to 300 yards. This ridge is approximately parallel with the T. & N. O. Ry.

A pit has been opened on the west side of one of these sand hills and a railway siding has been extended to the pit. Both sand and gravel have been obtained, the finer grained material being near the surface. The gravel is quite variable in size, and contains boulders up to 18 inches in diameter. This pit is about 250 by 7 by 2 yards. Just to the east of this, along the same railway siding, a larger pit has been opened. The gravel is apparently reassorted glacial material, consisting of pebbles of granite, gneiss and quartz. A line of kettle lakes between the pits and the railway gives further confirmation of the glacial origin of these deposits.

Distinct bedding in the deposit was not observed, but the face of the workings is not fresh, and the falling of the upper portion has probably masked the true condition.

Cochrane.—About one mile north of Cochrane there are several kettle lakes, surrounding which are deposits of morainic origin. To the west of the pumphouse there is a sand pit about 20 yards in diameter by 5 yards deep, which furnishes building sand.

A little further north, between two kettle lakes, is a gravel ridge in which is a pit known as the town pit. The gravel is cross-bedded and consists of small pebbles. The present excavation is about 75 by 25 by 7 yards, with a reserve of about equal dimensions.

About two miles southeast of Cochrane is a large gravel pit in a ridge to the east of a kettle lake. This pit is about 800 by 40 by 10 yards, and furnished ballast and filling for the T. & N. O. railway.

PORCUPINE BRANCH, T. AND N. O. RAILWAY

Timmins.—Sand and gravel has been taken from a pit south of the road from Timmins to Schumacher. The pit is about 12 feet deep and 15 yards in diameter. As a rule the pebbles are not more than four inches in diameter, and are composed of granite, gneiss, schists and basic igneous rocks. This material has been used for roads and building. Another pit on the same side of the road is about 75 by 25 by 7 yards, and has been practically exhausted. On the opposite side of the road is a pit near the railway which is more sandy, but furnishes material used for building.

Drinkwater pit.—On the north side of the railway is a pit 300 by 30 by 10 yards which has been abandoned.

Connaught.—At Connaught station a steam shovel was operating a gravel pit in 1917 and 1918, and 230 car loads were shipped.

Barber Bay.—Northwest of the railway there is a pit about 200 yards long by about 40 to 50 yards wide, with an average depth of 5 yards. Large boulders are not numerous, the average not exceeding four inches in diameter. The pebbles consist of gneiss, granite, schist, and greenstone. There is a large reserve yet available at this pit.

CANADIAN NATIONAL RAILWAY

Buskego.—About eight miles west of Cochrane a pit 600 by 100 by 15 yards furnished a sandy gravel which in some portions has been cemented by calcareous solutions. This was used for ballast on the Canadian National Railway, formerly called the National Transcontinental.

Drainage of some of the small lakes surrounding the pit could be effected easily and permit 20 feet additional depth to be worked by steam shovel.

Moonbeam.—A little west of Moonbeam, on the railway, near mile 57 (west of Cochrane), an old siding branches to the south to several ballast pits. The first of these is about a mile south of the track, and shows an excavation about 300 yards long by 15 yards wide and 10 feet deep. The upper portion of the deposit is sand, but the lower part is good, clean gravel suitable for concrete. The gravel is chiefly derived from Laurentian rocks, and the pebbles are usually small, though boulders as large as three feet in diameter are found.

About 1½ miles south of this first pit is another about 400 yards long by 50 yards wide and 10 yards deep. The character of the deposit is practically the same as in the first pit.

A third pit two miles south of the second one shows an excavation 300 yards by 20 yards by 5 yards in a ridge between two narrow lakes. The gravel is somewhat coarser than in the first two pits, and is suitable for ballast. One mile south of this pit is a fourth pit in a hill about a mile long by 400 yards wide and a maximum height of about 30 yards. The gravel is fairly coarse, with numerous pebbles from four to six inches in diameter, and boulders as large as six feet in diameter in places. The pebbles are principally derived from pre-Cambrian rocks, and consist of granite, gneiss, quartzite, and greenstone. There is a large reserve in this pit.

Harty.—About 400 yards south of Harty, mile 81, is a pit about 600 by 30 by 6 yards, which furnishes gravel for ballast. There is still a reserve.

Algoma District

CANADIAN NATIONAL RAILWAY

Mattice.—Near mileage 100.3, just east of the bridge over the Missinabi river, lot 27, con. IV, Eilber township, is an old pit from which gravel was obtained for ballast and concrete for the bridge piers. The excavation is about 80 by 40 by 5 yards, with possibly an equal reserve left. The pebbles consist of granite, gneiss, and limestone.

To the northeast of this pit, in lot 26, Con. IV, Eilber township, is a larger pit 400 by 50 by 5 yards, which furnished ballast. This deposit is practically exhausted, and the railway siding has been removed.

Hearst.—Four miles north of Hearst is a hill about 30 to 40 feet above the general level which is somewhat loamy in places. At a depth of three or four feet sand suitable for concrete, plastering and brick-work has been found. This hill extends for about a mile and a half in a N.E-S.W. direction. In some places gravel suitable for roads and concrete is encountered. The pebbles range from an inch or an inch and a half down to the size of a grain of wheat. The gravel is quite clean, particularly near the bottom of the pit. The hill is about 400 yards wide and about 15 yards high, and would probably furnish 10,000,000 cubic yards. Over some parts of the hill a deposit of moulding sand ranging from one to two feet in thickness is found.

ALGOMA CENTRAL AND HUDSON BAY RAILWAY

Hearst to Hawk Junction.—Between Hearst and Oba no sand or gravel deposits were observed. The first deposit of this kind was seen near Lake Oba. These deposits were used for ballast by the Algoma Central and Hudson Bay railway. Deposits of a similar character occur near a number of lakes in this region. Between Franz and Hawk Junction the country is more rocky, but several large silty gravel hills were seen along the railway.

Michipicoten River.—North of Michipicoten river there is a sandy beach with several terraces above. The sand in the terraces is not very clean, but large reserves are available for water transportation. The beach sand is clean and would probably furnish good building material.

Wawa Station.—One-half mile south of Wawa station is an old ballast pit which was used by the Algoma Central & Hudson Bay railway. The material is a sandy gravel.

Hawk Junction to Sault Ste. Marie.—Along the line of the Algoma Central and Hudson Bay railway from Hawk Junction to Sault Ste. Marie there are numerous terraces at different elevations which would furnish large quantities of sand and gravel. Material has been taken from some of these for ballast for the railway,

but with the exception of a few pits near Sault Ste. Marie none of them have been used for any other purpose. Until this region is more thickly settled, there is little prospect of these deposits being utilized.

Sudbury District

Sudbury.—On the south side of Elm Street West there is a large deposit of sand and gravel that has been used extensively for building purposes. All grades from fine sand to gravel with pebbles two inches in diameter are found. As a rule the several grades are very clean, and the gravel is suitable for concrete work.

The highest point of the deposit is 920 feet above sea level, and the thickness is about 25 feet. Outcrops of rock are shown in the bottom of the pit.

The material consists principally of fragments of quartz and basic rocks, probably of the Sudbury series. Oblique bedding is shown, and evidently the deposit is found under water. The sand on the surface has been subjected to the action of wind, so that some parts of the deposit now present a dune-like appearance.

CANADIAN PACIFIC RAILWAY

Cartier.—About one mile north of Cartier station and west of the railway tracks is a terrace about 20 feet higher than the tracks. A pit about 400 yards long has been worked here for railway ballast. At present the pit is not in use. The material appears to be chiefly sand. The region here is a sandy plain, with a number of rocky hills, and covered with numerous boulders of granite and similar rocks.

Larchwood to Levack.—Half a mile northwest of Larchwood the Canadian Pacific railway crosses the Vermilion river, which flows between banks of sand and clay. About two miles west of Larchwood, where the track turns to the west, the railway cuts through a ridge of sand about 50 yards wide and about 30 feet high. This sand is horizontally stratified. The ridge runs in a northwest direction more or less parallel with the railway for a third of a mile, and can be followed for more than a mile. In the railway cut the material is fine-grained sand, but near Phelan it develops into a large gravel deposit, which has been worked as a ballast pit. The present excavation is about one-half mile long, 100 yards wide, and about 15 yards deep. The gravel is quite clean and contains few pebbles more than six inches in diameter. The small pebbles are not much rounded, indicating that they had not been transported a great distance. The pebbles consist principally of granite, diabase, gabbro and sandstone, and the upper portion is as a rule sandy.

The north end of the pit is worked at present by steam shovel. Here alternating beds of sand and gravel of different grades showing oblique stratification are shown. The intermixture of these by the steam shovel gives a product not as clean as the gravel, near the centre of the pit, which is of excellent quality for concrete work. The material is used for filling and ballast. In 1917 the average production was from 2,000 to 3,000 yards per day for four months. This pit was first opened about 35 years ago, but was idle for many years. A large reserve, several hundred yards wide, remains.

Windy Lake.—About one mile south of Windy Lake station there is a large gravel pit which was used for ballast but is now abandoned. This pit is about 1,500 by 75 by 10 yards in size. It is located in a terrace to the north of Windy lake and on the west side of the railway. The reserve in this deposit is probably three times the amount taken out. Near the centre of the pit the gravel is very clean, and would be suitable for concrete work. Towards the ends of the pit the material is more loamy, but the upper part has fallen over the face so that the stratification is concealed and it is impossible to tell what proportion of clean sand or gravel is present.

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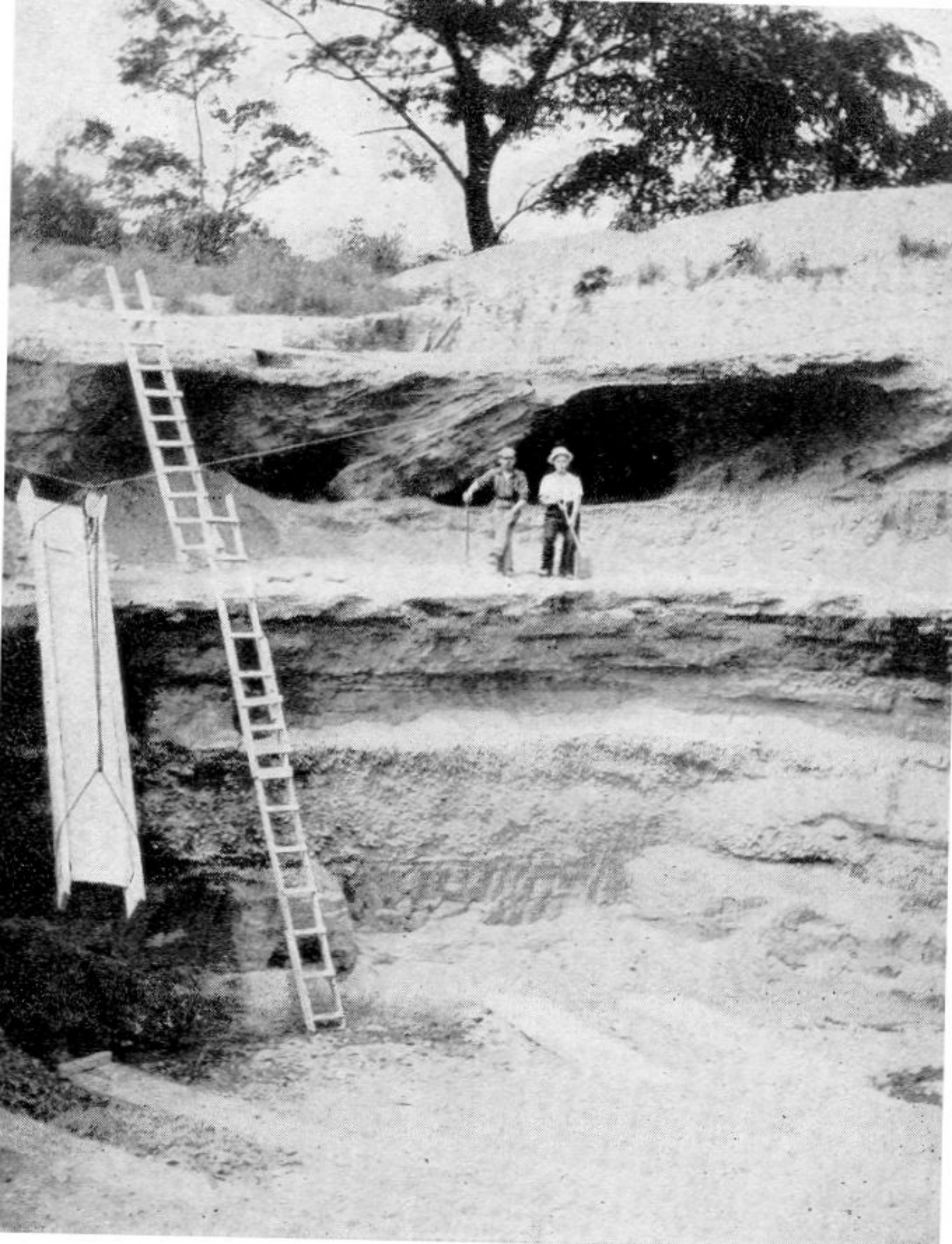
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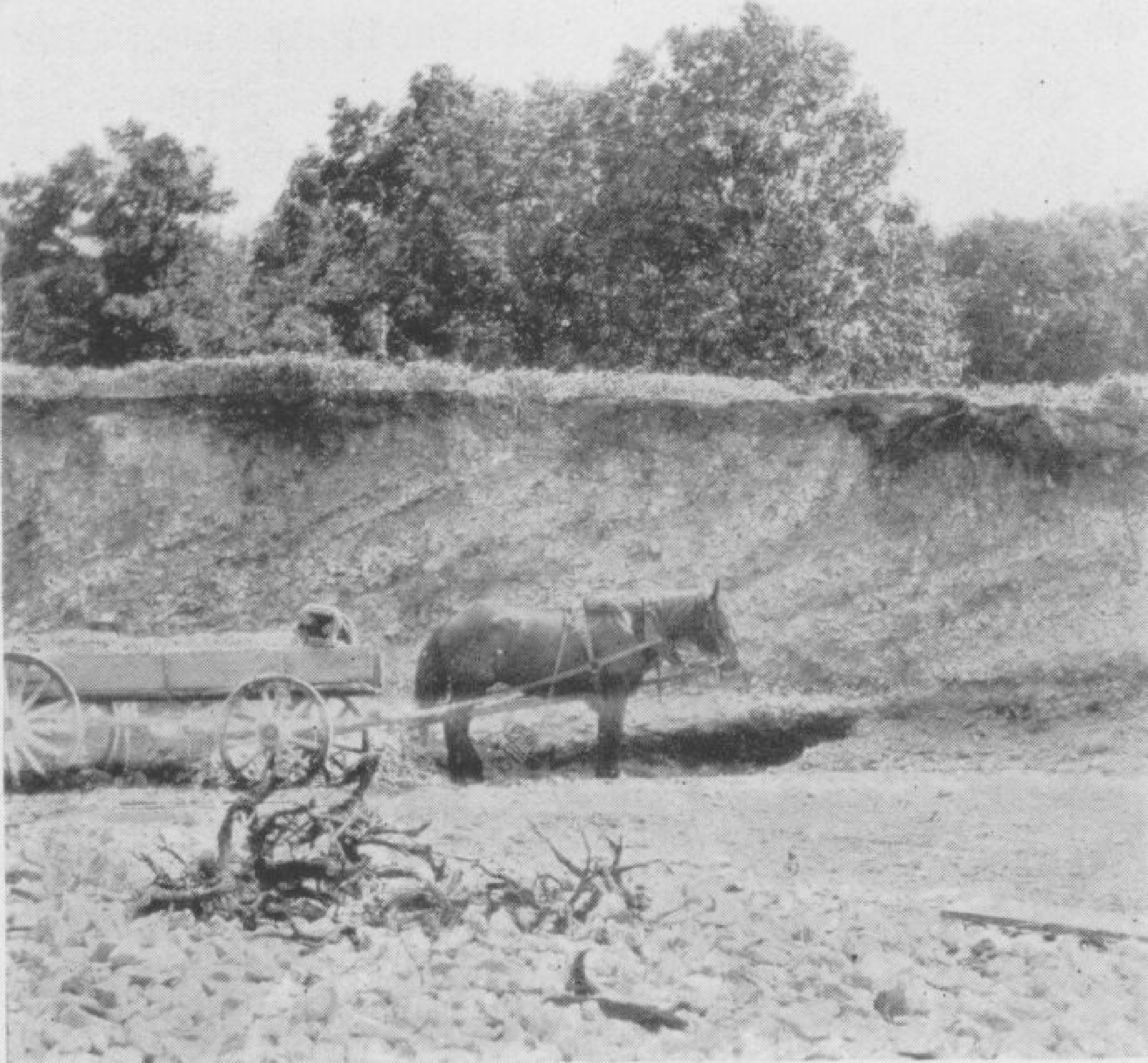






















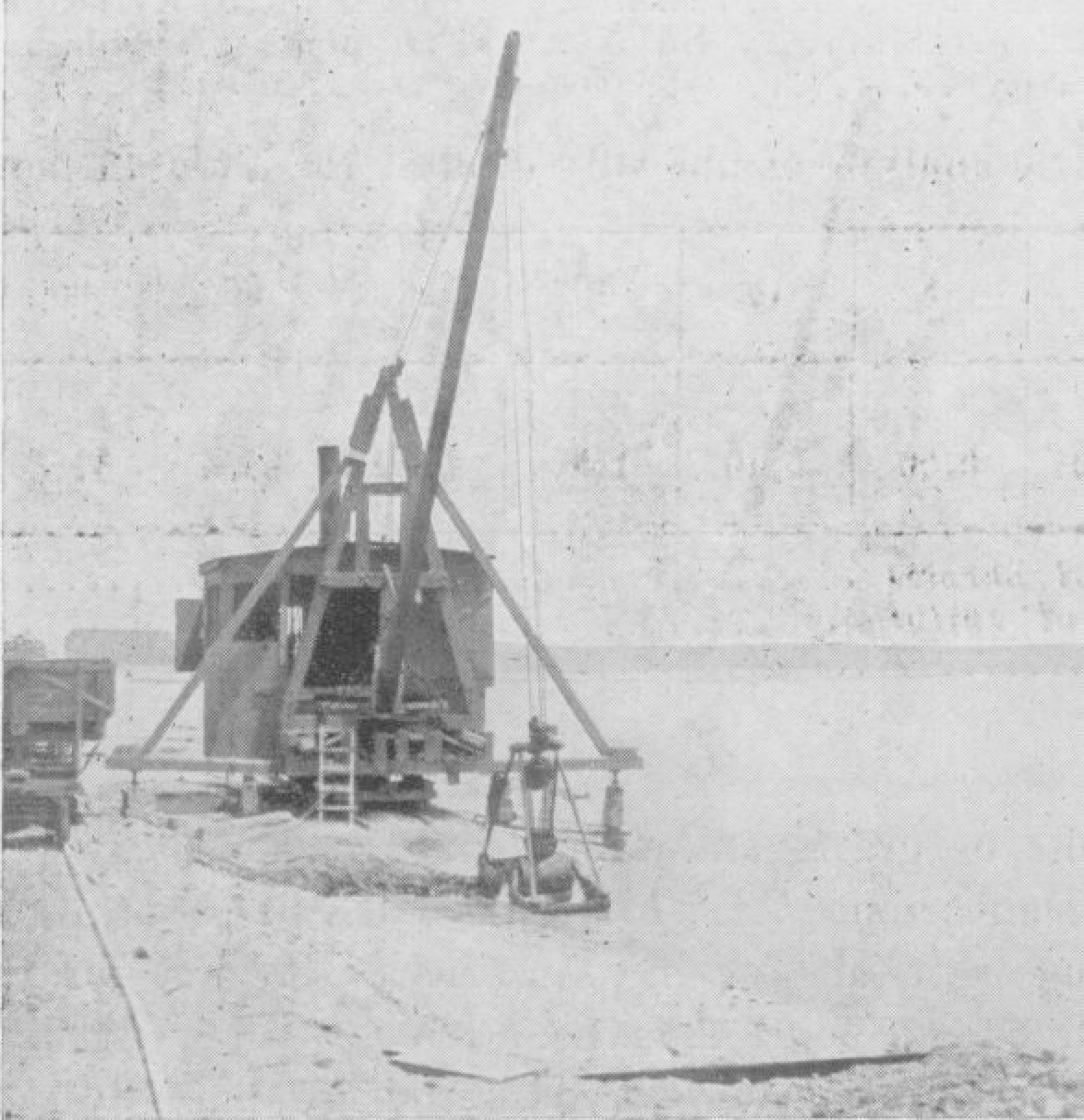


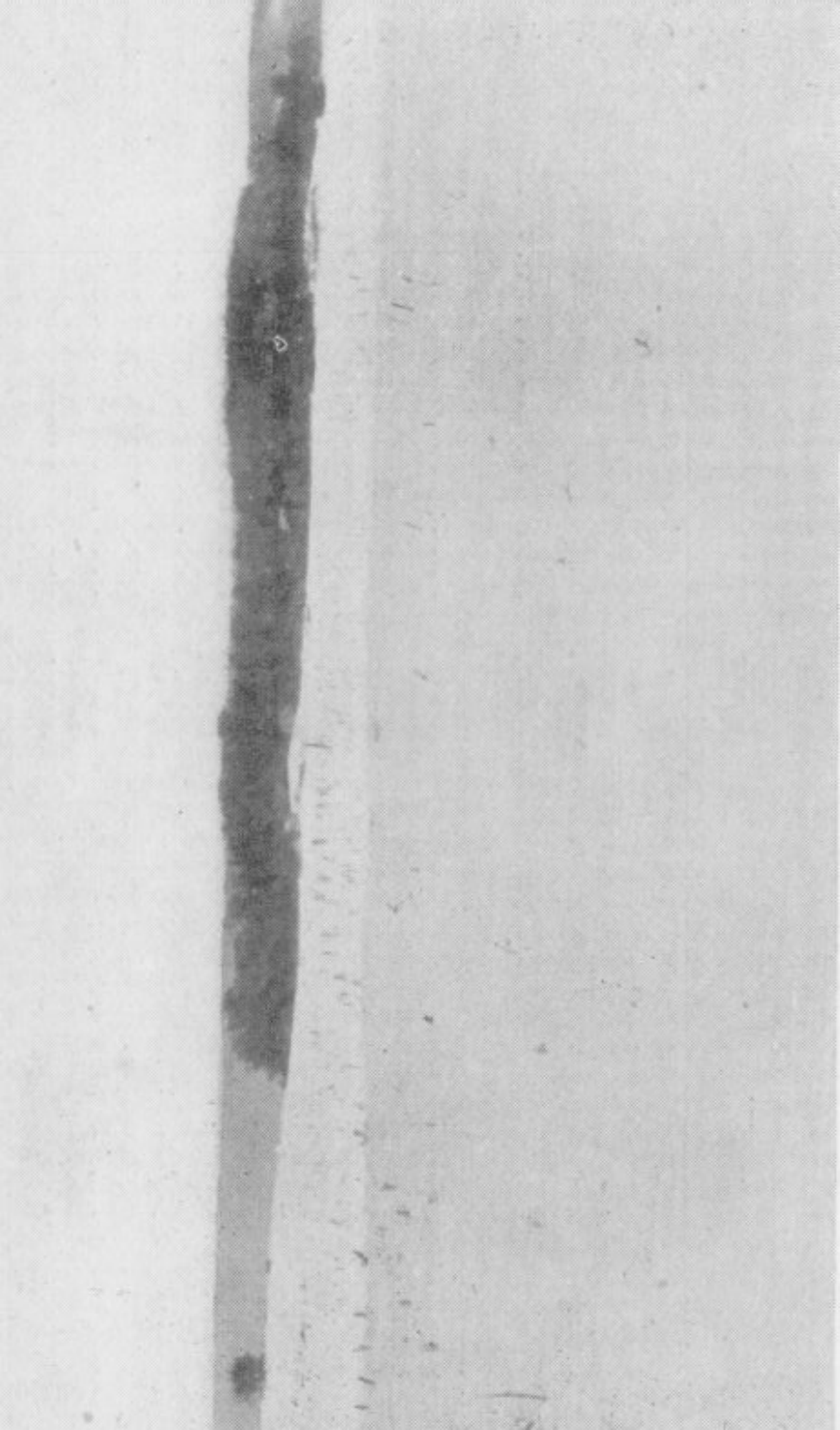














Report of

ONTARIO BUREAU OF MINES, 1918

Vol. XXVII., Part III.

Section I

COBALT

ITS

OCCURRENCE, METALLURGY, USES AND ALLOYS

By

Charles W. Drury

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Introductory Note by Author

In preparing this review of the occurrence, metallurgy, uses, chemistry and alloys of cobalt the author has made an attempt to collect all published information concerning this metal, and has added some remarks of his own.

Owing to the growing importance of cobalt and its compounds, and also to the interest that is being taken in the metal because of the similarity of some of its properties to those of nickel, it was felt a compilation and summary of all scattered information should be made. Besides having the general information in accessible form, it is hoped that the various summaries and the list of references in the review, especially those in the section on alloys, will be of assistance to any investigators attempting to study the metallurgy or the alloys of the metal cobalt.

C. W. D.

Queen's University,
Kingston, Canada,
July 1st, 1918.

COBALT

ITS OCCURRENCE, METALLURGY, USES AND ALLOYS

By Charles W. Drury

CHAPTER I

COBALT MINERALS, THEIR COMPOSITION AND OCCURRENCES

Summary of Most Important Deposits of Cobalt

Of the present known deposits of cobalt ores there are only five that are either being worked or are suitable for working at present, viz., those of Cobalt, Ont., Missouri, New Caledonia, Belgian Congo, and Schneeberg, Germany.

Those of Cobalt are the largest, and the shipping ore and concentrate contains an average of 7 to 10 per cent. of cobalt, 5 per cent. of nickel, 25 per cent. of arsenic and 300 to 1,000 ounces of silver. The higher grade silver ores are associated with calcite in narrow veins. The cobalt and nickel minerals occur chiefly as arsenides.

The ores of southeastern Missouri, occurring in the vicinity of Fredericktown, are associated with an entirely different class of minerals, as may be seen from the following approximate composition of the ore: copper, 2 to 3 per cent.; lead, 1.5 to 2.5; cobalt, 0.5 to 0.7, and nickel, 0.7 to 0.9 per cent. Arsenic and silver are not found with the Missouri cobalt ores. The copper and lead occur chiefly as sulphides, and the cobalt and nickel are more closely associated with the copper than the lead minerals. Iron and zinc sulphides are also present.

In the New Caledonia deposits, the cobalt occurs chiefly in the oxide form, the ore averaging 3 to 4 per cent. cobalt oxide. Manganese, nickel and iron oxides occur with the cobalt.

The association of cobalt with copper in Belgian Congo is of importance. As mentioned again in the report, in 1913 8,064 tons of copper, containing from 2.8 to 3.25 per cent. cobalt, were exported to Germany to be refined electrolytically. As this tonnage could yield perhaps 150 tons of cobalt, it is important when the total world's production is not more than about 500 tons.

The cobalt ores of Schneeberg are associated with nickel and bismuth minerals, the bismuth being the most important. Few analyses have been published showing the content of the ore, but those given for development work show about 2 per cent. of cobalt and 1 per cent. of nickel, the percentage of bismuth being considerably more than of cobalt and nickel.

It is a most difficult task to estimate the tonnage of cobalt ores available or developed. There is no question that the Canadian deposits will be the greatest source of cobalt for some years. The ores of Missouri, although containing considerably less cobalt than those of the other countries, are extensive, and will be sufficient to supply practically all the demands in the United States, which are now about 150 tons annually. The Missouri ores are being treated at present by the Missouri Cobalt Company, which is the only producer of cobalt in the United States. The reason why the deposits of New Caledonia are not being operated is the low price of cobalt and the high cost of transportation. However, if the price of cobalt continues to advance, there is no doubt that they will be reopened.

Cobalt Minerals

Cobaltite, Cobalt Glance.

Isometric; pyritohedral. Commonly in cubes, or pyritohedrons, or combinations resembling common forms of pyrite. Also granular, massive to compact.

Cleavage; cubic, rather perfect. Fracture uneven. Brittle. H.=5.5. G.=6-6.3. Lustre metallic. Colour; when freshly broken, silver-white inclined to red, also steel-gray with a violet tinge, or grayish black when containing much iron. Streak grayish black.

Composition; sulpharsenide of cobalt, CoAsS or $CoS_2.CoAs_2$, sulphur 19.3, arsenic 45.2, cobalt 35.5.

Occurs at Tunaberg, Riddarhyttan, Vena, and Hakansbö, in Sweden; at the Ko and Bjelke mines of Nordmark; also at Skutterud in Norway. Other localities are Querbach in Silesia; Schladming, Styria; Siegen in Westphalia (from the Hamberg mine, the ferrocobaltite); Dobsina, Hungary; Val d'Annivier, Valais; Botallack mine, near St. Just, Cornwall; Daschkessan, near Elizabethpol, in the Caucasus; Khetri mines, Rajputana, India. The ore from the Khetri mines was sold to the Indian enamellers and jewellers under the name of sehta. Deposits also occur at Tambillos and at Huasco, Chile.

In the United States, it occurs with chalcopyrite and gold in the Quartzburg district, near Prairie City, Grant county, Oregon.

In Canada, at Cobalt, Ontario.

Smaltite, Gray Cobalt Ore.

Isometric; pyritohedral. Commonly massive; in reticulated and other imitative shapes.

Cleavage; o distinct; a in traces. Fracture granular and uneven. Brittle. H.=5.5-6. G.=6.4-6.6 Lustre metallic. Colour; tin-white, inclining when massive, to steel-gray, sometimes iridescent, or grayish from tarnish. Streak grayish black. Opaque.

Composition; essentially cobalt diarsenide. $CoAs_2$, arsenic 71.8, cobalt 28.2.

Occurs usually in veins, accompanying ores of cobalt and of silver and copper. Such associations are found at Freiberg, Annaberg, and particularly Schneeberg, in Saxony; at Joachimsthal in Bohemia, the reticulated varieties are frequently found embedded in calcite; also at Wheal Sparnon in Cornwall; at Tunaberg in Sweden; Allemont in Dauphiné; at the silver mines of Tres Puntas and Veta Blanca, Chile.

In the United States, it occurs in calcite gangue, associated with small quantities of erythrite and native silver, near Gothic, Gunnison county, Colorado.

In Canada, at Cobalt, Ontario.

Linnæite, Siegenite, Cobalt Pyrites.

Isometric. Commonly in octahedrons. Also massive, granular to compact.

Cleavage; cubic, imperfect. Fracture; uneven to subconchoidal. Brittle. H.=5.5. G.=4.8-5. Lustre; metallic. Colour; pale steel-gray, tarnishing copper-red. Streak blackish gray.

Composition; $Co_3S_4=CoS.Co_2S_3$, sulphur 42.1, cobalt 57.9. The cobalt is replaced by nickel (siegenite) and to some extent by iron and copper in varying proportions.

Occurs in gneiss with chalcopyrite, at Bastnaes, near Riddarhyttan, and at Gladhammar, Sweden; at Müsen, near Siegen, in Prussia, with barite and siderite; at Siegen (siegenite), in octahedrons.

In the United States, it occurs with chalcopyrite, pyrrhotite, galena, and bornite in a number of mines of southeastern Missouri, especially in Madison county, at Mine la Motte and Fredericktown, and in St. Francois county; also at Lovelock's Station, Nevada; at Mineral Hill copper mines, Carroll county, Maryland, and at Finksburg, Maryland, associated with copper ores, sphalerite and pyrite, in chlorite schist.

Erythrite, Cobalt Bloom, Red Cobalt, Cobalt Ochre.

Monoclinic. Crystals prismatic and vertically striated. Also in globular and reniform shapes, having a drusy surface and a columnar structure; sometimes stellate. Also pulverulent and earthy, incrusting.

Cleavage; b highly perfect. Sectile. H.=1.5-2.5. G.=2.9. Lustre of b pearly, other faces adamantine to vitreous, also dull and earthy. Colour; crimson and peach-red, sometimes gray. Streak a little paler than the colour, the dry powder deep lavender-blue.

Composition; hydrous cobalt arsenate, $Co_3As_2O_8.8H_2O$. As_2O_5 38.4, CoO 37.5, water 24.1. The cobalt is sometimes replaced by nickel, iron, or calcium.

Occurs at Schneeberg in Saxony, in micaceous scales; in brilliant specimens, consisting of minute aggregated crystals, at Saalfeld in Thuringia; also at Riechelsdorf in Hesse; Modum in Norway; with bismuth at Bieber in Hesse; Andalusia, Spain; Piedmont, Italy. The earthy peach-blossom varieties have been observed at Allemont, in Dauphiné, France; at the Botallack mine, near St. Just, Cornwall; near Alston in Cumberland; and near Killarney in Ireland. A perfectly green variety occurs at Platten in Bohemia, and sometimes red and green tinges have been observed on the same crystal.

In the United States, erythrite occurs in the northeast part of Churchill county, Nevada; near Blackbird, Lemhi county, Idaho; at Josephine mine, Mariposa county, and at Kelsey mine, Los Angeles county, California; also at Lovelock mine, Humboldt county, Nevada.

In Canada, at Cobalt, Ontario.

Willyamite.

Cleavage; cubic. Fracture; uneven. Brittle. H.=5.5. G.=6.87. Lustre; metallic. Colour; between tin-white and steel-gray. Streak; grayish black.

Composition; $CoS_2.NiS_2.CoSb_2.NiSb_2$. A sulph-antimonide of cobalt and nickel.

Found at the Broken Hill mines, in Willyama township, New South Wales, associated with dyscrasite in a calcite and siderite gangue.

Skutterudite.

Isometric; pyritohedral. Also massive granular.

Composition; cobalt arsenide, $CoAs_3$.

Cleavage; a, distinct. Fracture uneven. Brittle. H.=6. G.=6.72-6.86. Lustre; metallic. Colour; between tin-white and pale lead-gray, sometimes iridescent.

Found at Skutterud, near Modum, Norway, in a hornblende gangue in gneiss with titanite and cobaltite, the crystals sometimes implanted on those of cobaltite.

Bismutosmaltite.

Composition; $Co(As.Bi)_3$. A skutterudite containing bismuth. Colour; tin-white. G.=6.92.

Occurs with other bismuth minerals at Zschorlau, near Schneeberg, Saxony.

Asbolite, Asbolan, Earthy Cobalt, Wad.

Composition; an impure mixture of manganese and other metallic oxides. Some varieties have been known to contain as much as 32 per cent. of cobalt oxide.

Occurs at Riechelsdorf in Hesse; in Westerwald district between Rhenish Prussia and Westphalia; at Saalfeld in Thuringia; at Nerchinsk in Siberia; at Alderley Edge in Cheshire; Asturias, Spain; and New Caledonia.

An earthy cobalt mineral occurs at Mine la Motte, Missouri, associated with copper, iron, nickel, lead and sulphur; also near Silver Bluff, South Carolina.

Roselite.

Triclinic.

Composition; $(Ca.Co.Mg)_3As_2O_8.2H_2O$. H.=3.5. G.=3.5-3.6. Occurs in small crystals; often in druses and spherical aggregates. Colour; light to dark rose-red.

Found at Schneeberg, Saxony, on quartz (1842); later obtained from the same region at the Daniel and Rappold mines; also reported from Schapbach, Baden.

Sphærocobaltite.

Rhombohedral. In small spherical masses, with crystalline surfaces, rarely in crystals. H.=4. G.=4.02-4.13. Lustre; vitreous. Colour; rose-red altering to velvet-black. Streak; peach-blossom red.

Composition; cobalt carbonate—$CoCO_3$.

Occurs sparingly with roselite at Schneeberg, Saxony.

Remingtonite.

A rose-coloured incrustation, soft and earthy. Streak; pale rose-coloured.

Composition; a hydrous cobalt carbonate.

Occurs as a coating on thin veins of serpentine, which traverse hornblende and epidote at a copper mine near Finksburg, Carroll county, Maryland.

Safflorite.

Orthorhombic. Similar to smaltite, essentially cobalt diarsenide, $CoAs_2$. Form near that of arsenopyrite. Usually massive, sometimes showing fibrous radiated structure. Lustre; metallic. Colour; tin-white, soon tarnishing to dark gray.

Occurs with smaltite and implanted upon it, at Schneeberg, Saxony. Also similarly associated at Bieber, near Hanau, in Hesse; at Wittichen in Baden; Tunaberg in Sweden.

Glaucodot.

In orthorhombic crystals. Also massive. Brittle. H.=5. G.=5.90-6.01. Lustre; metallic. Colour; grayish tin-white. Streak; black.

Composition; a sulpharsenide of cobalt and iron. (Co,Fe)AsS.

Occurs in chlorite slate with cobaltite in the province of Huasco, Chile; also at Hakansbö, Sweden.

Alloclasite.

Commonly in columnar to hemispherical aggregates. H.=4.5. G.=6.6. Colour; steel-gray. Streak; nearly black.

Composition; probably essentially Co(As,Bi)S, with cobalt in part replaced by iron; or a glaucodot containing bismuth.

Occurs at Orawitza, Hungary.

Bieberite.

Composition; hydrous cobalt sulphate; $CoSO_4.7H_2O$.

Occurs as rose-coloured stalactites in the old mines at Bieber, in Hesse; at Leogang, in Salzburg; at Tres Puntas, near Copiapo, Chile.

Cobaltomenite.

Probably cobalt selenite, $CoSeO_3.2H_2O$.

Occurs with chalcomenite (hydrous cupric selenite), at Cerro de Cacheuta, Argentina.

Jaipurite.

Composition; described as a simple cobalt sulphide, CoS, occurring massive. G.=5.45. Colour; steel-gray.

It is stated that this mineral was used by Indian jewellers.

Carrollite.

Isometric, rarely in octahedrons. Usually massive. H.=5.5. G.=4.85. Colour; light steel-gray, with a faint reddish hue.

Composition; a copper cobalt sulphide, $CuCo_2S_4=CuS.Co_2S_3$, cobalt 38.0, copper 20.5, sulphur 41.5.

Occurs at the Patapsco mine, near Finksburg, Carroll county, Maryland, and also at the Springfield mine, associated and mixed with chalcopyrite and chalcocite.

Sychnodymite.

Isometric, in small steel-gray octahedrons.

Composition; essentially $(Co,Cu)_4S_5$. Part of the cobalt may be replaced by nickel.

Occurs, associated with quartz, siderite, and tetrahedrite, at the Kohlenbach mine, southeast of Eiserfeld in the Siegen district, Prussia.

Pateraite.

An impure, massive mineral of black colour, supposed to be a molybdate of cobalt. Vogl discovered pateraite associated with uranium ores in the Elias mine, Joachimsthal, Bohemia.

Transvaalite.

An oxidation product of cobalt arsenide.

Occurs in black nodular masses forming veins in quartzite at a cobalt deposit, 30 miles north of Middleburg, Transvaal, South Africa. An analysis of a sample of transvaalite showed 1 oz. 12 dwt. of gold per ton.

Heterogenite; Heubachite; Winklerite.

These are hydrated oxidized cobalt minerals, containing nickel, copper, iron, or manganese.

Cobalt is also an occasional constituent of many other minerals, especially of pyrrhotite (sulphide of iron) and arsenopyrite (sulpharsenide of iron), and is usually present in nickel ores. Cobaltiferous varieties of arsenopyrite, known as danaite, are probably due to isomorphous intergrowths of glaucodot.

Metallic cobalt has been recorded as occurring in meteorites.

Summary of the World's Cobalt Deposits*

*A large part of the description of the world's cobalt deposits as given in this section is taken from the Nineteenth Annual Report of the Ontario Bureau of Mines, Part II, by Willet G. Miller.

Germany and Austria

Deposits of cobalt-silver ores resembling those found in the vicinity of Cobalt, Canada, are found in Germany and Austria. The two areas in these countries are those of Annaberg and Joachimsthal. Mining was begun in the latter about the end of the fifteenth century, while it is stated the deposits of the former were discovered in 1492.

The ores of those two regions are similar to those of Ontario, and contain compounds of cobalt, nickel, bismuth, and silver, with the ore of uranium, which has not been found in the Ontario deposits. The rocks belong to the older systems, but are different in composition from those of Cobalt.

At Joachimsthal, in Bohemia, there is a series of mica schist and limestone cut by dikes of basalt. The veins are said to be older in age than the basalt, and younger than the other rocks mentioned. The veins, which are narrow, contain quartz, hornstone, calcite, and dolomite as gangue material, and often show a brecciated structure.[1] The minerals of these veins are given in the following list:

1. Silver ores: native silver, argentite, polybasite, stephanite, tetrahedrite, proustite, pyrargyrite, and sternbergite.

2. Nickel ores: niccolite, chloanthite, and millerite.

3. Cobalt ores: smaltite as well as bismuth-bearing linnæite and asbolite.

4. Bismuth ores: native bismuth together with bismuthinite and bismuth ochre.

5. Arsenic ores: native arsenic and arsenical pyrites.

6. Uranium ore: uraninite or pitchblende.

[1] Beck, Erzlagerstätten, p. 290, 1903. Beyschlag, Krusch and Vogt, Die Lagerstätten der Nutzbaren Mineralieu und Gesteine. Stelzner-Bergeat, Die Erzlagerstätten.

Associated with these are galena, zinc blende, pyrite, marcasite, and copper pyrites.

Among these ores those of cobalt and nickel are generally the older; those of silver the younger. The veins cut through dikes of quartz-porphyry, and are in turn cut by basalt and later dikes.

Of similar composition to those of Joachimsthal are the veins of Annaberg in Saxony. In this neighbourhood the rock is gray gneiss. There are two groups of veins, but the younger, carrying the silver-cobalt ores, are the more important of the ore bodies. The gangue material is chiefly barite, fluorspar, quartz, and breunnerite, with various cobalt, nickel, and bismuth ores, viz., chloanthite, smaltite, red and white nickel pyrites, annabergite, native bismuth, and rarely bismuthinite. Of the silver ores, pyrargyrite, proustite, argentite, native silver, and silver chloride are found. The subordinate gangue minerals are hornstone, chalcedony, amethyst, calcite, aragonite, kaolin, and gypsum; while among the ores are copper pyrites, galena, zinc blende, pyrite, marcasite, tetrahedrite, siderite, uraninite, uranochalcite, uranochre, gummite, and native arsenic. The fact that a large amount of silver chloride was mined at one time, is interesting.

From a large number of observations, the following is given as the relative ages of the various minerals of the Annaberg veins:

V. Decomposition products: annabergite and cobalt bloom.
IV. Silver ores and native arsenic.
III. Calcite and uraninite.
II. Breunnerite and cobalt-nickel-bismuth ores.
I. Barite, fluorspar, and quartz.

The silver-cobalt veins cut the older tin and lead veins of the district as well as the dikes of microgranite and lamprophyre. The latter, especially, are often cut by the silver-cobalt veins. These are cut by basalt, which occurs not only in true dikes, but also in boss-like forms.

Somewhat similar silver-cobalt ores are found in certain veins at Schneeberg, but they are not so strikingly like those of Joachimsthal and Annaberg. A like association of ores is found at Wittichen, where the veins occur in granite.

According to Von Cotta, the rocks of the Joachimsthal district consist of mica schist, together with more or less hornblende schist and crystalline limestone, the whole being cut by numerous dikes of quartz-porphyry and basalt. There are also two large granite masses which rise out of the mica schist. There are lodes of tin, silver, and iron compounds. Tin is found only in the granite region. Silver lodes are divided into four groups fairly distinct from one another. One set contains about 17, while another has 21 lodes. There are also others which do not come to the surface. Von Cotta also states that both classes of lodes intersect the mica schist, with all its subordinate strata, quartz-porphyry, and often even the dikes of basalt and wacké;[1] and that there seem to be cases where dikes of the basalt and wacké have intersected lodes or have penetrated their fissures. From this it may be deduced that the silver lodes were almost contemporaneous with the formation of the basalt, in that their fissures, in part follow the basalt dikes and in part are intersected by the basalt. At all events they stand in a certain genetic connection

[1] Wacké is an old term for a soft, earthy variety of trap rock.

to the porphyry, which here is evidently of much greater age than the basalt. The subject is still somewhat obscure. The silver lodes have not yet been found in the granite. Other writers do not agree with Von Cotta, as they appear to be of opinion that the basalt is younger than the veins.

The following notes are taken from Phillips' "Ore Deposits," p. 436, 1896.

The mountains known as Erzgebirge lie on the boundary between Saxony and Bohemia. Joachimsthal lies on the Bohemian side, and is therefore an Austrian town, while Annaberg is in Saxony.

The country rock in the neighborhood of Joachimsthal is for the most part mica schist enclosed between masses of granite. In the eastern part of the mine there are some masses of included limestone, but in the western part, where the veins are not infrequently associated with dikes of porphyry, the gangue is almost quartzose. There are seventeen veins striking north and south, and seventeen others of which the direction is east and west. It has been constantly observed that the former exhibit a tendency to become enriched where they pass through the porphyry or included limestone, while the latter is not similarly affected when they come in contact with these rocks. The ores mined contained silver, cobalt, nickel, bismuth, and uranium. The uranium ores of Joachimsthal became valuable a few years ago, when it was found that uraninite was the chief commercial source of radium.

In 1864, when one shaft had reached a depth of 1,440 feet, a heavy outburst of water, at a temperature of 25°C. and evolving sulphuretted hydrogen, took place, and greatly interfered with underground operations. It was two years before this water could be successfully tubbed off and mining continued.

Cobalt minerals associated with granite are found in several other localities in the Erzgebirge, as well as at Wittichen and at Wolfach, in the Black Forest, where the veins occur in granite.

In Thuringia fault fissures in the Kupferschiefer and Zechstein are filled with barite, calcite and fragments of the country rock, together with smaltite, asbolite, and erythrite. They have been worked especially at Schweina, near Liebenstein.

The palæopicrite of Dillenburg (Nassau) contains cobalt, together with nickel, copper, and bismuth. At Querbach and Giehren, in the Riesengebirge, the mica schist near the contact with gneiss is impregnated with cobaltite, chalcopyrite, pyrite, pyrrhotite, arsenopyrite, blende, galena, magnetite, and cassiterite.

In the Fichtelgebirge, ores of cobalt and nickel are associated with siderite, bismuth, and barite. Siderite and copper ores are found with them in the Siegen district, Prussia.

In Alsace veins of smaltite, chloanthite and native silver in a calcite gangue were formerly worked at Sainte-Marie-aux-Mines.

Messrs. Schmidt and Verloop [1] have described the cobalt and nickel deposits of Schladming, Styria. The predominating ores are given as: niccolite, chloanthite, gersdorffite, and smaltite. Native bismuth and arsenic, arsenical pyrites and löllingite are also found.

[1] Schmidt and Verloop, Notiz über die Laerstätte von Kobalt und Nickelerzen bei Schladming in Steiermark: Zeitschr. prakt. Geologie, Vol. XVII, 1910, pp. 271-275.

During the period from 1877 to 1880 there were obtained 29.3 tons of ore, containing 4,497 ounces of silver, 198 pounds of bismuth, 878 pounds of uranic oxide, 1.5 tons of arsenic, and 314 pounds of cobalt-nickel with a little lead, representing a total value of £1,687.

About this time it became evident that the uranic oxide was the most valuable product of these mines, and workings were especially directed to develop the minerals yielding it.

The Schneeberg mines during the year 1881 produced 158 tons of nickel and cobalt ores, valued at £5,902; 1,315 tons of silver ore, and 59 tons of bismuth ore, worth £3,292 and £16,933 respectively.

The production of cobalt ores in Prussia and Bavaria is given below.

PRODUCTION OF COBALT ORES IN PRUSSIA.[1]

Year	Cobalt Ore		Year	Cobalt Ore	
	Metric tons	Value		Metric tons	Value
		$			$
1852	233	16,376	1880	48	2,974
1853	12	5,652	1881	33	2,052
1854	14	6,676	1882	66	3,311
1855	10	4,534	1883	98	4,869
1856	6	3,882	1884	67	2,030
1857	3	1,761	1885	59	1,326
1858	1	767	1886	19	808
1859	.....	.....	1887	11	343
1860	0.3	17	1888	33	992
1861	1	72	1889	503	2,739
1862	1	75	1890	651	10,739
1863	1	291	1891	576	9,209
1864	143	1,470	1892	534	14,550
1865	0.2	37	1893	203	8,491
1866	.....	.....	1894	203	5,741
1867	23	12,313	1895	120	6,298
1868	25	8,371	1896	181	9,868
1869	27	6,764	1897	121	6,256
1870	16	3,762	1898	34	1,700
1871	18	4,228	1899	17	850
1872	219	14,547	1900	4	160
1873	286	13,820	1901	36	2,168
1874	254	35,757	1902	76	.....
1875	200	19,789	1903	65	.....
1876	158	19,076	1904	41	.....
1877	70	5,233	1905	22	.....
1878	46	2,955	1906	7	.....
1879	49	3,074			

Cobalt products were made in Prussia continuously from 1852 to 1911. No cobalt ore was produced in Prussia after 1906 and very little since 1897, so that most of the ore treated must have been imported.

In 1884 and 1885 only was there any production of cobalt ores in Bavaria. During these years there were produced 160 tons and 349 tons of ore, valued at $600 and $1,050 respectively.

[1] Most of the figures in this and the following tables were taken from the Mineral Industry.

The production of cobalt ore in Saxony has not been published separately, but is given with bismuth and nickel ores. From 1878 to 1901 there was produced 25,350 tons of cobalt, bismuth, and nickel ores.

In 1904, one cobalt-silver mine in the Schneeberg district had a production valued at $132,147. The values were in silver, cobalt, nickel, bismuth, arsenic, uranium, samples, etc. These ores were treated at the "blue colour works," at Schneeberg. Both the government and private companies were interested in the industry. For a detailed description of the cobalt industry in Saxony, the reader is referred to "The Early History of the Cobalt Industry in Saxony," by Mickle, Report of Bureau of Mines, Ontario, Vol. XIX, 1913, pt. ii., pp. 234-251.

PRODUCTION OF COBALT ORES IN AUSTRIA.

Year	Nickel and Cobalt Ore		Year	Nickel and Cobalt Products	
	Metric tons	Value		Metric tons	Value
		$			$
1856	136	18,806	1856		
1857	387	5,508	1857		
1858	342	3,050	1858		
1859	371		1859	11	
1860	281		1860	5	
1861			1861		
1869 (a)	166	662	1869 (a)		
1870	50	108	1870		
1871			1871		
1872			1872		
1873	452	12,244	1873	23	20,150
1874	156	12,546	1874	37	22,460
1875	112	9,864	1875	22	18,892
1876	97	8,340	1876	22	13,734
1877	105	4,790	1877	14	7,896
1878	76	2,242	1878	6	3,502
1879	27	718	1879	5	1,280
1880	16	440	1880	4	1,142
1881	40	200	1881		
1882	15	210	1882	19	1,336
1883	4	158	1883		
1884	5	340	1884		
1885	137	1,546	1885		
1886	37	154	1886		
1887			1887		
1888			1888		
1889			1889		
1890	3.4	126	1890		
1891			1891	1.5	180
1892	0.3		1892	0.15	78
1893			1893	0.12	64
1894	0.5		1894	0.1	62
			1895		
			1896		
			1897	37.6	10,022
			1898	58.8	10,800
			1899	38.1	17,868
			1900	31.2	13,668
			1901	20.5	1,198

(a) From 1861 to 1869 inclusive, no record is given of any production of nickel and cobalt ore or products in Austria.

Deposits of the Chalanches, France

Silver, cobalt, and nickel ores somewhat similar to those of Germany occur in a network of narrow veins in crystalline schist at the Chalanches, in the Dauphiné, France. These deposits were discovered in 1761, and have been described by T. A. Rickard.[1]

The following notes are from Mr. Rickard's paper:

During the earliest period of mining at the Chalanches, some bodies of rich silver, nickel, and cobalt ore were found near the surface. It is said that two shots produced sufficient silver to pay for the two buildings known as the pavilions of Allemont, with their various ornamentations, including the fleur-de-lis which still adorn the roof. As 200 to 300 kilos of silver would at that time be worth from $10,000 to $15,000 this statement does not seem incredible.

It is remarkable that although the silver is always associated in the lodes with rich nickel and cobalt ores, often with bunches of stibnite, and more rarely and erratically with gold, the government engineers took no notice of any metal other than silver. The speiss[2] containing nickel and cobalt was rejected with the slags, and was used to fill the swamps or form road beds, which, in later times, were furrowed and turned over to recover their valuable contents.

The possibility of utilizing three metals instead of one seems to have dawned upon the engineers quite as a discovery; and this fact stimulated the repeated spasmodic attempts to rehabilitate the old mine. The arsenides of nickel and cobalt were sold in England and Germany. A German chemist was employed at Allemont to manufacture cobalt pigments for the arts, but was not successful, and the attempt was abandoned.

In 1891 gold was first recognized. However, its importance proved greater from a scientific than from a commercial point of view. The old mine-workings, aggregating 20 kilometres in length, showed that a great deal of unsuccessful exploration had been carried out.

The geological formation is simple. A network of veins traverses crystalline schists of variable character. The country rock forms a part of the great crystalline formation usually referred to as the Archaic schists of the Alps, though in point of fact they probably include rocks from the Archaic to the Carboniferous. Lithologically, certain sections suggest the Huronian and Laurentian. These schists lie immediately upon the granite; they are extremely variable in character, so that at different places they can be described as gneissoid, granitoid, talcose, micaceous, graphitic, or amphibolic. There are also blocks of rock containing epidote.

The maps of the mine exhibit a wonderful network of galleries spreading like a cobweb over an area of about 600 by 300 metres. It is computed that the workings aggregate in length not less than twelve miles, an extent in remarkable contrast to the relatively small quantity of ore produced.

It has been thought by several observers that the lodes were more numerous near the surface than in the interior of the mine. This is due to the fact that any single fissure, in approaching the surface, spreads itself out into a number of subordinate fractures. It has also appeared that the lodes gained in regularity as they penetrated the mountain. Caillaux, therefore, adds that this fact seems to indicate the probable occurrence in depth of only a small number of lodes, but that those surviving will have a regularity of structure greater than those which have been hitherto exploited. The veins vary in width from a knife-blade to 80 centimetres (31.5 inches); their usual thickness lies between 3 to 30 centimetres (0.1 to 1 foot).

Examination of the old workings proves clearly that farther from the surface the country rock gets harder, the vein matter loses its soft character, and the veins become fewer in number, more regular, narrower, and less ore-bearing. Approaching the surface, on the contrary, the schists are fractured in a multiplicity of directions, the veins become larger, their filling is generally earthy, and they throw off branches, at the intersections of which the ore bodies are found. In general, mineralization becomes more pronounced near the surface; this being due, not merely to the oxidation of the sulphides, but to an actual relative increase of 'orey' matter.

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[1] Rickard, The Mines of the Chalanches, France. Am. Inst. Min. Eng. Trans., Vol. XXIV, 1894, pp. 689-705.

[2] Speiss is a product formed in smelting which contains most of the metals in the form of arsenides.

The observations led to the conclusion that the richest part of the mine was that which was within the influence of oxidation, and that both chemical agencies and structural conditions favoured an enrichment of ore near the surface. This statement is particularly applicable to the silver contents. It also holds true of the gold, but it is less accurate with respect to the nickel and cobalt. The richness in silver of the oxidized ores suggests secondary precipitation. This is confirmed by the fact that the silver appears to be thrown down upon the nickel and cobalt arsenides and often envelops them in such a way as to impart the rudiments of a nodular structure. The hard, undecomposed arsenides contain small amounts of silver. The gold, occasionally present, is associated with soft, maroon-coloured, earthy iron-bearing vein matter. The nickel and cobalt minerals appear to be primary, and are more persistent than those of silver and gold.

If we accept the current theory that the nickel and cobalt came from the leaching of magnesium silicates (and facts are numerous pointing that way), then we must conclude that the origin of the nickel and cobalt ores of the Chalanches was not the immediately adjacent rocks, but ones similar, which underlie them at a greater depth. The silver and gold, it may be suggested, were precipitated from other solutions, and at a period other than that which saw the deposition of the nickel and cobalt. The precious metals were probably derived from a deeper-seated source, and may have been leached from the granite which underlies the schists and is penetrated by the basic eruptives. In both cases the various metals must have come from a depth where leaching action was powerful, and from which ascending currents brought the metallic constituents, the subsequent precipitation of which produced valuable ore-deposits.

Quartzose veins containing ferriferous smaltite were prospected in 1784 at Juzet, near Nance, Montauban-de-Luchon, Haute-Garonne. The ores produced together with those from Gistain on the Spanish side of the Pyrenees, were treated at Saint-Marnet.

Norway

The following description of the cobalt deposits of Norway is given by Phillips:[1]

The cobaltiferous fahlbands of the districts around Skutterud and Snarum occur in crystalline rocks varying in character between gneiss and mica schist; however, from the presence of hornblende, they sometimes pass into hornblende schists. These schists, of which the strike is north and south, and which have an almost perpendicular dip, contain fahlbands very similar in character to those of Kongsberg. They differ from those of that locality, however, inasmuch as while here the fahlbands are often impregnated with ore, those of Kongsberg, although to some extent containing disseminated sulphides, are only of importance as being zones of enrichment for ores which occur in veins. The ore zones usually follow the strike and dip of the surrounding rocks, and vary in width from 15 to 30 feet. The distribution of the ores is by no means equal. The predominant rock of the fahlbands is a quartzose, granular mica-schist, which gradually passes into quartzite, ordinary mica-schist, or gneiss. The ores were cobalt glance, arsenical and iron pyrites, molybdenite, and galena. It is remarkable that in these mines nickel ores do not accompany the ores of cobalt in any appreciable quantity. The principal fahlband is known to extend for a distance of about six miles, and is bounded on the east by a mass of diorite which protrudes into the fahlband, while extending from the diorite are small dikes or branches traversing it in a zigzag course. It is also intersected by dikes of coarse-grained granite which do not contain any ore, but which penetrate the diorite.

The Skutterud mine in 1879 produced 7,700 tons of cobalt ore, which yielded 108 tons of cobalt schlich,[2] containing from 10 to 11 per cent. of cobalt, and worth about £11,000. These deposits, which at one time were among the world's chief producers of cobalt, are of too low grade to be worked now.

Silver veins were discovered at Kongsberg in 1623. These veins resemble those of Cobalt in width, in that the numerous veins or stringers occur in small areas, and in the gangue mineral which is essentially calcite. However, nickel and cobalt minerals are not characteristic of the Norwegian deposits.

[1] Phillips, Ore Deposits, 1884, p. 390.
[2] Schlich is a term given to washed cobalt ore.

PRODUCTION OF COBALT ORES IN NORWAY.

Year	Cobalt Ore		Year	Cobalt Ore	
	tons	value		tons	value
		$			$
1866	85	20,600	1884	90	12,922
1867	30	7,500	1885	101	13,702
1868	5	4,368	1886	123	11,960
1869	30	14,456	1887	57	4,160
1870	10	4,056	1888	84	8,060
1871	25	13,520	1889	152	14,300
1872	65	35,152	1890	213	19,500
1873	75	40,560	1891	187	13,000
1874	65	35,100	1892	123	8,580
1875	60	32,500	1893	123	12,150
1876	95	49,400	1894	89	8,100
1877	105	52,000	1895	45	4,050
1878	105	52,000	1896	29	2,700
1879	108	52,000	1897	24	2,700
1880	87	45,500	1898	21	2,160
1881	80	41,600	1899	.....	.....
1882	99	52,000	1900	.....	.....
1883	84	14,326			

Most of the cobalt ore mined in Norway was exported.

In 1896 the cobalt works at Modum operated on a limited scale, employing 36 men.

Sweden

At Tunaberg, cobalt ore occurs in a bed of granular limestone in gray gneiss. The limestone contains, principally, hornblende, mica, and serpentine; also lead, silver, copper and cobalt minerals, copper pyrites and cobalt glance being the most frequent.

Other localities are Vena, near Askersund, on Lake Wetter, and at Gladhammar, south of Westerwik.

The following table shows the extent of the working of the cobalt deposits in Sweden.

PRODUCTION OF COBALT ORES IN SWEDEN.

Year	Cobalt Ore	Year	Cobalt Ore
	Metric tons		Metric tons
1870	58	1882	516
1871	.....	1883	177
1872	41	1884	56
1873	17	1885	137
1874	41	1886	164
1875	74	1887	231
1876	101	1888	143
1877	153	1889	266
1878	726	1890	145
1879	223	1891	244
1880	331	1892	53
1881	556	1893	101

In the years 1887, 1888 and 1889 there were also produced 376, 258, and 177 kilos of concentrated ore.

In 1888, 1889, 1890, 1891, 1892, and 1893, there were produced 7,270, 14,154, 15,444, 13,772, 15,703, and 7,255 pounds of cobalt oxide respectively.

Italy

Cobalt and nickel ores occur with quartz, calcite, and ores of copper in Piedmont.

Switzerland

Cobalt and nickel ores occur in Valais, and at Ayer in the Val d'Annivier and at Kaltenberg in Turktmanntal.

New Caledonia

Until the discovery of the cobalt deposits, at Cobalt, Ont., Canada, in 1903, about six countries were supplying the world with cobalt ores, New Caledonia producing probably 85 or 90 per cent.

When the ore from Ontario was put on the market, the prices fell materially in New Caledonia, and cobalt mining has now practically ceased in that country. It seems strange that Ontario should be the only serious competitor which this French colony, in the Southern Pacific, has in both nickel and cobalt.

The cobalt deposits of New Caledonia occur under conditions similar to those of nickel, and the two metals are frequently associated in economic quantities. New Caledonia is a non-glaciated country. The rock peridotite underlies a considerable part of the surface. This rock weathers readily, and so, over a large part of the surface, the alteration product, serpentine, occurs. The surface of the serpentine is more or less broken down, forming comparatively loose or slightly coherent deposits. It is in association with these that the cobalt is found, as asbolite, earthy cobalt, or cobaltiferous wad. Asbolite is a mixture of oxides of cobalt, manganese, and other metals and can hardly be called a distinct mineral. It has been proved that the cobalt, nickel, and other metals found in this decomposed rock were originally constituents of the peridotite.

The peridotites are believed by some writers to be post-Cretaceous in age, and are said to be in the form of a surface flow covering the uneven or eroded surface of the underlying Cretaceous strata. These rocks which are high in magnesia and low in iron, constitute the great serpentine formation of New Caledonia. They are more or less charged, when fresh, with crystals of ferro-magnesian pyroxene. The unaltered rock belongs, therefore, in Rosenbusch's classification, to harzburgite. Dunite, a variety of peridotite of which the main constituent is olivine, is found with chrome iron ore. The peridotites usually show traces of advanced alteration, which has resulted in more or less transformation of olivine to serpentine, and in the development of talc from pyroxene. At times the alteration is sufficiently advanced to produce perfect crystals of antigorite, with some films of talc.

Since these rocks always contain a little manganese, nickel, and cobalt, it would appear that these metals occur in the olivine as well as in the enstatite. Grains of chrome ore are abundant in all samples. The rocks are often traversed by less basic dikes of the character of gabbro. Diorite sometimes outcrops in the middle of the serpentine exposures.

In one deposit,[1] it is said that the decomposed material occupies a profound depression in the serpentine. This basin is filled by a red, clay-like deposit which has a depth of about 52 metres in the centre and 10 or 12 metres around the border. The richest ores appear to occur near the centre of the basin and near the contact of the serpentine.

It will be seen that all the cobalt deposits are irregular in form, and hence it is difficult to estimate their value.

Much of the mineral mined contains only two or three per cent. of oxide of cobalt and after washing probably 4.5 per cent. Cobalt ores from New Caledonia were purchased (1904) on a basis of 4 per cent. CoO, for which ore 330 francs[2] ($66.00) per ton was paid. In purchasing ores containing cobalt in excess of 4 per cent. CoO, a premium, which varied with the grade of ore, was allowed. The grades were divided as follows: those containing between 4 and 5 per cent. cobalt oxide. 5 and 6 per cent., 7 and 8 per cent., and above 8 per cent. Premiums of 0.8, 0.9, 1.0, and 1.5 francs for the different grades respectively were allowed for each 0.1 per cent. above the minimum per cent. of each grade. On this basis mineral carrying 8 per cent. would be worth 750 fr. ($150) a ton.

The prices paid for cobalt ore in New Caledonia in 1908 were about as follows: for 4.5 per cent. ore, $23 a ton; for 5 per cent. ore, $27 to $28 and 90 cents for each 0.1 per cent. above. At these prices, only rich, well-situated, and developed mines could be worked. An 8 per cent. New Caledonia ore at the price quoted would bring $54 a metric ton.

Ouvrard[3] reports the price of cobalt ore from New Caledonia and Chile as $35.00 per ton, c.i.f. European ports, for ore containing 4 per cent. cobalt; with a premium or penalty of $1.20 for each 0.1 per cent. cobalt above or below 4 per cent.

Previous to 1910 the Anglo-French Nickel Company of Swansea, Wales, bought some ore at Cobalt for the cobalt content alone, and paid 30 cents a pound for the metallic cobalt in an 8 per cent. ore. This is about $53 per ton for such ore.

The following analysis shows the composition of the New Caledonia ores: MnO_2 18, CoO 3, NiO 1.25, Fe_2O_3 30, Al_2O_3 5, CaO and MgO 2, silica 8, and loss on ignition 32 per cent.

In the following table the amount of cobalt ore exported from New Caledonia between 1893 and 1909 is given.

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[1] Glasser, Report to the Minister of the Colonies on the Mineral Wealth of New Caledonia, 1904.

[2] A franc is worth about 20 cents.

[3] Ouvrard, Industries du Chrome, du Manganese, du Nickel, et du Cobalt, p. 253, Doin and Sons, Paris, 1910.

EXPORTATION OF COBALT ORE FROM NEW CALEDONIA.

Year	Cobalt Ore (Metric tons)	Year	Cobalt Ore (Metric tons)
1893	(a) 520	1903	8,292
1894	(a) 4,156	1904	8,964
1895	5,302	1905	7,919
1896	4,823	1906	2,487
1897	4,757	1907	3,943
1898	2,373	1908	3,405
1899	3,294	1909	979
1900	2,438	1910	.....
1901	3,123	1911	.....
1902	(b)	1914	(c) 920

(a) In 1893 and 1894, 169 and 7 tons, respectively, of matte were exported.
(b) Not reported.
(c) During 1914, New Caledonia exported 920 tons of ore and 25 tons of matte; Mineral Industry, Vol. 23, 1914, p. 548.

New South Wales

New South Wales was the second largest producer of cobalt ore before the discovery of the deposits at Cobalt, Ontario. The deposits, which are situated near Port Macquarie, are similar to those of New Caledonia.

During 1898, 1899, and 1900, 119, 193, and 145 tons of cobalt ore, valued at $2,800, $4,595, and $7,950 respectively were shipped.

In 1903 the quantity of cobalt ore exported from the deposits near Port Macquarie amounted to 153 tons, valued at $7,850. Since 1903, there have not been any shipments of cobalt ore made from New South Wales.

South Australia

Cobalt ore, containing smaltite and other minerals, occurs at Bimbowrie, near Olary, on the Broken Hill line, but little work has been done on the deposit.

Africa

While, as we have seen, silver has been worked in association with cobalt, the latter metal has been seldom found in association with gold in important quantities. However, one such occurrence is in the Middleburg district in northern Transvaal. In the vein in this district, the gangue material is kaolin, with which is mixed gold-bearing quartz. In the quartz are small nest-like aggregations of smaltite and copper ores, and at times molybdenite, also the secondary minerals cobalt bloom, limonite and skorodite.

A small amount of ore was produced in 1890 and also in 1895. During 1895 a quantity of ore analyzing 7 to 10 per cent. was reported to have been exposed. A brief account[1] of one of the cobalt deposits states:

[1] Geology of the Neighborhood of Middleburg, Transvaal Mines Dept., Pretoria, 1907.

Cobalt, in the form of smaltite and erythrite, is found at Balmoral, and also just beyond the northern boundary of the map in the valley of the Kruis river. At Balmoral the cobalt is associated with feldspar and actinolite, together with secondary quartz and calcite, in veins most probably of igneous origin, which traverse a series of highly altered sedimentary rocks of shaly character in the neighbourhood of the junction of the Waterberg and Transvaal systems.

Three additional references to cobalt deposits of the Transvaal are given below.

Beck, Note on Cobalt Lodes of the Transvaal: Trans. Geol. Soc., South Africa, vol. 10, 1907, p. 10.

Mellor, Note on the Field Relations of the Transvaal Cobalt Lodes: Trans. Geol. Soc., South Africa, vol. 10, 1907, p. 36.

McGhie and Clark, Transvaalite—A new Cobalt Mineral from the Transvaal: Jour. Soc. Chem. Ind., vol. 9, 1890, p. 587.

The crude copper produced by the Union Minière du Haut Katanga, Belgian Congo, of which 8,064 tons were produced and shipped to Germany in 1913, contained from 2.8-3.25 per cent. of cobalt. This formed a by-product easily saved in electrolytic refining and has been one of the chief sources of German cobalt in recent years.[1]

Cobalt and nickel oxides in small quantities (less than one per cent.) associated with chromite ores are found in Sekukuneland and in the neighbourhood of Selukiva (Rhodesia).

India

Cobalt ores[2] in small quantities were found in some of the mines of Rajputana, and were used for colouring glass bangles. Ores of this metal also occur in Tenasserim. Both cobalt and nickel are present in small quantities in the pyrrhotite from the Khetri mines, and traces of nickel sometimes occur in iron ores from Bhangarh.

Linnæite has recently been identified among some copper ores from Sikkim.

United States

Although there are no extensive deposits of cobalt in the United States, reports show that small quantities of cobalt oxide have been produced annually since 1869. Most of this was recovered in the refining of the copper-nickel ores of Sudbury, but at present practically all the cobalt is slagged in the converter, so that very little reaches the refinery. There has also been a small amount of cobalt oxide recovered from the lead-copper ores of Missouri, but with the exception of the years 1903 and 1908, the amount obtained has been small. In the years mentioned 120,000 and 100,000 pounds of oxide respectively were produced. Since the discovery of the cobalt deposits at Cobalt, Canada, cobalt ores have been shipped to the United States for treatment. Also the unrefined cobalt and nickel oxides produced at the smelter of the Canadian Copper Company[3] between 1905 and 1913, were shipped to the

[1] Min. Sci. Press, Vol. CVIII, 1914, p. 322; Mineral Resources of United States, U.S. Geol. Sur., Part I, 1913, p. 339.

[2] Phillips, Ore Deposits, 1884, p. 436.

[3] The production of the Canadian Copper Co. is given under the Metallurgy of Cobalt.

United States to be separated and purified. Previous to 1900, the Mine la Motte Company shipped ores to Swansea, but about this time a plant was erected at the mine to recover the cobalt oxide. This plant produced 120,000 pounds in 1903, but was closed shortly afterwards. In 1906 the North American Lead Company erected a refinery at Fredericktown, Missouri, to recover cobalt oxide from Missouri ores. This plant was operated during 1907, 1908, and 1909, but was closed in 1910. The reconstruction of this refinery was commenced in 1916 by the Missouri Cobalt Company, and during 1918 a quantity of cobalt oxide was produced. The Missouri Cobalt Company has erected a mill with a daily capacity of 300 tons.

In 1903 cobalt and nickel ore associated with fluorspar was said to have been discovered near Marion, Kentucky.

In 1905 one or two small shipments of cobalt ore from deposits in Grant county, Oregon, were made to France. These deposits are described as occupying fissures in a dark-greenish, partly altered, diabase-porphyry. The ore bodies appear to be more or less lenticular in shape, and vary from a few inches to several feet in width. The principal minerals are chalcopyrite, smaltite, arsenopyrite, pyrite, pyrrhotite, malachite, and bornite with a quartz and calcite gangue. The chief metals present were gold, cobalt, and copper. From a sample of the ore carrying smaltite and chalcopyrite the former mineral was found to have the composition given below, No. 1. This smaltite has a rather unusual appearance, resembling somewhat acicular or fine columnar stibnite. In composition it is close to that from Gunnison county, Colorado, an analysis of which is given by Dana, No. 2 below. The Standard Consolidated Mines Company, Oregon, worked during 1905 a few veins of cobalt ore carrying gold and silver. An analysis of a picked specimen of the ore follows, No. 3.

—	No. 1 [1]	No. 2	No. 3 [2]
Cobalt	14.88	11.59	9.91
Nickel	1.12	trace	0.57
Arsenic	64.06	63.82	42.66
Sulphur	0.57	1.55	.....
Iron	11.14	15.99	14.93
Insoluble	2.22	.....	.....
Calcium carbonate	6.34	.....	6.8
Silver	.....	.....	5.2 oz.
Gold	.....	.....	1.62 oz.

Smaltite occurs in a calcite vein in granite at Gothic, Colorado.

Near Blackbird, Lemhi county, Idaho, lenticular bodies of cobalt-nickel ore occur in pre-Cambrian schists and quartzites which are cut by diabase and lamprophyre dikes.

In Los Angeles county, California, cobalt silver ores are found in barytic lodes.

[1] Analysis made by A. G. Burrows, Ontario Bureau of Mines.

[2] Mineral Industry, Vol. XIV, 1905, p. 461.

The following table shows the cobalt oxide produced and imported into the United States:

PRODUCTION AND IMPORTS OF COBALT OXIDE.[1]

Year (a)	Production pounds	Imports pounds	Year (a)	Production pounds	Imports pounds
1869	811	.....	1894	6,763	24,020
1870	3,854	.....	1895	6,400	36,155
1871	5,086	.....	1896	12,825	27,189
1872	5,749	.....	1897	19,300	24,771
1873	5,128	1,480	1898	9,640	33,731
1874	4,145	1,404	1899	10,200	46,791
1875	3,441	678	1900	12,270	54,073
1876	5,162	4,440	1901	13,360	71,969
1877	7,328	19,752	1902	20,870	79,984
1878	4,508	2,860	1903	120,000	73,350
1879	4,376	7,531	1904	22,000	42,353
1880	7,251	9,819	1905	(b)	70,048
1881	8,280	21,844	1906	.....	41,084
1882	11,653	17,758	1907	.....	42,794
1883	1,096	13,067	1908	100,000	1,550
1884	2,000	25,963	1909	.....	9,818
1885	8,423	16,162	1910	.....	6,124
1886	8,689	19,366	1911	.....	22,934
1887	5,769	26,882	1912	.....	31,848
1888	7,491	27,446	1913	.....	28,729
1889	12,955	41,455	1914	.....	109,484
1890	6,788	33,338	1915	.....	190,145
1891	7,200	25,483	1916	.....	238,934
1892	7,869	32,833	1917	.....	236,822
1893	8,422	28,164			

[1] Mineral Industry.

(a) Production is stated for calendar years; imports for fiscal years ending June 30 until 1887, and for calendar years subsequently.

(b) Since 1904, with the exception of 1908, no record is given of any cobalt oxide having been produced in the United States. However, since 1905, the total production of mixed cobalt and nickel oxides of the cobalt smelter of the Canadian Copper Co. was shipped to the United States to be refined. The amount recovered from this source may be closely approximated by referring to the production of the Canadian Copper Company. See section entitled "Metallurgy of Cobalt."

The annual consumption of cobalt oxide in the United States amounts to approximately 200,000 pounds, and although the sum of the figures in the table does not equal this amount, except in a few years, this is merely because the cobalt materials imported were classified as some product other than cobalt oxide, e.g. cobalt ore, and zaffer. Zaffer is a term applied to finely-ground roasted cobalt ores or products.

In 1913 the import duty on cobalt oxide was reduced from 25 to 10 cents per pound.

Mexico

Cobalt-bearing minerals have been found at several localities in Mexico, but little has been published concerning these occurrences. Near the village of Pihuamo in the state of Jalisco, cobalt minerals occur in veinlets cutting a large vein of magnetite associated with pyrite and pyrrhotite. The chief rock in the vicinity is described as andesite. It is said that a number of tons of ore containing 8 or 9 per cent. of cobalt were mined in this district. The minerals are cobaltite and

small quantities of smaltite and cobalt bloom. The vein matter consists of greenish calcite, and a little barite. Niccolite also appears to be present.

The following Mexican localities are also reported to contain cobalt minerals: Iturbide, in Chihuahua; Guanacevi, in Durango; Cosala, in Sinaloa; at the Mirador mine in Jalisco. Small shipments of ore containing 30 per cent. of cobalt and 7 per cent. of nickel were made from the Esmeralda and Pihuano mines in Jalisco. A pink cobaltiferous variety of smithsonite occurs at Boleo, Lower California. An article dealing with the cobalt deposits in Jalisco has been published by Navarro, Mem. y Rev. Soc. Cientif., Antonio Alzate, vol. 25, 1907, pp. 51-57.

Peru

Nickel and cobalt minerals are reported to occur in the Department of Cuzco.

Chile

Nickel and cobalt minerals are found associated with the ores of silver at several places in Chile. Among these are Mina Blanca de San Juan, Department of Freivna, Province of Atacama; Minillas, Cambillos Brutre, in the Province of Coquimbo; and Tajon del Yeso, in the Province of Santiago. The ores of the Colorado mine of Chanaicillo are nickel-bearing. Veins of nickel ore are found also at San Pedro, near Flamenco, a small port south of Chanaial.

During the latter part of 1901 shipments of cobalt ores were made from Caldera to the United Kingdom, and it was anticipated then that the returns would show sufficient profit to render the re-opening of the mines advisable.

The San Juan group of mines, lying north of the Port of Peña Blanca are located on well formed lodes varying from one to six feet in width. The ore consists of oxide, arsenate, and sulpharsenide of cobalt with an average content of about 4 per cent. of cobalt. The workings reached a depth of 120 to 200 feet.

Cobalt mines[1] were operated in the Provinces of Atacama, Coquimbo, and Aconcagua. The production in 1903 was 284 metric tons of 7.15 per cent. ore. The largest producer was the Rosa Amelia mine, situated in the Department of Freivna, Atacama, this mine in 1903 producing 133 tons of ore. In the Goyenechea mine, in the Department of Chanaial, an argentiferous cobalt ore was mined carrying 8 per cent. of cobalt.

Mining of cobalt glance and erythrite was also carried on at Tambillos and Huasco.

The quantity of cobalt ores mined in Chile between 1844 and 1905 was 6,384 tons.

Argentina

A cobalt deposit was discovered in 1904 at Valla Hermoso, Vinchina, Provincia de la Rioja, Argentina, and was worked on a small scale.[2] The ore occurs on the western slope of the Cerro de Famantina, a spur of the Andes, in a talcose schist, usually near its contact with an acid, igneous rock. A number of veins appear at the surface, but only one has been exploited. The ore body varies in width from 0.9 m. to 1.3 m., with an average of about 1.1 m. The ore consists of cobaltite and

[1] Mineral Industry, Vol. XIII, 1904, p. 338.
[2] Mineral Industry, Vol. XIII, 1904, p. 336.

arsenopyrite in a gangue of quartz. This was hand-cobbed into first and second class ores. The first class assayed 6.0 to 7.0 per cent., and the second class, 3.0 to 4.5 per cent. cobalt. The first class contained 0.75 to 1.0 oz of gold and 5 to 10 oz. of silver per ton. About 300 tons were produced, of which 150 were hand-cobbed, and of this only a few tons were first class ore. The distance of this property from Monozasta, which is the nearest railway station on the F. C. A. Del Norte line, is 120 miles. All the ore that was concentrated was shipped to England.

Great Britain

For many years small supplies of cobalt ore were obtained from the mines at Moel Hiraddug, near Rhyl; Cornwall; in Flintshire, and Cumberland. However, no production is recorded since 1890.

From 1860 to 1890 there were produced 1,242 tons of cobalt and nickel ore valued at $36,710.

Spain

Mining of cobalt ores was carried on in Spain between 1871 and 1897 in the Valley of Gistain, Huesca, near the French frontier. At Guadalcanal, in Andalusia, veins containing ores of silver, cobalt, and sometimes copper, in a calcite gangue, were at one time important. However, only small quantities were produced, as may be seen from the following table:

PRODUCTION OF COBALT ORES IN SPAIN.

Year	Cobalt Ore		Year	Cobalt Ore	
	tons	value		tons	value
		$			$
1871	4	.....	1887	436	13,914
1872	40	.....	1888	68	5,476
1873	4	.....	1889	141	4,876
1874	82	.....	1890	111	4,368
1875	89	.....	1891	60	1,804
1876	115	.....	1892	24	72
1877	433	.....	1893	18	194
1878	100	.....	1894	52	624
1879	110	.....	1895	7	84
1880	129	.....	1896	18	1,800
1881	102	13,720	1897	13	3,400
1882	40	5,234	1898	.....	.....
1883	19.4	2,486	1899	.....	.....
1884	.....	.....	1900	.....	.....
1885	.....	.....	1901	.....	.....
1886	132	17,200			

Russia

A deposit of cobalt ore, free from nickel, occurs at Dachkessan, Government of Elizabethpol. This deposit is in the form of a dike of diorite impregnated with cobalt minerals associated with iron and copper pyrites. The workings are now abandoned.

China

Very little is known of any cobalt deposits in China. Bowler[1] states that cobalt ore is found at the base of a range of sandstone hills near the town of Tsangscheng, the geological formation being probably Upper Cambrian. These deposits are now either exhausted or very little worked.

Further information about the treatment of these ores will be found under the "Metallurgy of Cobalt."

Ontario, Canada[2]

Situation and Discovery

The ore bodies at Cobalt, which carry silver, cobalt, nickel, and arsenic, were discovered in 1903 during the building of the Timiskaming and Northern Ontario railway. The first of these deposits to be worked lies within half a mile of Cobalt station, which is about 330 miles north of Toronto. One of the oldest known ore bodies in North America, the argentiferous galena on the east side of Lake Timiskaming, is distant only eight miles from Cobalt station. This galena deposit, known as the Wright mine, was apparently discovered by voyageurs over 150 years ago.

It may be added that the building of the Canadian Pacific railway exposed the Sudbury nickel deposits 90 miles southwest of Cobalt. It can thus be said that each of the two railways in this part of Ontario, brought to light an important mineral field.

The Sudbury deposits have received a great deal of attention from geologists of this and other continents. One group, among whom may be mentioned Barlow,[3] Coleman,[4] and Vogt, regard them as due to magmatic segregation from an original igneous magma, without further concentration. Another group, among whom are Dickson,[5] Beck,[6] and Knight,[7] contend that these deposits are the result of aqueous igneous action, and that the sulphides were deposited after the accompanying rocks were formed.

Before proceeding to a consideration of the cobalt veins, a table showing the age relations of the rocks at Cobalt is given below.

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[1] Bowler, Chinese Treatment of Cobalt Ores. Chemical News, Vol. LVIII, 1888, p. 100.

[2] Miller, Willet G., The Cobalt-Nickel Arsenides and Silver Deposits of Timiskaming, Ontario. Reports of Bureau of Mines, Ontario: Vol. XIV, Pt. II, first edition, 1905; second edition, 1906; third edition, 1908; fourth edition, Vol. XIX, Pt. II, 1913. The larger part of the description of the deposits at Cobalt is taken from Dr. Miller's reports.

[3] Barlow, Nickel and Copper Deposits of the Sudbury Mining District. Geol. Survey of Can., 1901, Pt. H.

[4] Coleman, The Sudbury Nickel Region, Ontario Bureau of Mines, Vol. XIV, 1905, Pt. III; The Nickel Industry, with Special Reference to the Sudbury Region, Ontario, Department of Mines, Ottawa, 1913.

[5] Dickson, The Ore Deposits of Sudbury, Ontario. Am. Inst. Min. Eng. Trans., Vol. XXXIV, 1904, pp. 3-67.

[6] Beck, The Nature of Ore Deposits, p. 41.

[7] Knight, Origin of Sudbury Nickel-Copper Deposits. Eng. and Min. Jour., Vol. CI, 1916, p. 811; also Report Royal Ontario Nickel Commission, 1917.

Age Relations of Rocks of Cobalt and Adjacent Areas [1]

PALEOZOIC

Silurian

Niagara

(*Great unconformity*)

EOZOIC OR PRE-CAMBRIAN

Later Dikes

Nipissing Diabase

(*Intrusive contact.*)

Cobalt Series

(*Unconformity*)

Lorrain Granite

(*Intrusive contact.*)

Lamprophyre Dikes

(*Intrusive contact.*)

Timiskaming Series

(*Unconformity*)

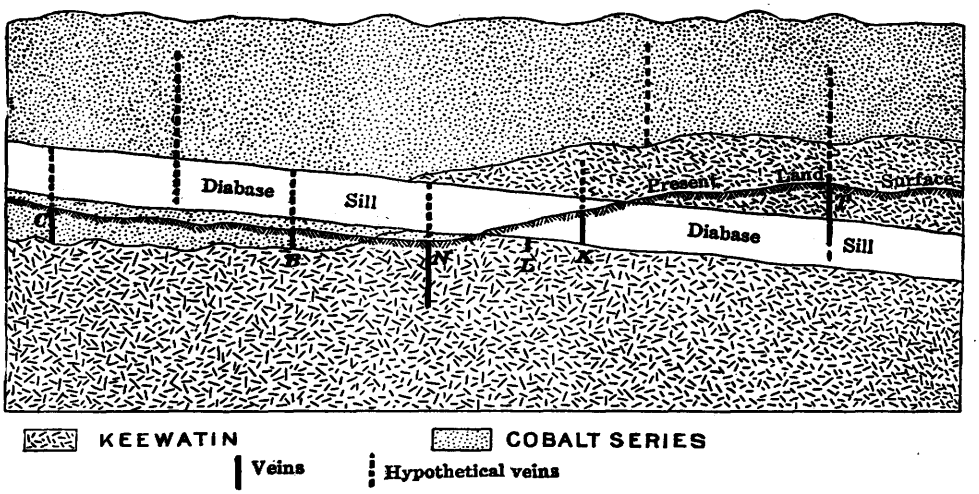
Keewatin Complex

Character and Origin of Cobalt Veins

The deposits at Cobalt occupy narrow, practically vertical fissures, and joint-planes in the metamorphosed Cobalt series. A few productive veins of similar form have been found in the intrusive Nipissing diabase. Others occur in the Keewatin, which is the oldest series of the area, and which consists of basic volcanic rocks. The most productive veins in the Keewatin have been No. 26 on the Nipissing and the vein system on the Timiskaming-Beaver. The former vein lies close to the western edge of the diabase sill. Before erosion of the sill took place, vein No. 26 lay beneath the sill or in its foot-wall. The Timiskaming-Beaver veins, on the other hand, lie in the upper or hanging wall of the sill. There are veins which run from the conglomerate and other fragmental rocks of the Cobalt series into the underlying Keewatin; and there are veins, e.g. the Nova Scotia and Timiskaming veins, which run downward from the Keewatin into the underlying, intrusive Nipissing diabase. A vein on the Cobalt Central passes from the surface downward through the Nipissing diabase into the Cobalt series, which here forms the foot-wall of the diabase sill. Moreover, "blind" veins, or veins that do not outcrop at the surface, have been worked on several properties. One of the most interesting of these occurs beneath Peterson lake. This vein is in the Keewatin, which is here overlain by the Nipissing diabase sill. The vein runs up to the bottom of the sill, but not into it. The figure on page 24 shows the relationship of the rocks and the type veins described.

[1] Miller, W. G., The Cobalt-Nickel Arsenides and Silver Deposits of Timiskaming, Ontario, fourth edition, Ont. Bur. Min., Vol. XIX, 1913, Pt. II, p. 48.

The veins of most of the producing mines lay below the diabase sill before it was eroded, e.g., those on the Coniagas, Nipissing, Hudson Bay, Trethewey, Buffalo, Mining Corporation, Crown Reserve, Drummond, Lawson at Kerr lake, LaRose and McKinley-Darragh at Cobalt lake. The King Edward, Silver Cliff, and some of the O'Brien veins lie within the sill. In the outlying camps good examples of veins occurring in the sill are the Wettlaufer of South Lorrain, and Miller-Lake O'Brien of Gowganda.



Generalized vertical section through the productive part of the Cobalt area.

The section shows the relations of the Nipissing diabase sill to the Keewatin and the Cobalt series, and to the veins. The eroded surface is restored in the section. The sill is less regular than the illustration shows it to be.

B and C represent a large number of veins that are in the fragmental rocks, Cobalt series, in the lower or foot-wall of the eroded sill. N represents a type of vein, such as No. 26 on the Nipissing, in the Keewatin below the eroded sill, and L a type such as one under Peterson lake, in the Keewatin foot-wall, but not extending upward into the sill; K, a vein in the sill itself, such as No. 3 on the Kerr Lake property; T, a vein such as that on the Timiskaming or Beaver properties, in the Keewatin hanging wall and extending downward into the sill.

At Diabase mountain the top of the hill is diabase, while the rocks below the diabase are composed of slates and conglomerates lying on Keewatin greenstones, so that certain veins, as on the Penn-Canadian and Bailey, started in the sill and continued downward into the underlying rocks.

At the Timiskaming shaft the upper contact between the Keewatin and the diabase is approximately 575 feet from the surface. Along this contact, both above and below, the Timiskaming and Beaver mines have recovered their richest ores. In order to ascertain the thickness of this diabase sill it was diamond-drilled, and the lower contact between the diabase and the Keewatin formations was found at an approximate depth of 1,670 feet from the surface, showing the sill to have a thickness of about 1,100 feet. After diamond drilling was finished, a shaft was sunk through the sill. Exploration work from this shaft, conducted along the bottom of the sill and in the rocks immediately below, has failed to disclose economic ore bodies up to the autumn of 1918.

The following paragraphs, regarding the origin of the ores at Cobalt, are copies from W. G. Miller's report.[1]

The material in the veins at Cobalt has, in all likelihood, been deposited from highly heated and impure waters which circulated through the cracks and fissures of the crust and probably were associated with—followed—the Nipissing diabase eruption.

The waters are said to be associated or connected with the diabase eruption in the sense that they probably represented the end product of the eruption. In many volcanic regions, hot springs are present long after the rocks have solidified. In the Cobalt area the fissures and joints now occupied by the ores were probably produced by the gradual shrinkage in cooling of the diabase, the ores being deposited by the waters which represented the last stage of vulcanicity.

It is rather difficult to predicate the original source of the metals—silver, cobalt, nickel, arsenic, and others—now found in these veins. They may have come up from a considerable depth with the waters, or they may have been leached out of what are now the folded and disturbed greenstones and other rocks of the Keewatin. Analyses of various rocks of the area have not given a clue to the origin of the ores. However, the widespread occurrence of cobalt veins in the diabase, or in close association with it, shown by discoveries throughout a region three thousand square miles or more in extent, appears to be pretty conclusive proof that the diabase and the ores came from one and the same magma.

As the ore bodies in the vicinity of Cobalt station, and elsewhere in Ontario, may be said to be unique among those known in North America, we have no chance of instituting comparisons on this continent. Some European veins, however, such as those of Annaberg, Joachimsthal and other localities[2] show a similar association of minerals.

These European ores are considered by most authors to be genetically connected with intrusions of granite. At Joachimsthal the veins are said to be cut across by basic dikes, and there is evidence to the effect that at the time of the eruption of the dikes the vein formation had not yet been completed. Since especially nickel and cobalt minerals are characteristically connected with basic rocks, the question arises as to whether the European ores mentioned may not be more closely connected in origin with basic rocks than they are considered to be. There may be deeper seated intrusions of these rocks slightly older than the dikes.

Ores and Minerals

The most important ore in the veins at Cobalt is native silver, associated with which is usually some dyscrasite, argentite, pyrargyrite and other compounds of silver, smaltite, niccolite, and related minerals. Many of the minerals occur mixed in the ores and for this reason some of them have not been clearly identified. Another feature of the minerals, which renders their identification difficult, is the fact that most of them occur in the massive form. Crystals when present are small, being frequently almost microscopic in size. The following minerals have been identified and can be conveniently classed under the headings:

I. Native Elements.—Native silver, native bismuth, graphite.

II. Arsenides.—Niccolite, NiAs; chloanthite, $NiAs_2$; smaltite, $CoAs_2$; and löllingite, $FeAs_2$.[3]

III. Arsenates.—Erythrite, or cobalt bloom $Co_3As_2O_8.8H_2O$; annabergite, or nickel bloom $Ni_3As_2O_8.8H_2O$; scorodite, $FeAsO_4.2H_2O$.

IV. Sulphides.—Argentite, Ag_2S; millerite, NiS; argyropyrite?; stromeyerite? $(Ag,Cu)_2S$; bornite, Cu_5FeS_4; chalcopyrite, $CuFeS_2$; sphalerite, ZnS; galena, PbS; pyrite, FeS_2.

V. Sulpharsenides.—Mispickel, FeAsS; cobaltite, CoAsS.

VI. Sulpharsenites.—Proustite, Ag_3AsS_3; xanthoconite? Ag_3AsS_3.

[1] Miller, W. G., Ont. Bur. Min., Vol. XIX, 1913, Pt. II, p. 8.

[2] See description, page 6.

[3] Ellsworth, A Study of Certain Minerals from Cobalt, Ontario. Ont. Bur. Min., Vol. XXV, 1916, Pt. 1, p. 223.

VII. Antimonides.—Dyscrasite, Ag_6Sb; breithauptite, NiSb.

VIII. Sulphantimonites.—Pyrargyrite, Ag_3SbS_3; stephanite, Ag_5SbS_4; polybasite? Ag_9SbS_6; tetrahedrite, $Cu_8Sb_2S_7$; freibergite? (silver bearing tetrahedrite).

IX. Sulphobismuthites.—Matildite, $AgBiS_2$, emplectite, $CuBiS_2$.

X. Mercury.—Amalgam (?).

XI. Phosphate.—Apatite.

XII. Oxides.—Asbolite; heubachite?; heterogenite?; arsenolite, As_2O_3; roselite? $(Ca,Co,Mg)_3As_2O_8.2H_2O$.

XIII. Veinstones.—Calcite, dolomite, aragonite, quartz, barite, fluorite.[1]

The above table contains a few minerals that have been found in only one or two veins and cannot be considered characteristic. Millerite, for instance, is of rare occurrence, and emplectite has been found only in the Floyd mine, near Sharp lake, in the western part of the Cobalt area. Bornite, chalcopyrite, zinc blende, galena, and pyrite are not characteristic of most of the ore, these minerals occurring more frequently in the wall rock or in non-silver bearing ore of the Keewatin. Apatite in recognizable crystals has been found in the ore of only one mine. Mercury appears to occur in the ore of all the mines that contain high values in silver, but whether it occurs only as amalgam or in other forms has not been determined.

A question-mark has been placed after the names of several minerals in the table which have been reported to occur in the veins, but whose identification has not been made complete by chemical analyses or crystallographic measurements. Gold in small quantity has been found in a number of veins, especially in those in which cobaltite or mispickel are characteristic minerals.

Certain shipments from the Timiskaming mine contained copper in economic quantities.[2]

While we have both native silver and arsenides in abundance, the compounds of arsenic and silver occur only in small quantities. Antimony, which is not abundant, is found in some compounds where we would expect to find arsenic, since the latter is so much more common.

One would also expect to find more compounds of bismuth, since this metal occurs in the free state in considerable quantities in some of the deposits. It might also be expected that native arsenic would occur, but so far it has not been found.

Nearly all the chemical groups of minerals found in the celebrated Joachimsthal deposits of Bohemia are present in the Timiskaming ores. The most important exception is uraninite or pitchblende, which came into prominence a few years ago as the chief source of the element radium.

Order of Deposition of Minerals

The following table shows, in descending order from the youngest to the oldest, the general succession in order of deposition of the principal minerals of the Cobalt area proper. There appear to be, however, minor exceptions to this order.

[1] Barite and fluorite have not been found in the veins at Cobalt proper, but they occur with silver-cobalt ores in one or two veins near Elk lake, and in Langmuir township in the southeast part of the Porcupine area. Small veins of barite have also been found in the Nipissing-diabase in Leonard and Lawson townships, in the Gowganda silver area.

[2] Miller, W. G., Ont. Bur. Min., Vol. XIX, 1913, Pt. II, p. 10.

III. Decomposition products, e.g. erythrite or cobalt bloom, annabergite or nickel bloom, and asbolite.

II. Rich silver ores and calcite.

I. Smaltite, niccolite, and dolomite or pink spar.

After the minerals of group I were deposited the veins were subjected to a slight movement. In the cracks thus formed the minerals of group II were deposited. A few veins that escaped the disturbance do not contain silver in economic quantity.

This order of deposition appears to be the same as that of the minerals in the Annaberg deposits of Germany and those of Joachimsthal, Austria.[1]

Messrs. Campbell and Knight[2] subjected specimens of the cobalt-silver ores of Cobalt to examination, using methods employed in metallography. While their results confirm, in a general way, Miller's observations on hand specimens, and on blocks of ore, they have worked out the order of deposition of the minerals in greater detail. They state that, although all of the structures met with in this examination cannot be satisfactorily explained, they point to the following order of deposition for the principal constituents. First came the smaltite, closely followed by the niccolite; other minerals in small amount came down at this time. Then, after a period of slight movement in which the first minerals were more or less fractured, calcite was deposited as a ground-mass. Later came argentite, which was followed by native silver and native bismuth. Lastly came the surface decomposition products, erythrite and annabergite.

Arranged in order, the succession is, then, as follows:

Smaltite, niccolite, period of movement and fracturing, calcite, argentite, native silver, native bismuth, period of decomposition, and finally erythrite and annabergite.

At Annaberg, bismuth ore is thought to have been deposited with the cobalt-nickel minerals and not with the rich silver ore. Moreover, at the time Messrs. Campbell and Knight made their examination of the ores from Cobalt it was not known that two carbonates occur in the gangue, viz., calcite (white) and dolomite (pink). The latter has been found to belong to an older generation than the former.

Any statement as to the form in which the native silver came in solution into the veins must be merely hypothetical. Silver carbonate, Ag_2CO_3, like calcium carbonate, $CaCO_3$, is soluble in excess of carbon dioxide, CO_2. Hence when the calcite, $CaCO_3$, of the cobalt-silver veins was being carried in solution, it does not seem improbable that silver carbonate may have been in solution at or about the same time.

Palmer and Bastin[3] discuss metallic minerals as precipitants of silver and gold, and their experiments show that certain sulphides and arsenides of copper and

[1] Beck, The Nature of Ore Deposits, Weed's translation, pp. 285-289.

[2] Campbell and Knight, Microscopic Examination of the Cobalt-Nickel Arsenides and Silver Deposits of Timiskaming. Economic Geology, Vol. I, 1906, pp. 767-776. The Paragenesis of the Cobalt-Nickel Arsenides and Silver Deposits of Timiskaming. Eng. and Min. Jour., Vol. LXXXI, 1906, p. 1089.

[3] Palmer and Bastin, Metallic Minerals as Precipitants of Silver and Gold. Economic Geology, Vol. VIII, 1913, p. 140.

nickel, e.g. chalcocite and niccolite, precipitate metallic silver very efficiently from dilute aqueous solutions of silver sulphate. However, the more common sulphides, such as pyrite, galena, and sphalerite were relatively inactive as precipitants of silver from aqueous sulphate solutions.

Argentite, proustite, and native silver in hair-like form, appear to be of secondary origin. These minerals are found in vugs in the lower workings of the mines where the ore has become leaner, or below the productive zone in the veins.

The silver-bearing solutions working downward beneath the sill, in the fractured rocks, lost their silver content by precipitation on coming in contact with the cobalt-nickel minerals before a great depth was reached. Hence it is not surprising to find that rich silver ore does not extend to as great a depth beneath the sill as do the cobalt-nickel ores. Practically all the samples of native silver, excepting those that show a crystalline form or occur in veinlets, contain mercury.

Cobalt minerals are also found in areas lying at some distance from the town of Cobalt. The most important deposits occur in South Lorrain, Casey township, and Gowganda. The Lake Superior silver deposits also contain small amounts of cobalt.

Other minor occurrences of nickel-cobalt ores in Canada are given in the "Annual Report of the Geological Survey of Canada," vol. XIV, 1901, pt. H, to 1917.

The following table shows the production of the Cobalt district from 1904 to 1917.

Total Production of Cobalt Mines 1904-1917[1]

Year	Nickel		Cobalt		Arsenic		Silver		Total value
	tons	value	tons	value	tons	value	ounces	value	
		$		$		$		$	$
1904..	14	3,467	16	19,960	72	903	206,875	111,887	136,217
1905..	75	10,000	118	100,000	549	2,693	2,451,356	1,360,503	1,473,196
1906..	160	.....	321	80,704	1,440	15,858	5,401,766	3,677,551	3,764,113
1907..	370	1,174	739	104,426	2,958	40,104	10,023,311	6,155,391	6,301,095
1908..	612	.....	1,224	111,118	3,672	40,373	19,437,875	9,133,378	9,284,869
1909..	766	.....	1,533	94,965	4,294	61,039	25,897,825	12,461,576	12,617,580
1910..	504	.....	1,098	54,699	4,897	70,709	30,645,181	15,478,047	15,603,455
1911..	392	.....	852	170,890	3,806	74,609	31,507,791	15,953,847	16,199,346
1912..	429	14,220	964	314,381	4,166	80,546	30,243,859	17,408,935	17,818,082
1913..	377	13,326	821	420,386	3,663	64,146	29,681,975	16,553,981	17,051,839
1914..	(a) 90	28,978	(a) 351	590,406	2,030	116,624	25,162,841	12,765,461	13,501,469
1915..	(b) 35	28,353	(b) 206	383,261	2,490	148,379	24,746,534	12,135,816	12,695,809
1916..	(b) 79	59,380	(b) 400	805,014	2,160	200,103	19,915,090	12,643,175	13,707,672
1917..	(b)155	125,071	(b) 337	1,138,190	2,592	608,483	19,401,893	16,121,013	18,028,597
Total.	4,058	283,969	8,950	4,388,400	38,789	1,524,569	274,724,172	151,950,561	158,176,339

[1] Ont. Bur. Min., Vol. XXVII, 1918, p. 16.

(a) Metallic contents of nickel and cobalt oxides respectively.

(b) Metals and metallic contents of all nickel and cobalt compounds.

In the following table a record of silver shipments since 1904 is given.

Silver Production, Cobalt Mines, 1904 to 1917[1]

Year	No. of producing mines	Shipments and Silver Contents								
		Ore		Av. per ton	Concentrates		Av. per ton	Bullion	Total	
		tons	ounces	ounces	tons	ounces	ounces	ounces	ounces	value
										$
1904	4	158	206,875	1,309	.....	.....	.....	.....	206,875	111,887
1905	16	2,144	2,451,356	1,143	.....	.....	.....	.....	2,451,356	1,360,503
1906	17	5,335	5,401,766	1,013	.....	.....	.....	.....	5,401,766	3,667,551
1907	28	14,788	10,023,311	677	.....	.....	.....	.....	10,023,311	6,155,391
1908	30	24,487	18,022,480	736	1,137	1,415,395	1,244	.....	19,437,875	9,133,378
1909	31	27,729	22,436,355	809	2,948	3,461,470	1,174	.....	25,897,825	12,461,576
1910	41	27,437	22,581,714	821	6,845	7,082,834	1,030	980,633	30,645,181	15,478,047
1911	34	17,278	20,318,626	1,176	9,375	8,056,189	858	3,132,976	31 507,791	15,953,847
1912	30	10,719	15,395,504	1,436	11,214	9,768,228	871	5,080,127	30,243,859	17,408,935
1913	35	9,861	13,668,079	1,386	11,016	8,489,321	770	7,524,575	29,681,975	16,553,981
1914	32	4,302	6,504,753	1,511	12,152	8,915,958	733	9,742,130	25,162,841	12,765,461
1915	24	2,865	6,758,286	2,359	11,996	10,001,548	834	7,986,700	24,746,534	12,135,816
1916	28	2,177	4,672,500	2,146	8,561	7,598,011	887	7,644,579	19,915,090	12,643,175
1917	28	2,288	3,271,353	1,429	13,720	6,445,243	469	8,053,318	19,401,893	16,121,013
To'l.	....	151,568	151,712,958	1,001	88,964	71,234,197	801	50,145,038	274,724,172	151,950,561

As the camp has developed, the average grade of ore shipped has gradually lowered in value. The introduction of concentration plants in 1908 has tended to keep the shipments up to a high standard, but there is a growing tendency to treat the ore at the mines and recover the silver as bullion for shipment. The average concentration ratio of the different mills during 1914 was 47-1. Further information on the treatment of the ores at Cobalt will be found under the heading "Development of the Metallurgy of the Silver-Cobalt Ores of Ontario."

In the purchasing of the cobalt ores payment is made for the silver and in some cases for the cobalt, the amount paid for the silver varying with the grade of the ore. The different schedules that have been adopted are given in the descriptions of the Coniagas Reduction Co. and the Deloro Mining and Reduction Co. under the "Metallurgy of Cobalt."

In 1905 the price offered for cobalt in ores containing about 6 per cent. cobalt, fell from 65 to 35 cents a pound and at the same time the allowance which had been made previously for the nickel and arsenic, viz., 12 and 0.5 cents a pound respectively was cancelled.

Between 1905 and 1909, ten cents per pound was allowed for the cobalt in the ores if they contained more than 6 per cent., except where the nickel was greater than the cobalt.

Between 1909 and 1914 very little was realized for the cobalt except in the case of high grade ores.

Since 1914, some of the companies have been paying for cobalt, but in some cases not for silver in the same ore. The amount paid for cobalt varies with the

[1] Ont. Bur. Min., Vol. XXVII, 1918, p. 16.

grade of the ore and is about as follows: five cents a pound for the cobalt in ores between 6 and 8 per cent., ten cents a pound in ores between 8 and 10 per cent., and fifteen cents a pound in ores over 10 per cent. cobalt.

Most of the cobalt ores that are purchased for the recovery of the cobalt are treated by Canadian smelters. However, a quantity of ore is imported by smelters in the United States, the chief importer being the American Smelting and Refining Company. The Pennsylvania Smelting Co., Carnegie, Pa.; the Balbach Smelting and Refining Co., Newark, N.J.; and the United States Metals Refining Co., Chrome, N.J., also import small quantities of cobalt ores.

Shipments of cobalt-nickel residues from the Nipissing high-grade mill containing 9 per cent. cobalt and 4.5 per cent. nickel have been made by the Nipissing Mining Co. to H. Wiggin and Co., Birmingham, England.

A few shipments containing 4,500 ounces of silver per ton were made previous to 1913 to the Government smelter, Saxony, Germany.

United States smelters imported during 1915, 7,310 tons of ore from the Cobalt district containing 3,580,843 fine ounces of silver, as against 7,206 tons containing 3,966,301 fine ounces in 1914.

In 1916 shipments of ore and concentrates from Cobalt to refineries in the United States comprised 364 tons of ore carrying 408,014 ounces, and 3,700.35 tons of concentrates carrying 1,629,841 ounces—a total of 2,037,855 ounces of silver. In 1917 to refineries in the United States there were consignments from Cobalt amounting to 6,307 tons, from which 2,914,267 fine ounces of silver were recovered. These shipments were on the whole of considerably lower grade than those to the home refineries, averaging only 462 ounces of silver to the ton, as against 810 ounces. Much the larger quantity treated by U. S. plants was at the works of the American Smelting & Refining Company, Denver, Col., and Perth Amboy, N.J. Of the total quantity of silver contained in the product of the Cobalt mines in 1917, namely 19,401,893 ounces, 14,504,681 ounces were refined at the mines in Cobalt or in Ontario works, being about 75 per cent. of the whole.

Additional References

Occurrence and Utilization of Cobalt Ores, Bulletin Imperial Institute, London, Vol. XIV, 1916, pp. 417-437.

Wilson, M. E., Origin of Cobalt Series. Journal of Geology, Vol. XXI, 1913, pp. 121-141.

Power, F. Danvers, The Mineral Resources of New Caledonia, Institution Mining and Metallurgy, Trans., Vol. VIII, 1899-1900, pp. 426-472. This article contains an extensive bibliography.

CHAPTER II

THE METALLURGY OF COBALT

Very little is known about the details of the metallurgy of cobalt in comparison with our knowledge of the other metals, except by those directly connected with the industry. It is not a new subject, since the treatment of cobalt ores was practised for several hundred years in Europe, where the output of the world's supply of cobalt was controlled until the discovery of the Canadian cobalt deposits in 1903. New South Wales, Norway, New Caledonia, Germany, Chile, and Hungary were the chief producers of cobalt ores, while the largest refineries were located in Germany and England. Since 1902 there has been very little cobalt ore mined outside of Canada, except in the United States during 1903 and 1908, when there was a production of 60 and 100 tons respectively of cobalt oxide from the ores of Missouri. Until 1913, the world's annual production of cobalt oxide amounted to approximately 250 tons, but within recent years the production has increased until in 1916 it amounted to 400 tons. Within the last few years the quantity of cobalt metal produced has increased from practically nothing in 1913, to 165 tons in 1916, and 158 tons in 1917.

The price of cobalt oxide (70 per cent. cobalt) fluctuated little previous to 1907, the oxide selling at prices varying from $1.60 to $2.00 a pound. In 1907 the price rose to $2.50, but in 1908 it dropped to $1.40. Since 1908 the price has gradually declined, the average for 1915 being 90 cents a pound. Owing to the increased present demand the price has risen to $1.50 (1917). The value of metallic cobalt is given (1917) as $2.00 to $2.25 a pound.

In reviewing the metallurgy of cobalt, two noticeable changes are evident; first, previous to the discovery of the large cobalt deposits in Canada, practically all compounds of cobalt were produced in Europe; and second, in the European refineries ores were treated for the cobalt content alone, while from the ores of Canada, metallic silver, cobalt, nickel, and arsenic oxide are recovered. The associated metals are often a source of revenue for the smelters.

Since most of the cobalt compounds produced in Europe were used in the ceramic industries, and as the requirements of these industries at the time were not such as to demand a high-grade cobalt oxide, it is reasonable to conclude that the processes used in Europe did not produce a high-grade cobalt oxide. However, the demand of the ceramic industries at the present time is for a high-grade oxide, and this is supplied by the Canadian smelters at practically one-half the price that the low and medium cobalt compounds or smalts were sold at in Europe ten years ago.

The elements arsenic, sulphur, copper, iron, and nickel, which are usually associated with cobalt ores, are common to the ores of Europe and Canada, while those from New Caledonia, though free from sulphur and arsenic, contain a large percentage of manganese. However, arsenic and sulphur cannot be altogether considered as impurities in cobalt ores, since the presence of either element enables the ores to be reduced in blast-furnaces to produce a speiss or matte.

The metal cobalt or the oxide has never been recovered in a pure form from ores by dry methods alone, because of its association with metals possessing very similar properties; hence we find chemical or wet methods employed to separate the associated elements. In any preliminary treatment or smelting of cobalt ores the behaviour of cobalt, nickel, and iron toward arsenic, sulphur, and oxygen is important. Of the three metals nickel, cobalt, and iron, nickel has the greatest affinity for arsenic, then cobalt, and lastly iron; while in the case of oxygen their affinities are reversed. As regards the behaviour of these metals towards sulphur, there is little difference, but nickel and cobalt seem to combine preferably with sulphur. Also, because the affinities of the three metals lie very close together, it is not possible to eliminate iron as oxide or silicate from a mixture of iron, nickel and cobalt by having just sufficient arsenic present to form arsenides of nickel and cobalt, nor is it possible to remove iron from the other two in a speiss or matte by regulating the extent of oxidation. In both cases some iron, nickel, and cobalt will be found together.

Cobalt ores are commonly smelted in blast furnaces to remove gangue minerals and other impurities, e.g., iron, sulphur, and arsenic. In the blast furnace smelting, a speiss[1] or a matte[2] and a slag are formed. In blast-furnace smelting of cobalt ores a certain amount of iron is always allowed to enter the speiss or matte, because when iron is present very little cobalt will be found in the slag, while a certain amount of iron is necessary to assist in the subsequent precipitation of arsenic.

The following classification illustrates the metallurgical treatment of cobalt ores. Although the production of smalt[3] directly from ore is not practised at the present time, this method is given in the classification since it was used formerly in Europe.

1. The Extraction of Cobalt Oxide.
    - A. Decomposition of arsenical and sulphide ores;
        1. By smelting in blast-furnaces producing,
            - (a) A speiss containing chiefly cobalt and nickel arsenides.
            - (b) A matte containing chiefly cobalt and nickel sulphides.
        2. By other processes.
            - (a) Wet processes.
            - (b) Dry processes.
    - B. Decomposition of oxidized ores;
        1. Wet processes.
        2. Dry processes.
    - C. Decomposition of Silicates.
2. The Production of Smalt.

I.—The Extraction of Cobalt Oxide

A. 1. Decomposition of Arsenical and Sulphide Ores in Blast Furnaces

All the cobalt ores smelted in Canada are arsenical ores containing silver, while those treated in Missouri are sulphide ores practically free from silver.

[1] Speiss is a metallurgical product in which the metals are present as arsenides.
[2] Matte is a metallurgical product in which the metals are present as sulphides.
[3] Smalt is a silicate of cobalt, used in the pottery industries.

From the arsenical silver ores, metallic silver and argentiferous speiss containing cobalt, nickel, iron and copper as arsenides are produced, while from the sulphide ores a matte containing the metals as sulphides is formed. If more than sufficient arsenic or sulphur is present than is necessary to combine with the cobalt, nickel, copper and part of the iron, any excess is removed by a previous roasting, or a number of different ores may be mixed to get the proper quantity of arsenic for the blast furnace charge. The usual blast furnace charge contains approximately 16 per cent. arsenic.

In the blast-furnace smelting of the silver cobalt ores of Canada, the products of smelting are metallic silver, approximately 850 fine, which represents about 85 per cent. extraction of the silver content of the ore; an argentiferous speiss containing arsenides of cobalt, nickel, copper, and part of the iron; a slag containing the lime, magnesia and part of the iron as silicates; and flue dust which contains fine particles of ore, crude arsenious oxide, and coke dust. In smelting sulphide ores, free from silver, matte, slag, and flue dust are produced. The speiss or matte then undergoes further treatment for the recovery of the cobalt, nickel, and silver.

The process of treating speiss or matte consists of grinding and roasting, followed by treatment with sulphuric acid and chemicals to convert the cobalt and nickel into soluble compounds, leaving most of the impurities in an insoluble state. However, small quantities of iron, nickel, copper, arsenic, and sulphur dissolve with the cobalt, and these must be removed, since they are objectionable in cobalt oxide to be used in the ceramic industries. The maximum limits of the above impurities in high-grade cobalt oxide are, approximately, iron 0.5 per cent., nickel 1.0 per cent., copper, arsenic, and sulphur 0.1 per cent each.

Treatment of ground unroasted speiss with acids and chemicals is also practised.

The smelting of arsenical ores of cobalt is conducted in blast-furnaces at present in Canada, chiefly at the smelters of the Deloro Smelting and Refining Company and the Coniagas Reduction Company. The blast-furnace smelting of sulphide ores is used by the Missouri Cobalt Company, Fredericktown, Missouri, which was formerly the North America Lead Company. Sulphide ores were also treated at one time at the Scopello works, Piedmont, Italy; at the Isabella works, in Silesia; at Schneeberg in Saxony; and at the Christofle works, at St. Denis, France.

A. 2 (a). Decomposition of Arsenical and Sulphide Ores by Wet Processes

No methods have ever been successfully practised to treat arsenical and sulphide cobalt ores directly by wet methods alone, the reason being that it is more profitable to concentrate this class of ores by producing a speiss or matte. A few attempts have been made to treat arsenical ores without a preliminary smelting in blast-furnaces, by first roasting the ore, which operation was followed by treatment with acids. Owing to the difficulties in operating such a process, and also to the high consumption of acids and chemicals, only small quantities of ore containing small amounts of soluble gangue minerals could be treated. The reagents tried were hydrochloric, sulphuric, or nitric acids, with or without the addition of chemicals. Solutions of ferrous chloride were also frequently tried.

A. 2 (b). Decomposition of Arsenical and Sulphide Ores by Dry Processes

An attempt was made in Germany to treat low-grade cobalt ores by roasting with the addition of salt and iron pyrites, the cobalt being converted into soluble cobalt chloride, while practically all the iron remained as insoluble oxide. There is no record of such a process ever having been operated on a commercial scale.

B. (1). Decomposition of Oxidized Ores by Wet Processes

The treatment of the ores from New Caledonia comes under this heading. Decomposition of the ore was effected by treatment with a hot solution of ferrous sulphate. For a detailed description of this method see the Herrenschmidt processes.

B. (2). Decomposition of Oxidized Ores by Dry Processes

An attempt was made during 1893 and 1894 to concentrate the oxidized ores of New Caledonia by producing a matte. As these ores did not contain sufficient sulphur to form a matte, this latter element must have been added, probably as pyrites.

C. Decomposition of Silicates

Silicates of cobalt cannot be smelted with arsenical or sulphide ores to form a speiss or matte, because cobalt silicate is not decomposed by iron arsenide or iron sulphide to form cobalt arsenide or sulphide. Nickel silicate, however, does react with iron pyrites to give nickel sulphide and iron silicate. It is possible, however, under strongly reducing conditions, to reduce some cobalt from the silicate.

The possibility of treating silicates by wet methods will depend altogether on whether or not the cobalt and gangue minerals are decomposable by acids. However, there are no known occurrences of cobalt silicates in nature.

As mentioned above, cobalt ores usually contain arsenic, sulphur, copper, iron, nickel, and manganese. The larger part of the arsenic, sulphur, and iron is removed in the preliminary blast-furnace treatment, but the chief difficulty in producing fairly pure cobalt oxide lies in the removal of the remaining small quantities of these elements. The removal of these impurities will be discussed in the order in which they are usually removed from cobalt-nickel solutions.

Removal of Arsenic from Cobalt-Nickel Ores and Solutions

Arsenic is a common impurity of cobalt ores, and is very objectionable, especially in cobalt metal which is added to other metals to make alloys. When dry or wet methods are employed to convert cobalt and nickel into soluble form, considerable arsenic dissolves with the former metals, and any arsenic in solution must be removed before proceeding with the precipitation of the cobalt and nickel.

The method of removing arsenic depends chiefly on the quantity and form in which it is present. In case of large quantities of arsenic, roasting to convert a greater part of it into volatile arsenious oxide is practised, but it is difficult to roast an ore containing more than 20 per cent. of arsenic to below 7 per cent., because of the formation of arsenates of iron, cobalt, and lime. The addition of carbon reduces any arsenates to arsenites, from which compounds volatile arsenious oxide is evolved on heating. This method, however, is too costly for any extensive use.

In case of roasted products or ores containing small quantities of arsenic in the form of arsenates, chemical methods must be used to remove this impurity.

When cobalt ores are treated in blast furnaces, considerable iron is allowed to enter the speiss or matte, so that the loss of cobalt and nickel in the slag will be low. A part of this iron is dissolved with the cobalt and nickel. Any dissolved iron assists in the removal of arsenic, for when a solution containing nickel, cobalt, iron, and arsenic is neutralized with ground calcium carbonate, the iron and arsenic combine to form ferric arsenate, $FeAsO_4$, a light-brown, flocculent to granular precipitate. Practically all the arsenic can be removed in this way, and if there is not sufficient iron in the solution to form ferric arsenate with all the arsenic, iron in some soluble form is added.

Arsenic may also be removed from speiss by heating the roasted product with sodium carbonate and nitre to form soluble sodium arsenate, the metals forming oxides. This method was practised for some time by the Canadian Copper Company, Copper Cliff, Ontario, in the treatment of the silver-cobalt ores. The leached speiss containing up to 3 per cent. arsenic was shipped to New Jersey to be refined.

Removal of Iron

Any iron not removed as ferric arsenate is precipitated by careful additions of calcium carbonate, the iron precipitating as ferric hydrate. To completely precipitate the iron it is essential that the iron be oxidized.

Removal of Copper

Copper, when present in cobalt-nickel solution in quantities over 0.5 per cent., presents considerable difficulty in its complete removal. Small amounts of copper will be precipitated completely from cobalt-nickel solutions along with the iron by the addition of calcium carbonate. However, when the ratio of the copper to the cobalt and nickel is greater than 1 to 6, it is advisable to remove the copper, either by iron plates or electrolytic methods.

Removal of Manganese

There is practically no manganese in the cobalt ores found at Cobalt, Canada, but practically all the cobalt ores from New Caledonia, previously in large use, carried a high percentage of this metal. In the manipulation of the New Caledonia ores the solutions containing cobalt, nickel, and manganese were treated with sodium sulphide, the cobalt and nickel being precipitated as sulphides, while practically all of the manganese remained in solution.

Separation of Cobalt from Nickel

After the arsenic, iron, copper, and manganese have been removed, the next step is to separate the cobalt and nickel. The commonest method is to precipitate the cobalt first, but it is possible to precipitate it after the nickel.

The separation of cobalt from nickel as practised at the present time is practically the same as it was a number of years ago. When a solution of calcium hypochlorite (bleaching powder) is added to a solution containing cobalt and

nickel, the cobalt is precipitated first as a black hydroxide, $Co(OH)_3$. The precipitation may be carried to a colourless solution[1] without precipitating any appreciable quantities of nickel. If it is desired to obtain pure nickel oxide, the first cobalt hydroxide is removed, and the precipitation of the remaining cobalt is continued until the solution is practically free from it, a quantity of black nickel hydroxide, $Ni(OH)_3$, being precipitated at the same time. This intermediate precipitation produces mixed oxides, which must be retreated to produce pure cobalt and nickel oxides. The nickel in solution is precipitated as nickelous hydroxide or hydrated carbonate by the addition of a solution of lime or sodium carbonate.

When cobalt and nickel are present as sulphates, it is customary to precipitate the cobalt by sodium hypochlorite instead of calcium hypochlorite, since the lime of the calcium hypochlorite reacts with the sulphate radicle to form insoluble calcium sulphate, which is difficult to remove. In case calcium sulphate is present in cobalt oxide, it may be removed by a treatment with a hot solution of sodium carbonate, the sodium carbonate and calcium sulphate reacting to form sodium sulphate and calcium carbonate. The sodium sulphate is removed by water and the calcium carbonate by treatment with dilute hydrochloric acid.

Cobalt may also be precipitated after the nickel. In this case soda is added to the boiling solution which precipitates nickel hydroxide and carbonate with a small amount of cobalt carbonate, while cobalt with a small amount of nickel remains dissolved. Cobalt is finally precipitated by additions of more soda or chloride of lime. The writer is not aware of this method being practised commercially.

Methods Used or Proposed to Treat Cobalt Ores for Cobalt Oxide

In the following pages of this section a brief outline is given of the methods practised successfully at the present time and those formerly employed in Europe. This is followed by a summary of all the processes that have been proposed to treat cobalt ores. Very few, if any, of these latter processes could ever be successful on a practical scale, while some are merely laboratory methods. An outline of all the processes is incorporated in this review merely as a reference for anyone undertaking an investigation of the recovery of cobalt from its ores. A more detailed description is given of the processes and smelters of the Coniagas Reduction Company, Limited, and the Deloro Smelting and Refining Company, Limited, since these two smelters are the most successful ones at the present time. The Herrenschmidt process is also considered in detail as a large quantity of New Caledonia ores were formerly treated by this method. All the other processes are grouped together, mention only being made of differences in the proposed treatments that may possibly be of interest.

The methods employed by Canadian companies are first described.

[1] A solution containing approximately 1.5 to 2 parts of nickel sulphate to 1 part of cobalt sulphate is practically colourless. If cobalt is present in a larger ratio, the solutions are pink to red in colour, while if the ratio of the cobalt to nickel is less the solutions are green.

Coniagas Reduction Company Limited[1]

The Coniagas Mines Limited, of Cobalt, Ontario, owns practically all of the issued capital stock of the Coniagas Reduction Co., Limited. The head office of the company is at St. Catharines, Ontario, but the smelter is situated at Thorold, six miles west of Niagara Falls. The company's property comprises 160 acres, of which the smelter occupies about four, with a frontage of 1,500 feet on the Welland canal. It is also served by the Grand Trunk, and Niagara, St. Catharines, and Toronto railways.

The construction of the smelter was begun in March, 1907, and actual smelting commenced in May, 1908. It was erected for the treatment of ores from the Coniagas mine, but its capacity is sufficient to smelt a certain tonnage of other silver ores from Cobalt.

The process in use at this smelter is as follows: The ore is crushed, ground in a Krupp ball-mill, and sampled by a Vezin automatic sampler, two separate samples being taken. The ground ore is smelted in a blast-furnace with limestone and iron ore, the products being impure metallic silver, an argentiferous speiss containing cobalt, nickel, and iron as arsenides, also flue dust, and slag. The impure silver is cast into anodes and refined electrolytically. The speiss is treated with chemicals to recover the silver, cobalt, and nickel. Various grades of cobalt oxide containing from 60 to 76 per cent. metallic cobalt, are produced, according to the demand of the market. The cobalt oxide contains less than 1 per cent. nickel and only small proportions of sulphur, lime, and iron. The arsenical fume from the dust-flues and collectors is treated to produce refined white arsenic, which assays over 99 per cent. arsenious oxide.

To operate the plant, from 200 to 300 horse-power is required, which is transmitted from Niagara Falls. The smelter has a monthly capacity of 250 tons of raw ore. The limestone flux is obtained from Port Colborne, 20 miles south, and the iron ore from Michigan.

This company produces refined silver, cobalt oxide and metal, nickel oxide and metal, white arsenic and metallic arsenic.

The output of the smelter since the commencement of operations is given below. The production of cobalt and nickel oxides, as shown in the table, represents the cobalt and nickel content in refined oxides and various products.

Year	Ore Treated	Silver—Fine	Cobalt Oxide	Nickel Oxide	White Arsenic
	tons	ounces.	tons	tons	tons
1908	266.80	360,683	5.5	1.5	13.5
1909	1,116.90	1,659,604	0.9	.....	100.0
1910	2,017.25	3,485,243	53.8	13.2	557.7
1911	2,821.50	5,770,271	60.5	17.3	766.1
1912	2,288.77	4,824,632	129.0	50.7	636.7
1913	2,509.80	4,977,012	250.6	115.6	319.4
1914	1,968.78	3,865,546	171.9	124.9	399.2
1915	2,541.00	3,445,661	59.0	99.8	472.8
1916	2,718.86	4,428,912	190.4	67.6	420.8
1917	2,633.25	2,954,665	49.6	38.9	555.3

[1] Cole, Arthur A., Report of the Timiskaming and Northern Ontario Railway Commission, Toronto, Canada, 1912, p. 69.

The smelting schedule of the Coniagas Reduction Company in condensed form is as follows:

Schedule.—Percentages of silver to be paid for on commercial assay of the silver content per ton of 2,000 pounds as follows:

55	per cent.	for	50	ounces	and	proportionate	increase	in percentage	up to 200
73	"	"	200	"	"	"	"	"	" 300
78	"	"	300	"	"	"	"	"	" 500
84	"	"	500	"	"	"	"	"	" 1,000
91.5	"	"	1,000	"	"	"	"	"	" 1,500
92.5	"	"	1,500	"	"	"	"	"	" 2,000
93.5	"	"	2,000	"	"	"	"	"	" 3,000
95	"	"	3,000 and over.						

Sampling to be at vendor's expense.

All ore purchased to be subject to a refining charge of 0.75 cent per ounce of silver content.

Payment:—75 per cent. of the amount 30 days after date of weighing and sampling reports; 25 per cent. of amount 90 days after date of said report.

Price of silver to be determined by New York quotation as given by Messrs. Handy and Harman to Western Union Telegraph Company on dates of settlement.

Deloro Smelting and Refining Company Limited[1]

The Deloro Smelting and Refining Company[2] is a close corporation controlled by M. J. O'Brien,[3] owner of the O'Brien mine, Cobalt, and Miller-Lake O'Brien mine, Gowganda.

The smelter is located at Deloro, Hastings county, Ontario, one mile from Marmora station, on the Canadian Northern railway.

The plant was built and operated first as an arsenic refinery by the Canadian Goldfields, but was entirely remodelled in 1907 by the present owners to smelt ores from Cobalt, particularly those of the O'Brien mine. During the year 1908 a separate and extensive plant was added for the production of cobalt and nickel oxides, and this has been in successful operation since May, 1910. When the plant was first erected the products were limited to silver, refined arsenic, and mixed oxides, but it has beeen gradually extended and at present the company produces refined silver, cobalt oxide and metal, nickel oxide and metal, and white arsenic. There is also an equipment for the production of the cobalt-chromium-tungsten alloy known as stellite, used for high-speed cutting-tools.

Treatment of Ores.—Ores and mill products from Cobalt are purchased on a basis of the silver content. Sampling is done carefully under the supervision of a representative of the seller, the process in use being as follows: Each carload of ore is stored in a separate bin, from which it is removed and crushed to 15-mesh in a ball-mill, to which is attached a Snyder sampler. This machine takes about 50 samples a minute, each one representing 10 per cent. of the ground material leaving the mill. The total sample is subdivided until a final sample of about 20 pounds is obtained. The coarse scales of silver which do not

[1] This company was formerly known as the Deloro Mining and Reduction Company, Limited.

[2] Cole, Arthur A., Report of the Timiskaming and Northern Ontario Railway Commission, Toronto, Canada, p. 74, 1913.

[3] Now M. J. O'Brien, Limited.

pass through the ball-mill screens are melted and cast into a bar which is weighed, sampled and assayed. The final assay of the ore is calculated from the assays of the ore and scales.

The following are typical assays of ores and mill products received at the smelter up to 1915:

Product	Ag per ton Oz.	Co	Ni	Cu	Fe	As	S	SiO_2	CaO	MgO
Ore (hand-picked).....	2,194	7.9	4.3	0.10	5.0	30.2	1.70	4.17	15.0	2.7
Jig product.....	1,442	10.4	5.8	0.20	6.5	47.2	3.70	4.5	5.2	0.8
Table concentrate.....	1,426	8.2	3.8	0.25	11.6	37.1	8.25	9.5	.....	.....
Slime "	324	2.1	0.5	.....	6.8	10.0	2.98	58.3	2.5	1.92

The ground ore with the required fluxes is mixed in a pug-mill and smelted in a low-pressure blast furnace, the products being metallic silver, an argentiferous speiss, slag, and flue dust.

The silver, which is about 850 parts fine, is charged into an oil-fired refining furnace and the impurities oxidized. Silver 996 parts fine is produced.

The argentiferous speiss is re-crushed, roasted in coal-fired reverberatory furnaces or in an oil-fired Brückner furnace, and the product conveyed to the chloridizing furnaces, where it is heated with salt.

The chloridized speiss is charged into agitating tanks where the silver is extracted by sodium cyanide. Metallic silver is precipitated from the cyanide solution by the addition of aluminum dust. This process was developed by Prof. S. F. Kirkpatrick, Queen's University, Kingston, Canada. The silver obtained is exceptionally high-grade, and the cyanide is to a large extent regenerated. The silver from the refining furnace is mixed with the silver precipitate from the cyanide process and treated with borax and nitre in an oil-fired tilting furnace, after which it is poured into moulds.

The residues from the cyanide treatment are given further treatment for the separation by precipitation of the cobalt and nickel.

Power is supplied to the smelter from Campbellford by the Hydro-Electric Power Commission of Ontario, over a 22-mile transmission line, at $20 per horse-power year. To operate the plant 300 to 400 horse-power is required.

The following table shows the production of the Deloro smelter since 1908:

Year	Ore Treated tons	Silver, Fine ozs.	Cobalt and mixed Oxides tons	Refined Arsenic tons
1908 to 1912.....	11,065	20,339,860	500	3,275
1913.....	2,920	6,350,500	190	893
1914.....	3,612	5,207,000	300	1,038
1915.....	4,634	6,429,794	256	1,634
1916.....	3,553	5,234,620	.....	1,627
1917.....	3,086	3,474,613	.....	1,809

Schedule.—Payment is made for 98 per cent. of the silver content of the ore determined by commercial assay, on the following terms and conditions:

Treatment charge, $25 a ton of ore.

Refining charge, 0.75 cent per ounce of silver content on ore assaying 3,000 ounces and over per ton; one cent per ounce on ore assaying 2,000 to 3,000 ounces per ton; one and one-half cents per ounce on ore assaying less than 2,000 ounces per ton.

Terms of payment, 75 per cent. of net proceeds 30 days after completion of sampling. All ore is to be delivered in carload lots f.o.b. Marmora station, and to be at the shipper's risk until sampling is undertaken.

Canadian Copper Company

The cobalt plant of the Canadian Copper Company was situated at Copper Cliff, about one-quarter of a mile south of the large copper-nickel smelter of the same company.[1]

The works were designed to smelt and treat ores and concentrates from the Cobalt silver mines, and were in operation from 1905 to 1913. This plant was closed because of the extended treatment of the ores in cyanide plants at the mines. The following is an outline of the method used:

Treatment.—The ore was crushed, ground in a ball-mill to 30-mesh, and from the ground ore, one-tenth was removed by a Snyder sampler. Sampling was completed by coning and quartering. The first quartering divided the sample into two parts, which were treated as two independent samples. The ore was charged with suitable fluxes into a 30 by 72-inch blast furnace, having a capacity of 25 to 30 tons per 24 hours. Limestone from Michigan was used as a basic flux, and low-grade cobalt ore as an acid flux when required.

The products of the blast furnaces were: silver, speiss, slag, and flue dust containing fine ore, coke, and crude arsenic oxide.

The silver and speiss were tapped from the furnace through the lower tap-hole and allowed to settle in a slag pot, the silver going to the bottom.

The silver button, assaying 850 parts fine, and weighing about 50 to 75 pounds, represented an extraction of about 75 per cent. of the silver in the ore. The grade of the silver was raised to 980 parts fine in an oil-fired refining furnace which had a capacity of 30,000 ounces. It was shipped in bars to the Balbach Smelting and Refining Company, Newark, N.J., for further refining. The slag from the refining furnace was returned to the blast furnace.

An average analysis of the speiss produced is as follows: silver 900 oz. per ton, arsenic, 24 to 30 per cent., cobalt 27, nickel 9 to 15, iron 20, copper 2, and sulphur 6.

Previous to 1909 the blast furnace speiss was ground and roasted to remove most of the arsenic. The roasted speiss was mixed with sodium carbonate and nitre and again heated. By this treatment the arsenic was changed to soluble sodium arsenate, the cobalt and nickel to oxides. After removing the soluble arsenate, the residue, termed leached speiss, containing 2 to 3 per cent. arsenic and considerable

[1] Bridges, The Metallurgy of Canadian Cobalt Ores. *Can. Min. Jour*, Vol. XXXVII, 1916, pp. 48, 68, 134.

silver, was shipped to New Jersey to be refined. The above method of treatment was changed about 1909 in order to recover more of the silver, the new process being as follows:

The speiss was ground to 30-mesh, mixed with 20 per cent. salt, and roasted in mechanically rabbled Edwards furnaces, fitted with water-cooled rabbles. Each furnace had a capacity of 2,400 pounds per 24 hours. The chloridized speiss was then treated with water to dissolve the soluble cobalt, nickel, and copper salts. The solution was passed through a tank containing scrap iron, which precipitated the copper, after which the cobalt and nickel were precipitated as hydroxides by caustic soda, converted into oxides in an oil-fired furnace, ground in a pebble-mill, and barrelled for shipment. An approximate assay of this material is as follows: silver 15 oz. per ton, arsenic 0.3, cobalt 40, and nickel 3 per cent. The small amount of nickel in the foregoing analysis in proportion to the cobalt is due to the nickel chloride being more readily decomposed than the cobalt chloride. The treatment of the speiss was continued with four covers of hyposulphite of soda solution, the residue finally containing 20 to 30 oz. of silver per ton. The silver was precipitated as sulphide by the addition of a saturated solution of sodium sulphide, filtered in a filter-press, dried, mixed with 100 per cent. sodium nitrate and 10 per cent. sodium carbonate, heated to redness in an oil-fired roasting furnace, and then transferred to tanks where it was leached with hot water. A spongy mass of metallic silver remained, with a small quantity of cobalt and nickel. The spongy mass, which contained from 60 to 65 per cent. of silver, was added to the bath in the silver-refining furnace.

The residues from the first hyposulphite leaching were mixed with quartz and smelted in a blast furnace to remove the iron. The resultant products were slag, speiss, and flue dust.

The slag, which contained 15 ounces silver per ton, 10 per cent. cobalt, and less than 1 per cent. nickel, was smelted with other high-silver slags, and pyrite from Capelton, Quebec.

The speiss from this second smelting had the following approximate composition: silver 300 ounces per ton, arsenic 25 to 30 per cent., cobalt 35, nickel 25, iron 3.5, and copper 2 per cent., also a little sulphur when the arsenic was low.

The second speiss was treated similarly to the first up to the time when the first residue was removed from the cylinders after treatment with hyposulphite. The second speiss residue, which contained 20 per cent. arsenic, was mixed with 20 per cent. sodium nitrate and 10 per cent. sodium carbonate, and roasted in a hand-rabbled reverberatory furnace. This treatment changed the arsenic to sodium arsenate, which was dissolved in hot water, the solution being discarded. The residue, after drying, had the following approximate composition: silver 20 to 30 oz. per ton, arsenic 0.3 to 0.7 per cent., cobalt 35 to 37, nickel 23 to 25, copper 3, and iron 5 per cent.

Payment was received for the silver in the residues, as well as for the cobalt and nickel oxides.

The arsenious oxide from the blast furnace and roasting furnaces was collected in flues and charged into an arsenic refining furnace. The residue, a clinker high

in silver, was returned to the blast furnace. The final product was refined white arsenic which contained 99.98 per cent. arsenious oxide (As_2O_3) and 0.3 ounces of silver per ton.

The slag from the blast furnace was rejected except when it assayed more than 10 ounces of silver per ton, in which case it was retreated in the blast furnace.

The 200 to 300 horse-power required was supplied from the company's plant at High Falls, 14 miles from the smelter.

The following table shows the ore treated and the production of the cobalt plant of the Canadian Copper Company from the commencement of operations to their close in 1913.

Year	Ore Treated Lbs.	Silver, Fine Ozs.	Metallic[1]		White Arsenic lbs.
			Cobalt lbs.	Nickel lbs.	
1906	1;767,692.5	1,282,692.78	9,021	3,987	.....
1907	4,560,627.5	3,829,542.82	331,151	138,427	510,622
1908	9,857,072.5	8,551,582.07	464,171	268,140	942,827
1909	10,651,189.5	8,779,014.55	690,737	463,588	1,242,722
1910	9,792,511.0	8,696,624.87	346,483	260,756	843,619
1911	6,744,108.0	6,584,102.46	238,684	234,323	680,074
1912	3,667,301.0	3,523,207.80	223,163	209,330	476,156
1913	186,602.0	47,590.00	15,506	7,161	95,669
Total	47,227,104.0	41,294,357.35	2,318,916	1,585,712	4,791,689

Canada Refining and Smelting Company Limited

The plant of the Canada Refining and Smelting Company Limited,[2] was situated in the southern part of the town of Orillia, Ontario, and adjacent to the Grand Trunk, Canadian Pacific, and Canadian Northern railways.

Construction was started early in September, 1910, and smelting was commenced in February, 1911.

The plant was designed for the treatment of silver ores from Cobalt, and had a capacity of about 13 tons daily. It produced refined silver, white arsenic, and mixed oxides of cobalt and nickel.

This plant has not been operated since early in 1913, but the treatment of the ore was as follows:

The crushing and sampling was done at Cobalt by Campbell and Deyell, samplers and assayers, before shipment to the smelter. The ore was smelted in a 48-inch circular shaft furnace, which produced silver, argentiferous speiss, slag, and flue dust.

The silver recovered from the furnace assayed 900 parts fine and represented an extraction of 80 per cent. It was refined to 996 parts fine in a cupellation furnace of a capacity of 10,000 ounces. The slag from the refining furnace

[1] These figures represent the metallic nickel and cobalt contained in the crude oxides in which form they were shipped.

[2] Cole, Arthur A., Report of the Temiskaming and Northern Ontario Railway Commission, Toronto, Canada, p. 68, 1913.

reverted to the blast furnace. Limestone and iron ore were used as fluxes when required, the limestone being obtained from Longford quarry, nine miles distant from the smelter, and the iron ore brought from Midland, Ontario.

The speiss was ground, roasted and re-ground. It was treated with chemicals, when most of the metals except the silver were dissolved. The impure silver-bearing residue was separated from the liquor in filter-presses and recharged into the cupola furnace.

The iron, arsenic, and copper were first precipitated from the liquor, and finally the cobalt and nickel precipitated together as carbonates. The mixed carbonates were heated in a hearth furnace and converted to oxides which, after being ground, were barrelled and shipped. The oxides assayed 40 per cent. of cobalt and 25 per cent. of nickel.

The flue dust was treated to recover pure arsenious oxide.

About 300 horse-power was required by the plant. This was supplied by the town of Orillia, from a hydro-electric installation 18 miles distant from the town, at the rate of $18.40 for 24-hour service per horse-power year. About 80 men were employed.

Metals Chemical, Limited

During 1915 Metals Chemical Limited, Welland, Ontario, erected a plant to treat low-grade Cobalt ores and residues. The ores are smelted in a blast furnace, with a capacity of 30 tons of ore per day. The products of the furnace are silver, speiss and slag. The speiss is roasted to remove the arsenic and the roasted product treated with chemicals to dissolve the cobalt and nickel. The following products are shipped: cobalt oxide, cobalt carbonate and sulphate, nickel oxide and sulphate, refined silver and white arsenic (As_2O_3).

The Standard Smelting and Refining Company Limited, erected during 1914, a small plant at North Bay, Ontario, to treat ores from Cobalt. This company in 1915 moved its works to Orillia, Ontario, and cobalt ores were treated during part of 1916. The company went into liquidation and the plant was taken over by the International Molybdenum Co.

Under the provisions of the "Metal Refining Bounty Act," passed by the Ontario Legislature in 1907, there was paid a bounty of six cents a pound on the metallic contents of cobalt and nickel oxides produced within the Province. The total bounties to be paid in any one year were not to exceed the sum of $30,000 for cobalt and $60,000 for nickel. This Act expired in April, 1917. The table given below shows the total amount paid in bounties.

Summary of Bounties Paid

Company	Cobalt	Nickel	Total
	$ c.	$ c.	$ c.
Deloro Smelting and Refining Co., Ltd.....	48,930 93	8,166 96	57,097 89
Coniagas Reduction Co., Ltd.....	67,174 99	27,539 01	94,714 01
Metals Chemical Ltd.....	9,577 60	6,766 04	16,343 65
Canadian Smelting and Refining Co., Ltd..	1,026 05	681 84	1,707 89
Standard Smelting and Refining Co., Ltd..	214 92	.....	214 92
Dominion Refineries Limited	62 59	.....	62 59
Total.....	126,987 08	43,153 85	170,140 95

Previous to 1913 a large amount of cobalt ore had beeen shipped to the United States to be refined, as there was an import duty of 25 cents per pound on refined cobalt oxide. However, in 1913 the charges on cobalt products entering the United States were changed and at present are as follows:

Product.	Old Tariff	New Tariff
Cobalt oxide	25 cents per lb.	10 cents per lb.
Cobalt metal	free	free
Cobalt ore	free	free
Cobalt alloy steel	0.2 to 7 cents per lb. according to the value and 20 per cent. above 40 cents per lb.	15 per cent. ad. val.

A synopsis follows of the methods employed in Europe for the production of cobalt oxide, and of the numerous processes which have been proposed, many of which have never been put to the test of actual practice.

Herrenschmidt and Constable Processes[1]

These processes were used chiefly on the ores from New Caledonia and Australia.

Process No. 1.—The cobalt ore was smelted with argentiferous lead or copper sulphides in a blast furnace, the products being a matte containing the cobalt, nickel, copper, or lead as sulphides, and a silicate slag containing the iron and manganese. The matte was ground and heated to convert the sulphides of the metals into soluble sulphates, the lead sulphide, however, forming an insoluble sulphate. The sulphate solution was then treated by one of the following methods:

(*a*) The copper in the solution was precipitated by iron, the solution filtered upon a layer of New Caledonia mineral, the iron in solution precipitating, and a corresponding amount of cobalt, nickel, and manganese dissolving. Magnesia (MgO) was added next to precipitate the nickel, cobalt, and manganese. The precipitate was treated with a fresh quantity of solution containing cobalt, nickel, and manganese sulphates, by which treatment the manganese hydroxide dissolved, while a corresponding quantity of cobalt and nickel hydroxides was precipitated.

(*b*) To the sulphate solution, calcium chloride was added to change the sulphates into chlorides. The solution was filtered to remove the calcium sulphate and any insoluble matter, and then treated with lime, the iron and part of the copper being precipitated as hydroxides. The last of the copper was precipitated with nickel hydrate or carbonate. The solution was then treated with calcium or sodium carbonate which precipitated the cobalt, nickel, and copper. The precipitate of mixed carbonates or hydrates was redissolved, and the solution treated to remove the copper as above, so that only cobalt and nickel remained in solution.

Process No. 2.—The ore was treated with hydrochloric acid, and the solution of chlorides was reduced by filtering on scrap iron. The solution of ferrous chloride obtained was used to attack fresh quantities of New Caledonia ore. The acid treatment was applied chiefly to the cobalt ores from Australia.

[1] Wagner's Jahresbericht, Vol. XXX, 1884; pp. 152, 396; Vol. XXXII, 1886, pp. 157-158; Vol. XXXVIII, 1892, p. 208; Jour. Soc. Chem. Ind., Vol. XI, 1892, p. 167; Schnabel, Handbook of Metallurgy, Vol. II, 1898, p. 603.

At the plant of the Malètra Co., Rouen, France, the pulverized ore from New Caledonia was treated with a ferrous sulphate solution and steam. The solution after such treatment contained the sulphates of cobalt, nickel, and manganese, the iron forming a basic sulphate precipitate. The iron precipitate, silica, and alumina were removed by filtering and washed in a filter press. To the sulphate solution sodium sulphide was added, which precipitated the sulphides of cobalt and nickel, as well as a small quantity of manganese.

The precipitate was filtered in a filter press, and, after washing, was digested with a calculated quantity of ferric chloride, which dissolved only the manganese sulphide. A black precipitate of cobalt and nickel sulphides remained, the solution containing the sulphates and chlorides of manganese and iron. The sulphide precipitate was dried, ground, and heated to form sulphates. The mixture of sulphates was dissolved in water and treated with a solution of calcium chloride, the calcium sulphate formed being removed. The solution was divided into two parts, A and B. To the first portion of solution A milk of lime was added to precipitate the cobalt and nickel; afterwards the precipitate was washed in a filter press to remove any excess of calcium chloride. The washed precipitate was digested with water and oxidized by chlorine mixed with air. A part of solution B containing cobalt and nickel chlorides was added to the hydroxides obtained from solution A, and the mixture agitated. By this treatment the nickel hydroxide was reduced by the cobalt chloride of solution B and dissolved, a corresponding quantity of cobalt precipitating, according to the following reaction.

$$Co_2O_3+Ni_2O_3+2CoCl_2=2NiCl_2+2Co_2O_3.$$

Another method of treating the ores from New Caledonia was to make a matte which was afterwards ground and heated to form sulphates. The sulphates were dissolved, and the iron was precipitated by careful additions of sodium carbonate. The copper was precipitated by hydrogen sulphide, and after boiling off the excess, the cobalt was precipitated by sodium hypochlorite. Bleaching powder cannot be used owing to the sulphates in solution. The nickel was precipitated from the remaining solution by sodium carbonate. Also metallic copper was precipitated from copper-cobalt-nickel-iron solutions by the addition of matte. The iron was precipitated by adding a salt of nickel or cobalt.

Borchers and Warlimont[1] proposed treating minerals containing sulphides of nickel, cobalt, copper, and iron by a partial roast at 500° C. In this treatment the cobalt and copper were changed almost completely to sulphates, the nickel remained partly as sulphide and partly as oxide, the iron as oxide and ferrous and ferric sulphates. The furnace product was treated with water for several days, when any copper sulphide remaining in the ore reacted with the ferric sulphate, forming copper sulphate and ferrous sulphate. This was followed by a treatment with a slightly acidulated solution which dissolved the sulphates of cobalt and copper and at the same time a small quantity of nickel and a little iron sulphate. The residue was treated to recover the nickel. The copper was removed from the cobalt solution by scrap iron, and calcium sulphide was added to precipitate the nickel and cobalt as sulphides.

[1] Eug. Prost, Cours de Métallurgie des Metaux autres que le Fer, 1912, p. 663, Ch. Béranger, Editeur, Paris.

Lundborg[1] describes the treatment of ores containing earthy cobalt formerly used at the Editha Smalt Works in Silesia. The ores were agitated with concentrated hydrochloric acid in clay vessels to dissolve the cobalt, some nickel and iron dissolving at the same time. The iron was precipitated from the solution by adding small quantities of marble. As soon as nickel began to be precipitated the separation of iron was known to be complete. To the filtrate soda was added to precipitate the nickel. When cobalt began to come down, the liquid was filtered, and the precipitation continued, a mixture of the two hydroxides forming until all the nickel had been precipitated. Cobalt hydroxide was precipitated from the final filtrate. The precipitate of mixed oxides was redissolved, and the two separated by fractional precipitation.

The matte, from the Sesia Works at Oberschlema, in Saxony, was similarly treated. It contained Ni 16, Co 14, Cu 50, and S 20 per cent. The powdered matte was roasted in a reverberatory furnace and treated with dilute sulphuric acid. The copper was precipitated by iron, after which the rest of the process was the same as that described above.

At Schladming, Styria,[2] ore containing 11 per cent. of nickel and 1 per cent. of cobalt was roasted in stalls and afterwards smelted in blast furnaces. The charge consisted of 89 parts of roasted ore, and 19 parts of quartz. In 24 hours five tons of ore were treated, using 1,800 pounds of wood charcoal. The speiss, which was tapped every two hours, contained Ni 45 to 47, Co 4 to 6, Fe 8 to 10, Cu 1 to 1.5, As 33 to 36, S 1 to 2, and carbon 1 to 2 per cent.

At the George Works at Dobschau, Hungary,[3] about 1876, ore containing nickel 4.5 and cobalt 1.5 per cent. was roasted in stalls, and then smelted in circular blast furnaces 16.5 feet high, with two tuyeres. The diameter of the furnace was 3 feet 4 inches at the level of the tuyere, and 4 feet at the mouth. The tuyeres were 2.75 inches in diameter, and the blast pressure equal to 2.5 inches of mercury. The charge consisted of 100 parts of ore, 3 to 4 quartz, 8 to 12 limestone, and 5 to 10 rich slag. The capacity of the furnace was 7 to 10 tons of ore per 24 hours, using 20 per cent. charcoal. The speiss contained from 16 to 20 per cent. of nickel and cobalt. This was roasted in stalls, and then smelted to form a concentrated speiss in a blast furnace similar to that used for the ore. The capacity of the furnace was about 11 tons per 24 hours. To the charge of roasted speiss, about 2.5 tons of quartz were added to flux the iron oxide formed during the smelting operation. Charcoal was used as a fuel, the consumption being about 26 per cent. of the weight of the charge. The concentrated speiss contained Ni and Co 31.9, Cu 1.9, Fe 26.4, As 36.3, and S 3.1 per cent.

The concentrated speiss was roasted and charged into a small blast furnace similar to that used for the ore. The capacity of the furnace was about two tons of roasted speiss. After the charge (100 parts of roasted speiss, 4 parts of quartz, 2 parts of glass and 1 part of soda), had melted, a strong air-blast was turned on, by which the iron was oxidized first. The iron oxide was slagged by addition of quartz, glass, and soda. To prevent large quantities of cobalt being slagged, the

[1] Schnabel, Handbook of Metallurgy, Vol. II, 1898, p. 602.
[2] Schnabel, Vol. II, p. 562.
[3] Schnabel, pp. 562, 586.

iron was not completely oxidized, 8 to 10 per cent. remaining in the speiss. The speiss formed by this operation was called doubly concentrated speiss and contained Ni and Co 50 to 52, Cu 1 to 2, Fe 8 to 10, As 38 to 40, and S 1 to 2 per cent. The slag contained 1 to 2 per cent. Ni and Co, and was re-charged into the blast furnace treating the ore.

The high-grade speiss was crushed in a stamp-battery, and then roasted for 12 to 14 hours in wood-fired reverberatory furnaces with a capacity of about 600 pounds to a charge. After roasting, 65 to 90 pounds of sawdust or coal dust was added which reduced any arsenates to arsenites, from which compound the last of the arsenic may be removed. The roasted product was treated with sulphuric acid and the solution filtered. Iron and copper were precipitated by additions of calcium carbonate to the boiling solution, after which cobalt hydroxide was precipitated by calcium hypochlorite, and nickel by milk of lime. The cobalt and nickel oxides were dried, washed, ground, and sold to the colour works in Saxony.

At Saint Benoit, near Liege,[1] speiss containing 45 per cent. of nickel was treated with concentrateed hydrochloric acid at 80° C. Iron was precipitated from the solution in the usual way, and then copper by calcium sulphide. Next cobalt was precipitated by chloride of lime, and lastly nickel by milk of lime.

Dixon[2] proposed smelting garnerite, a hydrated nickel magnesium silicate of New Caledonia, with the addition of arsenical materials, to form a speiss. This was roasted, and treated with hydrochloric acid. Into the chloride solution chlorine was passed to oxidize the iron, which was afterwards precipitated by the careful addition of nickel hydroxide. Cobalt was then precipitated as hydroxide by passing more chlorine through the solution, and adding more nickel hydroxide. The solution containing the nickel chloride was evaporated. The salts obtained were heated in a furnace through which steam or hydrogen was passed, producing nickel oxide or metallic nickel respectively. A little nickel was precipitated with the cobalt, but this was removed by leaching with dilute hydrochloric acid. It is also stated that the addition of manganese dioxide to a neutral cobalt and nickel solution completely precipitated the iron, but this is questionable, if not impossible. The statement is also made that anhydrous nickel oxide was used where hydroxide is mentioned above for precipitating iron and cobalt, but knowing the solubility of nickel oxide, the writer also questions such a statement.

At a works in Birmingham, England,[3] speiss was roasted and dissolved in hydrochloric acid. Iron was first oxidized, then precipitated as arsenate and hydrate, by neutralizing the hot solution with calcium carbonate. Copper was precipitated next by sulphuretted hydrogen, then the cobalt by calcium hypochlorite (bleaching powder), and finally the nickel by milk of lime. In precipitating the cobalt a small amount of quicklime was added to neutralize any liberated acid.

A direct treatment of unroasted matte with acid was formerly in use at the Scopello works in Piedmont.[4] Nickel matte, containing Ni 24, Co 6, Cu 12, Fe 23, and S 35 per cent. was treated with hydrochloric acid (33 per cent. HCl) in stoneware vessels surrounded by water. The sulphuretted hydrogen formed was

[1] Schnabel, Vol. II, p. 586.
[2] Chemical News, Vol. XXXVIII, 1878, pp. 268-270.
[3] Phillips. Elements of Metallurgy, 1891, p. 415.
[4] Schnabel, Vol. II, p. 581.

removed by a tube in the cover of the vessel and burned. After the matte had been treated three times with acid, the liquid was removed from the residue, which consisted of the copper sulphide of the matte and an appreciable quantity of nickel and cobalt sulphides. This was charged into the blast furnace during the smelting of matte or ore. The solution, containing chlorides of iron, nickel, and cobalt, was allowed to settle, and then evaporated to dryness in a cast-iron pot. The residue, a mixture of the three chlorides, was heated in a reverberatory furnace for 3 or 4 hours, with continual rabbling, during which process part of the iron was volatilized as chloride and part changed to ferric oxide.

The furnace product was agitated with water to dissolve the soluble cobalt and nickel chlorides, any undecomposed iron chloride present dissolving at the same time. The iron chloride was oxidized with chloride of lime and precipitated with calcium carbonate. Cobalt was precipitated next by further additions of chloride of lime to the iron-free solution, and finally nickel was precipitated with milk of lime.

The precipitates of cobalt and nickel hydroxides were washed in woollen sacks to remove any soluble lime salts, until no cloudiness was visible in the water on the addition of ammonium oxalate. The oxides were given a final wash with acidulated water.

Other Proposed Processes

Beltzer[1] outlines a process for the treatment of ores from Cobalt, Canada, as follows. The ore was to be first concentrated and the silver removed by amalgamation. The concentrate, after amalgamation, is roasted (*a*) with or without additions of carbon to remove the arsenic, as oxide, or (*b*) treated with lime or soda and the arsenic removed as soluble arsenite or arsenate, or (*c*) heated with sodium bisulphate and acid (66° Bé.) to remove the last traces of arsenic. By the last method of treatment the soluble sulphates of cobalt and nickel are formed. In case of treatment (*a*) or (*b*), the roasted product is afterwards given either a chloridizing roast with salt, or heated with hydrochloric acid, or sulphuric acid and salt. In any case, after dissolving the soluble salts and filtering the solution containing chlorides of nickel, cobalt, and a small quantity of iron, the cobalt is precipitated by Rose's method (caustic soda and current of chlorine) or by hypochlorite of calcium or sodium. The precipitation of cobalt may also be completed by the following method. If the cobalt and nickel are in the form of sulphates, calcium chloride is added, which converts the sulphates into chlorides. The solution is filtered and then divided into two parts, A. and B. The cobalt and nickel in solution A are completely precipitated by milk of lime, filtered and washed. The precipitate of cobalt and nickel hydroxides is mixed with water and oxidized by a current of chlorine and air. When the solution is saturated with chlorine, a part of solution B is added and the mixed solution boiled. The nickel hydroxide is reduced by the cobalt chloride of solution B and dissolves, a corresponding quantity of cobalt precipitating. In this way practically pure cobalt hydroxide is obtained.

[1] Beltzer, The Rational and Industrial Treatment of the Complex Ores of Silver, Cobalt, Nickel and Arsenic of Cobalt, Canada. Moniteur Scientifique, Vol. XXIII, 1909, pp. 633-647.

Quantities of solution B are added until the precipitate is practically pure cobalt hydroxide.

Beltzer also outlines the following electrolytic process to separate cobalt from nickel, but the process does not appear to be practicable. To the chloride solution salt is added and the solution electrolyzed, using platinum electrodes. Nascent chlorine and sodium hydrate are formed, the caustic soda precipitating the cobalt, the nickel remaining in solution.

A solution containing sulphates of cobalt, nickel, and a small quantity of iron may be treated by the following method. The iron is precipitated by milk of lime or nickel hydrate, a corresponding quantity of lime or nickel going into solution. Soda is added to precipitate the cobalt and nickel which are separated by additions of chlorine to a neutral solution. In the oxidation with chlorine, nickel dissolves, and at the same time a corresponding quantity of cobalt is precipitated so that the original rose colour, due to the cobalt, changes to a green. To be certain that the cobalt hydrate precipitate does not contain nickel, it is necessary to leave a little cobalt in solution.

Another process[1] consisted in mixing cobalt-silver ore with a lead furnace-charge and smelting. The lead collected the silver, and the cobalt and nickel formed a speiss. The speiss was roasted with carbon to remove arsenic, the cobalt combining with silica, which was added as silicate. The cobalt silicate was treated with hydrochloric acid, and the cobalt and nickel hydroxides were precipitated by lime water.

It does not appear to the author that the processes to treat cobalt ores, as outlined on the following pages, with perhaps a few exceptions, are anything more than laboratory experiments or ideas. As mentioned in the introduction, a summary of each is given merely to record all attempts that have been proposed to treat cobalt ores.

Readman[2] proposed mixing the ground ore with sodium sulphate in sulphuric acid, in the proportions of 100: 84: 65. The mixture was heated to a red heat, the cobalt, nickel, and manganese forming soluble sulphates. After dissolving the sulphates, the solution was neutralized with calcium carbonate and heated, the iron precipitating. The sulphate solution of cobalt, nickel, and manganese was treated with sodium sulphide to precipitate only the cobalt and nickel. In another process the use of ferric chloride was suggested. After treating the ore, the product was heated to render the iron insoluble. The cobalt and nickel were dissolved from the roasted mass.

Gauthier[3] used iron pyrites and gypsum to decompose cobalt ore, obtaining sulphates of cobalt and nickel.

Stahl[4] proposed roasting the mineral, then mixing it with salt and sulphide of iron. The copper, cobalt, and nickel were changed to soluble chlorides, the iron and manganese to insoluble oxides. The chloride solution was treated with

[1] Ouvrard, Industries du Chrome, du Manganese, du Nickel, et du Cobalt, p. 258, Doin and Sons, Paris, 1910.
[2] Ouvrard, p. 262; Jour. Soc. Chem. Ind., Vol. III, 1884, p. 524.
[3] Wagner, Jahresbericht, Vol. XXXII, 1886, p. 157.
[4] German Patent, No. 58,417, 1890. Wagner, Jahresbericht, Vol. XXXVII, 1891, p. 210, Ouvrard, pp. 265-266. Schnabel, Vol. 2, p. 605.

hydrogen sulphide to precipitate the copper, and after neutralization with soda, cobalt and nickel were precipitated by sodium sulphide along with any iron, manganese, and copper. The mixed sulphides were treated with dilute acid to dissolve any iron, manganese, or copper sulphides. The cobalt and nickel sulphides were roasted to sulphates and separated by one of the previously mentioned methods.

In the Natusch or Schoneis process[1] the roasted mineral was heated with ferric chloride. The chloride solution was treated with calcium sulphide, which precipitated the cobalt and nickel and a small quantity of manganese as sulphides.

Precourt and Falliet[2] suggested roasting cobalt ore with iron sulphide, FeS_2, the cobalt, nickel, and manganese being changed to soluble sulphates, most of the iron forming oxide. The iron was precipitated from the solution with calcium carbonate and removed. The sulphates of cobalt, nickel, and manganese were changed to chlorides by the addition of calcium chloride, calcium sulphate being precipitated and removed. Nickel and cobalt were precipitated with calcium sulphide, the manganese remaining in solution. The sulphides of nickel and cobalt were washed with dilute sulphuric acid to remove any manganese sulphide, and afterwards heated to form sulphates. To the filtered solution of the sulphates, hypochlorite was added. After making the solution alkaline it was made faintly acid, the cobalt precipitating as sesquioxide, the nickel remaining in solution.

Dyckerhoff[3] proposed decomposing ore containing silver, cobalt, nickel, and arsenic by roasting the ore with salt, clay, and pyrites, by which treatment the silver, cobalt, nickel, and arsenic were converted to chlorides. The insoluble silver chloride was removed, while the arsenic chloride was volatilized or changed to the volatile oxide. The cobalt and nickel remained as soluble chlorides.

In the Warren process,[4] cobalt ore was treated with hydrochloric acid and copper nitrate, the metals passing into solution. Milk of lime was added, which precipitated the iron as hydroxide and arsenate. Lime was removed by the addition of sulphuric acid, and afterwards the cobalt and nickel were precipitated as carbonates by soda. The solution was filtered, diluted, and chlorine gas passed through until the solution was saturated, after which it was boiled, the nickel hydroxide dissolving and cobalt hydroxide remaining. The solution was filtered and the nickel precipitated by caustic soda.

Gauthier[5] heated ground cobalt ore with hydrochloric and sulphuric acids and completed the process by the usual methods.

Carnott[6] heated the ore to render any iron insoluble, and then treated the product with hydrochloric acid and neutralized the solution with calcium carbonate to precipitate the iron. The filtered solution was treated with milk of lime, which precipitated first the cobalt, then the nickel, and finally the manganese. The fractional precipitation of the cobalt, nickel, and manganese was not satisfactory.

[1] Ouvrard, p. 264. Schoneis, Berg. u hüttenm. Zeitung, 1890, p. 453. Wagner, Jahresbericht, Vol. XXXVI, 1890, p. 338. Chemiker Zeitung, Vol. XIV, 1890, p. 770, p. 1475.

[2] French Patent 403,830, June 9, 1909. Jour. Soc. Chem. Ind., Vol. XXIX, 1910, p. 97.

[3] United States Patent, No. 1,085,675, Feb. 3, 1914.

[4] Chemical News, Vol. LVI, 1887, p. 193.

[5] Gauthier, Wagner Jahresbericht, Vol. XXXII, 1886, p. 157.

[6] Ouvrard, p. 258.

Clark[1] treated the ground mineral with a boiling solution of ferric chloride. The solution was evaporated to dryness and the residue calcined at 350° to 370° C. Cobalt, nickel, and manganese were changed to chlorides by the decomposition of the ferric chloride which formed ferric oxide. Cobalt and nickel sulphides were separated from manganese by precipitation with calcium sulphide. This method was tried at Glasgow, Scotland.

Dickson and Ratte[2] dissolved the cobalt, nickel, and manganese of a cobalt mineral by treatment with sulphurous acid, alone, or mixed with other acids. The iron oxide remained insoluble. The finely-ground cobalt mineral was mixed with water at 50° C. in vats provided with stirring arrangements, and the sulphurous acid introduced. The mixture was transferred to a second vat, where the iron oxide and the impurities settled. The solution was filtered through a bed of pulverized mineral, which retained the suspended impurities and neutralized the excess acid, while the last traces of iron were precipitated. From this solution the cobalt and nickel were precipitated as sulphides by sodium sulphide and afterwards separated.

Cobaltite was ground and carefully roasted with additions of small quantities of carbon.[3] The residue was treated with sulphuric acid. From the solution obtained the iron was precipitated with calcium carbonate, and other metals with hydrogen sulphide. The solution was filtered and treated to recover the cobalt and nickel.

Barth[4] gives some experimental results obtained in working on a method to treat a roasted speiss containing lead, cobalt, nickel, iron, and manganese. Decomposition by acids, chlorine, chloridizing roasting, and by sulphur dioxide was tried.

Phillips[5] outlines a process for smelting cobalt silver ores using sufficient iron matte and copper residue to form a speiss, an argentiferous copper matte, and a slag. The operation was repeated to obtain speiss free from silver and copper.

De Burlet[6] proposed extracting cobalt from cobalt and nickel silicate minerals and slags from copper smelting by treating them with dilute sulphuric acid, and after decomposition the mass was heated to 150°-200° C. to render the silica insoluble. The soluble salts were dissolved in hot water, the solution filtered, and calcium carbonate added to precipitate the iron and the greater part of the copper. The remaining copper was removed by electrolysis, and then the solution was treated with ammonia to obtain cobalt and nickel compounds. The ammoniacal solution was electrolyzed, using carbon or lead anodes and polished nickel-plated iron plates as cathodes. The surfaces of the cathodes were coated with paraffin to prevent the metal adhering. The metal fell to the bottom of the tank in thin flakes.

[1] Ouvrard, p. 263.
[2] French Patent, Sept. 5th, 1885.
[3] Ouvrard, p. 258.
[4] Barth, Treatment of a Roasted Lead-Cobalt-Nickel Speiss, Metallurgie, Vol. IX, 1912, p. 199. Chem. Abst., Vol. VI, 1912, p. 1732. Jour. Soc. Chem. Ind., Vol. XXXI, 1912, p. 391.
[5] United States Patent, 1,127,506, 1915.
[6] British Patent, 27,150, Nov. 25, 1913.

Cito,[1] after experimenting with other processes, patented the following treatment for ores from Cobalt, Canada. The raw ore was treated in a reverberatory furnace with copper and fluxes. Two products were obtained, viz., an alloy containing the copper and all the silver, nickel, cobalt, and arsenic; and a slag. The alloy was cast from the furnace into anode moulds. The metals were recovered by electrolysis, using an electrolyte of copper sulphate, and sheet copper cathodes. The copper was deposited on the cathodes in a pure form, the silver precipitated as slime, and the cobalt and nickel remained in solution. The arsenic was found partly in solution and partly as slime.

From the electrolyte containing copper, cobalt, nickel, and arsenic, copper was precipitated in the cold solution, and arsenic later in the hot solution, by hydrogen sulphide. The cobalt nickel solution was treated to recover the cobalt and nickel by the ordinary processes.

Andre[2] attempted to recover cobalt and nickel from a cobalt-nickel matte as an anode and using an electrolyte of dilute sulphuric acid or ammoniacal cobalt sulphate. A frame containing granulated metal was placed between the anode and cathode and on this copper and silver were precipitated.

Vortmann[3] proposed a process to obtain by electrolysis cobaltic oxide or hydrate from solutions containing cobalt and nickel. This process was based on the assumption that if a current is passed through solutions of cobalt and nickel containing no alkaline sulphates or other neutral salts of the alkalies, cobaltous and nickelous hydrates or basic salts of both form at the cathode. If the current is reversed the nickelous hydrate or corresponding basic salt dissolves, while cobaltous hydrate is oxidized to cobaltic hydrate. On changing the current to its original direction more of each lower hydrate is produced, and on again reversing the current the nickel is dissolved. In this way all the cobalt is finally precipitated as hydrate, and all the nickel remains in solution. If there is a small quantity of a chloride present in the liquid (equivalent to 1 per cent. of common salt), the cobaltous hydrate is very quickly oxidized to the higher compound by the small amount of chlorine or hypochlorous acid set free. In this case the constant change of current is unnecessary.

The separation of cobalt is assisted by gentle warming. After the precipitation is completed, the current is stopped and the liquid heated to 60° or 70° C. whereby any small quantity of nickelic hydrate remaining in the cobalt compound is dissolved. The nickel solution when filtered does not contain any cobalt.

Guiterman[4] has patented a process to extract cobalt oxide by electrolyzing a nickel and cobalt solution containing chlorides. The chlorine liberated at the anode reacts with the electrolyte to form hypochlorite, the hypochlorite reacting with the cobalt in solution to form hydrated oxide of cobalt and some free hydrochloric or sulphuric acids. To prevent the electrolyte becoming too acid, in which case the cobalt hydrate would redissolve, sodium carbonate solution is added.

[1] Cito, Trans. Amer. Electrochemical Soc., Vol. 17, 1910, p. 239.
[2] Ouvrard, p. 265
[3] German Patent, No. 78,236, May 10, 1894, Schnabel, Vol. II, p. 608.
[4] United States Patent 1,195,211, August 22nd, 1916.

The firm of Basse and Selve, Altena, Germany, have suggested a process[1] which consists first in adding certain organic salts to neutral or slightly acid solutions containing nickel, cobalt, iron and zinc, such as will prevent the precipitation of their oxides by alkalies. Such are acetic acid, citric acid, glycerine, and dextrose. The solution is made alkaline by soda or potash lye, and subjected to electrolysis with a current of 2.8 to 9.3 amperes per square foot. Iron, cobalt and zinc are deposited on the cathode, while nickel either remains entirely in the liquid or precipitates partly as hydrate, according to the alkalinity of the solution. The precipitation of the hydrate occurs if the current is continued for a long time. To the nickel solution free from other metals, ammonium carbonate is added to form carbonate of all the free alkali, after which it is electrolyzed. Nickel is formed as a bright deposit on the cathode.

Coppet[2] smelted ore to obtain a matte, which was ground and roasted to form oxides of copper, nickel, and cobalt. The oxides were reduced to the metallic state, then treated with a solution of a cupric salt. The copper was precipitated afterwards by metallic cobalt and nickel. No further explanation is given of this process. In another process the same author roasted matte to form sulphates or chlorides by the addition of salt. Copper was removed as above.

To treat nickel ores or products containing cobalt, the following methods have also been suggested. The complete treatment is not given in all cases but only those parts which differ from other processes.

Laugier[3] dissolved the ore in nitric acid, and evaporated the solution, the arsenic being precipitated as oxide during the evaporation or later by hydrogen sulphide. The solution was filtered, and heated till the excess of sulphuretted hydrogen was expelled, then the iron was oxidized. Sodium carbonate was added in excess, while the liquor was hot, to precipitate the nickel and cobalt in the form of carbonates, and the iron as hydrate. The precipitate was then washed and digested with an excess of oxalic acid solution, the soluble ferric oxalate being separated by filtration from the oxalates of nickel and cobalt which are insoluble even in excess of oxalic acid. The latter salts were mixed with dilute ammonia in a closed vessel. (Stromeyer[4] recommends strong ammonia), to dissolve the oxalates. The filtered solution, after exposure to the air for several days, deposited nickel ammonium oxalate and manganese oxalate, while the pure oxalate of cobalt remained in solution. The oxalate of nickel separated as above can be freed from the small quantity of the cobalt salt which precipitates with it, by re-treatment with ammonia. The residue, obtained by evaporating the ammoniacal solution of the cobalt oxalate, yielded sesquioxide of cobalt when ignited in the air, or metallic cobalt when ignited out of contact with the air.

Guesneville[5] treated cobalt ore with nitric acid, the iron and arsenic being removed as ferric arsenate by the addition of potassium carbonate. The cobalt was precipitated as oxalate by potassium acid oxalate.

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[1] Schnabel, p. 591.
[2] Ouvrard, p. 261. Jour. Soc. Chem. Ind., Vol. XII, 1893, p. 274.
[3] Laugier, Annales de Chemie et de Physique, Paris, Vol. IX, 1818, p. 698.
[4] Stromeyer, Jour pract. Chemie, Vol. LXVII, 1856, p. 185.
[5] Guesneville, Gmelin Kraut, Handbuch der anorganischen Chemie, Band 5, 1, 1909, p. 192.

De Witt[1] treated speiss with aqua regia and removed the excess acid. Ammonium chloride and ammonia were then added, followed by additions of potassium acid oxalate. The cobalt was recovered as oxalate.

Loujet[2] dissolved cobalt ore with hydrochloric acid, and to the solution a ferric salt was added, followed by additions of potassium carbonate, calcium carbonate, or calcium hydroxide. The iron and arsenic were precipitated as an insoluble ferric arsenate.

Wöhler[3] fused cobalt speiss with potassium carbonate and sulphur in the ratio 1: 3: 3. Most of the metals were converted into simple sulphides, but the arsenic sulphide formed a soluble potassium sulphoarsenate. The temperature had to be regulated so that the cobalt sulphide did not fuse, since it would enclose portions of the soluble sulphoarsenate.

Hermkstädt[4] fused cobalt glanco with potassium nitrate, and the arsenic was removed as potassium arsenate.

Patera[5] roasted ore with additions of carbon, then fused the product with calcium nitrate, soda, and potassium nitrate. Arsenic was removed as soluble arsenates of calcium, soda, and potassium. Nickel was precipitated from the solution by potassium or ammonium bisulphate as a difficultly-soluble complex salt containing only a small quantity of the cobalt compound.

Liebig[6] roasted the ore, then mixed it with ferrous sulphate and potassium bisulphate, and fused the mixture. The arsenic was removed as insoluble ferric arsenate. Ferrous sulphate was added before fusion to prevent the formation of cobalt arsenate. During the final stages of the fusion, the nickel sulphate was decomposed, forming oxide which did not dissolve with the cobalt. Cobalt carbonate was afterwards precipitated by the addition of potassium carbonate.

Barton and McGhie[7] suggested fusing arsenical minerals with sufficient sodium carbonate to combine with the arsenic to form soluble sodium arsenate.

McKenna[8] fused cobalt and nickel speiss with boric acid about equal in weight to the cobalt in the speiss. The heavier speiss separates from the lighter cobalt borate slag.

To separate cobalt from nickel, iron and manganese, the following processes have been suggested:

Sack,[9] by the addition of lead peroxide to a solution of cobalt, manganese, aluminum, and iron salts, precipitated hydrates of manganese and aluminum, basic ferric-sulphate and lead sulphate, practically all the cobalt remaining in solution. Any copper was first removed, and then the solution was mixed with a calculated amount of peroxide of lead. In case iron was present in large quantities, it was

[1] Jour. prakt. Chemie, Leipzig, Vol. 71, 1857, p. 239.
[2] Loujet, Monit. Indust., 1849, p. 1309. Jour. Soc. Chem. Ind., Vol. 1, 1882, pp. 258-259.
[3] Wöhler, Annalen der Physik and Chemie, Vol. VI, 1826, p. 227.
[4] Hermkstädt, Jour. für Chemie und Physik, Vol. XXXI, 1821, p. 105.
[5] Patera, Jour. prakt. Chemie, Vol. XVIII, 1830, p. 164.
[6] Liebig, Annalen der Physik und Chemie, Vol. XVIII, 1830, p. 164.
[7] French Patent, No. 387,766, Jan. 28th, 1908.
[8] United States Patent No. 1,166,067, Dec. 28th, 1915.
[9] Sack, German Patent No. 72,579, 1892.

precipitated after the copper with an alkaline or alkaline-earth carbonate. If a large amount of manganese was present, it was removed by fractional precipitation with a soluble alkaline or alkaline-earth sulphide.

Iron was precipitated from a cobalt nickel solution by additions of cobalt hydrate.[1]

To a solution containing cobalt, nickel and iron, soda was added which precipitated the iron, then ammonium chloride was added followed by potassium hydrate, and the mixture heated. Nickel hydroxide was precipitated, the precipitation of cobalt hydroxide being proportional to the decomposition of the ammonium chloride.[2]

Solutions containing cobalt, nickel, iron and manganese were treated with sodium acetate and heated, the iron being precipitated. Cobalt was precipitated from the neutral solution by hydrogen sulphide, the manganese acetate not being decomposed. Before the treatment with sodium acetate, the copper and arsenic were removed with hydrogen sulphide in an acid solution. Precipitation of the cobalt may also be made by the addition of potassium or barium sulphide. The sulphide precipitate was washed with cold dilute hydrochloric acid, which removed the sulphides of manganese, zinc, and iron, the cobalt sulphide remaining undissolved.[3]

A neutral solution of cobalt and nickel is mixed with potassium nitrite, potassium cobalt nitrite being formed. The presence of lime interferes with this separation, as a potassium lime nickel nitrite is precipitated at the same time.[4]

Barton and McGhie[5] separate cobalt and nickel from chloride solutions by subjecting the slightly acidified solution to fractional crystallization.

Miscellaneous Processes Summarized

Hybinette[6] outlines a process of separating copper from cobalt and nickel. The ore is roasted and the product separated by magnetic concentration. The magnetic concentrate, containing copper, cobalt, and nickel, is smelted to form a matte, which is roasted and leached with dilute sulphuric acid. A solution containing principally copper, and only small amounts of iron and cobalt, is obtained.

It has been proposed[7] to produce from sulphide ores a matte free from iron, and containing only sulphur, nickel, and cobalt. This matte was fused under a blast on a bed of quartz and sodium silicate in order to produce a silicate of cobalt. The latter compound was fused with soda and nitre to liberate the cobalt oxide. The method, however, does not appear to have come into use.

Richer[8] gives an interesting account of an old method to separate cobalt from nickel by crystallization from a solution containing a large quantity of ammonium sulphate. Mention is also made of the possibility of removing copper from cobalt oxide by heating with ammonium chloride.

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[1] Loujet, Monit. Indust., 1849, p. 1309.
[2] Phillips Wittstein, Repertorium für die Pharmacie, Vol. 57, p. 226.
[3] Wackenbroder, Gmelin Kraut, Handbuch der anorganischen Chemie, Band V, I, 1909, p. 193.
[4] Stromeyer, Jour. prakt. Chemie, Vol. LXVII, 1856, p. 185.
[5] German Patent 222,231, 1905. Metallurgie. Vol. VII, 1910, pp. 667-674.
[6] United States Patent, No. 1,098,443, June 2nd, 1914.
[7] Schnabel, Vol. II, p. 601.
[8] Tilloch, Phil. Mag., Vol. XIX, 1804, pp. 51-54.

Bücholz[1] outlines a method proposed to prepare cobalt and nickel oxides by dissolving the hydroxides in ammonia after precipitation.

Hauer[2] describes Patera's application of analytical methods for the production of cobalt and nickel oxides. In the process the iron and arsenic were precipitated with powdered calcium carbonate, the cobalt by calcium bleach, and the nickel by milk of lime.

Vivian[3] was granted a patent covering a process based on the affinity cobalt and nickel have for arsenic. In the specifications the claim is made that it is possible to separate cobalt and nickel from copper by regulating the amount of arsenic, and by having some sulphur present to combine with the copper.

Wright[4] proposed extracting cobalt and nickel from waste solutions from copper refining, by adding milk of lime, which precipitated the metals. After drying the precipitate it was mixed with sand, 15 to 20 per cent. of residue from the alkali works, 15 to 20 per cent. of carbon, and, if possible, with products containing arsenic. The cobalt and nickel were recovered as speiss.

Careis[5] proposed the following method to extract cobalt from ores. The ore was first dissolved in hydrochloric acid. The metals in solution were precipitated with soda, and the precipitate dissolved in sulphuric acid. The solution was neutralized with hot dilute sulphuric acid, whereby the copper and other metals, especially iron, were precipitated, the cobalt and nickel remaining in solution. The solution was mixed with hot ammonium or potassium sulphide, which precipitated the nickel. Metallic zinc was added to precipitate the cobalt from sulphate solution.

Grosse-Bohle[6] patented a process to precipitate cobalt and nickel from sulphate and chloride solutions by means of zinc.

Aaron[7] proposed precipitating cobalt and nickel from solutions as methylsulphocarbonates.

Neill[8] described the method used to treat the Mins la Motte ores.

Pelatan[9] published a clear description of the Herrenschmidt process as used at the Malétra works, Rouen, France.

Herrenschmidt and Capelle[10] issued a report for the French Government on the following processes: Carnot, Readman, Herrenschmidt, Clarke, Dixon, and Ratte.

Kripp[11] attempted to recover cobalt and nickel from copper ores containing silver. The silver was changed to chloride and removed, after which operation the

[1] Tilloch, Phil. Mag., Vol. XXIII, 1805, pp. 193-199.
[2] Jour. prakt. Chemie, Vol. LXVII, 1856, pp. 14-24.
[3] British Patent No. 13,800, Nov. 4, 1851; Percy, Metallurgy: Fuel, Clays, Copper, Zinc, etc., 1861, pp. 375-378.
[4] Bull. Soc. Chem., Vol. V (1st series), 1866, 475-476.
[5] Berg. u. hüttenm. Zeitung, Vol. XL, No. 23, 1881, pp. 215-216.
[6] German Patent No. 97,114, 1898. Abst. Fischer's Jahresbericht, Vol. XLIV, 1898, pp. 169-170.
[7] United States Patent, No. 330,454, Nov. 17th, 1885.
[8] Trans. Amer. Inst. Min. Eng., Vol. XIII, 1884-1885, pp. 634-639. Eng. Min. Jour., Vol. XXXIX, 1885, pp. 108-109.
[9] Genie Civil, Vol. XVIII, 1891, pp. 373-374.
[10] Moniteur Industriel, Vol. XV, 1888, pp. 145, 156, and 162.
[11] Wagner's Jahresbericht, Vol. XIV, 1868, pp. 111-112.

sulphur was precipitated with barium chloride, the iron by calcium carbonate, and the cobalt by a solution of calcium hypochlorite, stopping the precipitation at a reddish-coloured solution.

Hoepfner[1] was granted a patent covering the following process of treating cobalt ores. A matte was first produced, which was afterwards ground and treated with a cupric chloride solution. By this treatment the sulphides are dissolved, forming cuprous chloride. The metals were removed by electrolysis.

Hanes[2] gave some results obtained from the action of ammonia on cobalt-nickel arsenides. Hydroxides of cobalt and nickel are formed which dissolve in excess of ammonia. The metals may be obtained by electrolysis or by precipitation.

Metals Extraction Corporation[3] patented a process for the extraction and recovery of cobalt and nickel from ores and oxidized mattes. The ore or roasted matte was treated with magnesium chloride solution under pressure. The cobalt dissolved before the nickel.

Pederson[4] gave the results of an investigation of treating cobalt and nickel ores. The article deals more with ordinary chemical reactions.

Borchers[5] gave the following description of a process to treat ores and smelter products containing cobalt, nickel, and silver. The ores or products were first treated with alkaline bisulphate below 200° C., then roasted at 600 to 700°. The product was leached to remove the soluble sulphates. Refractory ores were first roasted with carbon.

Bernard[6] separated cobalt from nickel by precipitating the cobalt by hypochlorite that had been previously neutralized and freed from alkaline carbonates and caustic alkalies.

Lance[7] patented a process to separate the hydroxides of copper, zinc, cadmium, silver, nickel, cobalt, and tungsten. The process was based on fractional precipitation by ammonia.

Johnson[8] described a process for the treatment of copper matte containing cobalt, as follows. Matte containing copper 39 per cent., iron 1, cobalt 1, and sulphur 20 per cent., was crushed to 80-mesh and leached with hot 10 per cent. hydrochloric acid. The solution contained cobalt, nickel, and iron. The cobalt and iron were removed by treatment with chlorine and sodium carbonate or by hypochlorites.

Schreiber[9] devised the following process for the separation of cobalt, nickel, and manganese from crude liquors. The iron was precipitated first by the addition

[1] British Patent, No. 11,307, 1894. Abst. Jour. Soc. Chem. Ind., Vol. XIV, 1895, p. 754.
[2] Jour. Can. Min. Inst., Vol. VIII, 1905, pp. 358-362.
[3] French Patent, No. 367,717, July 4th, 1906. Jour. Soc. Chem. Ind., Vol. XXV, 1906, p. 1155.
[4] Metallurgie, Vol. VIII, 1911, p. 335. Abst. Jour. Soc. Chem. Ind., Vol. XXX, 1911, p. 900.
[5] British Patent, No. 18,276, August 8th, 1912. Jour. Soc. Chem. Ind., Vol. XXXII, 1913, p. 980.
[6] French Patent, No. 354,941, June 5th, 1905. Jour. Soc. Chem. Ind., Vol. XXIV, 1905, p. 1177.
[7] French Patent No. 342,865, May 3rd, 1904, second edition, Jan. 9th, 1905. Jour. Soc. Chem. Ind., Vol. XXIV, p. 845, 1905.
[8] United States Patent, No. 825,056, July 3rd, 1906.
[9] German Patent, No. 203,310, Sept. 29th, 1907. Jour. Soc. Chem. Ind., Vol. XXVII, 1908, p. 1158.

of calcium carbonate, then the copper by passing in hydrogen sulphide, and finally the cobalt practically free from nickel and manganese was precipitated with calcium hypochlorite. After removing the cobalt the precipitation was continued to precipitate the nickel and manganese, which was dissolved and re-precipitated.

Foote and Smith[1] discuss the dissociation pressures of certain oxides of copper, cobalt, nickel, and antimony.

Chesneau[2] prepared a number of the higher sulphides of cobalt and nickel and determined their solubility.

Mourlot[3] conducted a few experiments to determine the effect of high temperatures on copper, bismuth, silver, tin, nickel, and cobalt sulphides. He found cobalt sulphide is obtained by heating the anhydrous sulphate. At a high temperature it loses all the sulphur, the metal combining with any carbon present.

Manhès[4] claims to have devised an improved process for the treatment of arsenical and sulphide ores of cobalt and nickel. He first produced a speiss or matte which is either dissolved in hydrochloric acid or by electrolysis; or in a second dry refining process, air is blown through the matte which oxidizes the iron and sulphur. The metallic oxides formed by roasting were reduced to metal by carbon and lime, and the metal was used as anodes in the electrolytic refining. In a later patent[5] Manhès suggests adding coke in a converter for blowing matte. He also tried to prepare metallic cobalt and nickel from matte by adding fluxes to remove the sulphur.[6]

Garnier[7] also proposed blowing matte in a converter.

Langguth[8] describes a process used to smelt the cobalt and nickel ores of Norway. The ores were smelted in a blast furnace to produce a matte containing 30 per cent. cobalt and nickel. This was concentrated in a converter to 75 per cent., producing a slag containing 1 to 2 per cent. cobalt and nickel. The blowing operation required 20 to 25 minutes. Reference is also made to Manhès' work.

Savelsburg[9] described a process of blowing nickel and cobalt matte in a converter. Ground matte was blown without the application of heat to oxidize the iron without changing the sulphur content. The product was in a sintered condition satisfactory for melting.

Savelsburg and Papenburg[10] patented a process to convert oxide ores, especially those of cobalt and nickel, into sulphides. Crushed ore was mixed with sulphides and carbon, and briquetted. These were heated in a kiln furnace.

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[1] Jour Amer. Chem. Soc., Vol. XXX, 1908, pp. 1344-1250.

[2] Comp. Rend., Vol. CXXIII, 1896, pp. 1068-1071. Abst. Jour. Chem. Soc. (London), Vol. LXXII (2), 1897, p. 172.

[3] Comp. Rend., Vol. CXXIV, 1897, pp. 768-771. Abst. Jour. Chem. Soc. (London), Vol. LXXII, 1897, pp. 372-373.

[4] Jour. Soc. Chem. Ind., Vol. IV, 1885, p. 120.

[5] British Patent, No. 17,410, 1888; German Patent, No. 47,444, 1888.

[6] Jour. Soc. Chem. Ind., Vol. XIV, 1895, p. 581. British Patent, 6,914, 1894; German Patent, No. 47,427, 1894.

[7] Eng. and Min. Jour., Vol. XXXVI, 1883, p. 393.

[8] Min. and Sci. Press, Vol. LV, 1888, p. 102.

[9] German Patent, No. 222,231, Jan. 21st, 1908. Abst. Jour. Soc. Chem. Ind., Vol. XXIX, 1910, p. 1257.

[10] German Patent, No. 172,128, Jan. 21st, 1905. Abst. Fischer's Jahresbericht, Vol. LII, 1906, pp. 222-223.

Becquerel[1] applied the electric current to remove cobalt from solutions. The electrolysis was carried on in a cobalt chloride solution that had been neutralized with ammonia or caustic potash. Cobalt was deposited as a brilliant coating. Of the chlorine part escaped and part formed acid. The presence of too much acid gave a dark deposit.

Cohen and Solomon[2] were granted a patent for the electrolytic separation of cobalt from nickel. The addition of strongly oxidizing agents, especially persulphates, cause the precipitation of the cobalt first.

Le Roy[3] described an electrolytic method to extract cobalt and nickel.

Armstrong[4] patented a process for the treatment of complex cobalt ores and for refining cobalt and nickel arsenical and silver-bearing ores. The metals were obtained as chlorides, from which the cobalt was precipitated electrolytically as oxide.

Burlet[5] attempted to extract cobalt, nickel or copper from ores or products as follows. The silicate ore or slag was fused to remove the greater part of the copper as impure metal. The slag was then ground and treated with sulphuric acid. The iron and part of the copper were precipitated with calcium carbonate. The remaining copper, cobalt, and nickel were removed by electrolysis.

Wiggin and Johnstone[6] suggested improvements in the preparation of cobalt and nickel oxides. A cobalt-nickel-copper solution was electrolyzed, using a copper or brass cathode and a carbon anode. The copper was deposited, leaving in solution the cobalt and nickel, which were recovered in the ordinary way.

Martin[7] reduced cobalt and nickel as well as other metals in the ores by passing hydrocarbons over the ore at a bright red heat. The metals were afterwards recovered as an alloy by melting.

Mindeleff[8] attempted to extract cobalt and nickel from ores by reducing the compounds with hydrocarbons, and removing the metals obtained with a magnet.

Berndorfer Manufacturing Company[9] produced malleable and ductile nickel and cobalt by mixing the powdered metal with potassium permanganate, maximum 4 per cent., and melting the mixture.

Selve and Lotter[10] obtained nickel and cobalt free from oxides by the addition of 1.5 per cent. manganese during melting.

Krupp[11] found that cobalt and nickel were not malleable owing to the presence of carbon, but that the defect could be removed by adding manganate or permanganate of potash.

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[1] Comp. Rend., Vol. LVIII, 1862, pp. 18-20.
[2] German Patent, No. 110,615, 1900. Fischer's Jahresbericht, Vol. XLVI, 1900, p. 157.
[3] Bull. Soc. Industrielle de Mulhouse, Procès-verbeaux, Vol. LXXI, 1901, pp. 154-155.
[4] United States Patent, No. 881,527, March 10th, 1908.
[5] British Patent, No. 27,150, Nov. 25th, 1913. Abst. Jour. Soc. Chem. Ind., Vol. XXXIII, 1914, p. 1014.
[6] British Patent, No. 3,923, March 27th, 1885. Abst. Jour. Soc. Chem. Ind., Vol. V, 1886, p. 172.
[7] German Patent, No. 18,303, June 1st, 1881. Fischer's Jahresbericht, Vol. XXVIII, 1882, p. 120.
[8] British Patent, No. 10,491, Sept. 4th, 1885. Abst. Jour. Soc. Chem. Ind., Vol. IV, 1885, p. 746.
[9] German Patent, No. 28,989, 1884.
[10] German Patent, No. 32,006, 1885. Abst. Fischer's Jahresbericht, Vol. XXXII, 1886, p. 158.
[11] British Patent, No. 1464, 1884. Abst. Jour. Soc. Chem. Ind., Vol. III, 1884, p. 261.

Winkler[1] states that in the preparation of cobalt and nickel castings, a high temperature is necessary, refractory crucibles should be used, carbon and silicon should not come in contact with the molten metal, and that the metal must be protected from the atmospheric oxygen during casting.

Fleitmann[2] proposed a method to remove the brittleness in cobalt and nickel metal by adding magnesium before pouring.

Fink[3] outlines a process for the treatment of ores from Cobalt, Canada. The ore is ground to 40-mesh and mixed with fluxes to reduce the metals and make a slag. The charge is heated in a furnace at a temperature of 1,200 to 1,500° C. under reduced pressure for several hours. The arsenic is volatilized and condensed as metallic arsenic; and metallic silver, cobalt, and nickel speiss and slag are also formed. The products are further treated by known methods.

Levat, in a paper read before the French Association for the Advancement of Sciences, Sept. 29, 1887, gave the results of an investigation of the nickel, cobalt, and chromium ore deposits of New Caledonia.

Heard[4] gave a summary of the possibilities of the New Caledonia deposits.

2.—The Production of Smalt

Smalt is a potash aluminum cobalt silicate. It is prepared by melting together silica, potassium carbonate, and roasted cobalt ore. It was used extensively a number of years ago to produce blue-coloured glass and enamels. Owing to the difficulty in obtaining the same quality of colour intensity with different cobalt ores, the manufacture of smalt has gradually been abandoned. Cobalt oxides of uniform composition can be readily obtained, and these are used at present to prepare the different colours.

The production of smalt was formerly carried on chiefly in Saxony, and it is interesting to note that the Chinese have also prepared smalt for a number of years.

The first record of cobalt being used in Europe to colour glass dates from about 1540. It is stated a Nuremberg glass-maker was the first to try melting cobalt ore, termed "Kobold," with glass, and he obtained, much to his astonishment, a beautiful blue-coloured product.

A brief account of the operations as conducted in Saxony and China is given in the following paragraphs.

The Method Employed in Saxony to Prepare Smalt

The mineral was crushed, sorted and washed. This product, called "Schlich," was roasted in a rotary furnace, any arsenic evolved during the roasting being collected. During the roasting the cobalt was converted into oxide. The roasted product was finely ground and screened through a silk sieve, the powder being known as "zaffer" or "zaffler."

[1] Chem. News, Vol. XXXV, 1877, p. 166.
[2] Chem. News, Vol. XL, 1879, p. 67.
[3] United States Patent, No. 1,013.931, Jan. 9th, 1912.
[4] Eng. Min. Jour., Vol. XLVI, 1888, p. 103

To prepare smalt the roasted ore was mixed with sand and potassium carbonate and melted in a crucible. Crushed quartz was used for sand. Before being crushed, it was heated to a red heat in a lime kiln, crushed in stamp-batteries, washed to remove any light impurities, dried, and again heated to redness. The cobalt, being more readily oxidized than the nickel, passed into the slag, the nickel, combining with any arsenic, forming a speiss which settled to the bottom of the crucible. Any iron present was oxidized to ferric oxide, which is less injurious than ferrous oxide. The speiss was withdrawn either through an opening in the bottom of the crucible or carefully removed with a ladle. The purer the materials employed in the preparation, the more beautiful the product. The blue glass or slag containing the cobalt was poured into water, dried, and finely ground. The ground glass or smalt was mixed with water and allowed to stand for half an hour, during which time the coarse particles, known as "Streublau," settled. The coarse particles were afterwards reground.

The turbid water from the first washing was decanted into a second tank in which the pigment proper, termed couleur, settled to the bottom.

After twenty-four hours the turbid water was decanted into a third tank in which it remained until it was clear, when the finest and palest glass powder, "Aeschel," settled. The pigment, and also the aeschel, was next washed two or three times, the wash waters being filtered. The pigments in the various settling tanks were dried, screened, and packed into barrels.

About three-fifths of the glass taken from the pots was recovered. The presence of oxides other than those of cobalt and potash, even in small quantities, exerts a marked influence on the colour of the smalt. Barium produces an indigo tinge; sodium, calcium, and magnesium produce a reddish shade; iron, a blackish green, very objectionable in the brighter-coloured smalts; manganese, violet; nickel, violet, but less intense; copper, zinc, bismuth, and antimony, dull shades.

The smalt is classified according to its degree of fineness into coarse blue (Streublau) pigment, and Aeschel, the first size being denoted in the trade by H, the second by C, and the finest by E.

Respecting the intensity of the colour, each sort is distinguished as fine, middle, and ordinary by the letters F, M, and O. In the first class, colours of varying degrees of intensity are denoted by the letters, F, FF, FFF, FFFF, expressing two-fold, three-fold, and four-fold respectively. Qualities poorer in cobalt than the OC quality are distinguished by the use of indices, e.g., OC^2 (i.e., containing half the cobalt in the OC quality).

Smalts which contain more cobalt than the F quality are distinguished by doubling the latter F.

More intense than the last, FFFF, which is termed "Azure," or "King's Blue," do not occur.

The following list[1] gives the different brands of smalt:—

H	Ordinary smalt.
E	Aeschel.
B	Bohemian smalt.
CF	Ground pigment.

[1] Grünwald, Raw Materials of the Enamel Industry, 1914, p. 146.

FC ..... Fine pigment.
FCB ..... Fine Bohemian pigment.
FE ..... Finer Aeschel.
MC ..... Average.
MCB ..... Average Bohemian.
ME ..... Average Aeschel.
OC ..... Ordinary pigment.
OCB ..... Ordinary Bohemian pigment.
OE ..... Ordinary Aeschel.

The different colours are spoken of as azure blue, smalt blue, zaffer blue, Saxon blue, enamel blue, cobalt blue, etc.

The following are analyses of some varieties of smalt:

Percentage Composition of Some Typical Smalts

Component	Norwegian Smalt		German Smalt			French Smalt				
	Dark	Dark Aeschel	Pale	Coarse Blue	Pigment C.	I	II	III	IV	V
Silica	70.86	66.20	72.11	72.21	70.11	75	70	65	63	60
Cobalt oxide	6.49	6.75	1.95	20.54	21.58	20	26	30	30	30
Potash	21.41	16.31	1.80	6.75	7.20	2	3	5	7	10
Alumina	0.43	8.64	20.04	0.22	0.11	....	....	....	....	....
Arsenious acid	.....	.....	.....	.....	.....	1	1	1	1	1

There is also a French method of smalt preparation which consists in melting together cobalt oxide with quartz and potash. In this way a first-class product of desired intensity can be prepared, although the process is correspondingly more expensive.

The quartz is heated to redness and ground as in earlier methods, only instead of cobalt speiss pure cobalt oxide is here employed. The smalt so obtained is very pure, and more durable than the ordinary product.

The Chinese Method of Manufacturing Smalt[1]

In the Chinese glass works at Canton, the so-called lam-o-li-shek, i.e., "stone for blue glass," is employed for the production of a blue colour in glass and porcelain. It appears as if the Chinese are unaware how to produce colourless glass. They purchase glass fragments from Europe and America, which they classify according to colour and quality, and melt them in pots, 67 cm. at the top. One or two of these pots are placed in a rectangular furnace of primitive construction, which is heated with anthracite, for which purpose from 150 to 200 kg. of anthracite per pot are required. The blowpipe is short and wide, while the moulds are made of clay and dust. It is astonishing how the Chinese, by means of their small apparatus, are able to separate the cobalt from the iron, manganese and nickel, even when the cobalt content in the ore does not exceed 2 to 4 per cent.

[1] Bowler, Chemical News, Vol. LVIII, 1888, p. 100.

The crude cobalt mineral is first carefully washed, and every piece is scrubbed with a brush, in order to remove the adhering clay which contains iron. The ore is next dried and pulverized, then afterwards ground in a hand mill with water. The whole mixture is then conveyed to a vessel, in which it is vigorously stirred for several hours, after which it is allowed to settle over night. On the following day the water is decanted, taking with it the upper layer of the settled powder. The latter consists of the lighter earthy substances, while the residual mass is the oxides of iron, manganese, nickel and cobalt. This mass is removed, mixed with a small quantity of borax, and placed in one of the above-mentioned pots containing the glass. The melting is now carried out, and during the first twelve hours the fused mass acquires a dirty greenish-black colour. By degrees this mixed colour changes to a bright bluish-violet similar to amethyst. It appears as if the iron and nickel are completely reduced, for after 36 to 40 hours' heating scarcely any of the iron or manganese colour can be detected in the mixture.

The lowest portion of the fused glass in the pot is rejected. This part probably contains the impurities, such as iron, nickel, manganese, etc.

For the purpose of porcelain painting, the Chinese frit the same mineral with feldspar, kaolin, and much borax. This frit is ground to fine powder, and employed for painting on the biscuit. The Canton process is as follows:

The manipulator takes the burnt biscuit and covers this with a glaze consisting of borax, feldspar, and clay, which, when sufficiently dry, he paints upon, and in one single operation burns in both the enamel and colour.

An analysis of the mineral is given as follows: Iron oxide 35.0, Manganese oxide 13.1, Nickel oxide, 3.5, Cobalt oxide, 3.5, gangue 46.0 per cent.

The gangue consisted for the most part of silica and aluminium silicate.

Preparation of Metallic Cobalt

Metallic cobalt may be obtained from the oxide or oxalate by one of the following methods. Cobalt oxide is obtained by heating precipitated cobalt hydroxide or oxalate.

Reduction of the oxide in a carbon crucible or by the addition of carbon or starch.[1]

Reduction of the oxide[2] or oxalate[3] in a stream of hydrogen or hydrocarbons,[4] the reduction being complete at 500 to 600° C.

Reduction of the oxide by carbon monoxide.[5]

Reduction of the oxide by ammonium chloride.[6]

Reduction of cobalt chloride in a current of hydrogen.[7]

Reduction of the oxide by aluminium.[8] Goldschmidt process.

Precipitation from cobalt solutions by metallic magnesium.[9]

[1] Berthier, Annales de Chemie et Physique, Vol. 25, 1824, p. 98. Winkler, Jour. prakt. Chem., Vol. XCI, 1864, p. 213. Kalmus, Preparation of Metallic Cobalt by Reduction of the Oxide: Department of Mines, Canada, Bulletin No. 259, 1913, p. 4. Moissan, Comp. Rend., Vol. 116, 1893, pp. 349-351.

[2] Muller, Annalen der Physik und Chemie, Vol. CXXXVI, 1869, p. 51. Moissan, Annales de Chem. et Physique, 1880, Vol. V, sec. 21, p. 199. Glasser, Zeitschr. anorg. Chem., Vol. XXXVI, 1903, p. 19. Kalmus, Bulletin 259, p. 11.

[3] Wolff, Zeitschr. anal. Chem., Vol. XVIII, 1879, p. 38. Berzelius, Gmelin Kraut, Handbuch der anorganischen Chemie, 1909, Band. 5, 1, p. 194. Brunner, Idem, p. 194.

[4] Martin, German Patent, No. 18303, June 1st, 1881. Fischer's Jahresbericht, 1882, Vol. 28, p. 120.

[5] Mond, Hirtz, and Copaux. Note on a volatile compound of cobalt with carbon monoxide: Chem. News, Vol. XCVIII, 1908, p. 165. Mond Nickel Co., Hirtz, and Copaux, British Patent, No. 13,207, 1908: a patent covering the manufacture of cobalt carbonyl or carbonyls by heating cobalt or material containing cobalt in carbon monoxide or gas containing the latter. Kalmus, Bulletin 259, p. 25.

[6] Rose, Gmelin Kraut, Handbuch der anorganischen Chemie, Band V. 1, 1909, p. 192.

[7] Peligot, Compt. Rend., Vol. XIX, 1844, p. 670. Baumhauer, Zeitschr. anal. Chem., Vol. X, 1871, p. 217. Schneider, Annalen der Physik und Chem., Vol. CI, 1857, p. 387. Wagner, Jahresbericht, 1857, p. 226.

[8] Kalmus, Bulletin 259, p. 32.

[9] Siemens, Zeitschr. anorg. Chem., Vol. XLI, 1904, p. 249.

Distillation of cobalt amalgams.[1]

Electrolytic methods.[2]

Fink[3] proposes the following treatment for the production of metallic cobalt. Powdered smaltite is mixed in the proper proportion with powdered lime and calcium carbide and heated in a vacuum for 1 to 2 hours, at a temperature of 1500° C. The reaction of lime and calcium carbide yields metallic calcium, which in turn reacts with the cobalt arsenide, forming calcium arsenide and metallic cobalt.

Precipitation of cobalt from solutions by zinc.[4]

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Report and Appendix of Royal Ontario Nickel Commission, 1917.

Development of the Metallurgy of the Ontario Silver-Cobalt Ores

In reviewing the development of the metallurgy of the silver-cobalt ores of Ontario, it is necessary to make three divisions, viz., the progress in ore-dressing methods, the introduction of new processes in the extraction of the silver, and the improvements in the treatment of the ores for the cobalt. At the same time, it cannot be too strongly emphasized that co-operation and publicity of results have contributed no small part to the success achieved in the treatment of the Cobalt ores.

The importance of the Cobalt deposits may best be realized from the following figures. In 1903 when the silver deposits of Cobalt were discovered, Canada produced silver valued at $1,709,642, while in 1913 the production was valued at $19,040,924. During the same period the value of the annual production of cobalt rose from practically nothing to $500,000. Besides the value of cobalt, appreciable returns are realized from the arsenic and nickel.

Previous to the discovery of the deposits at Cobalt, most of the world's supply of cobalt ore was shipped from New Caledonia to Europe for treatment. In fact,

[1] Moissan, Compt. Rend., Vol. LXXXIII, 1879, p. 180; Bulletin Soc. Chem., Pt. II, Vol. XXXI, 1879; p. 149; Annalen de Chem. et. Physique, Vol. V, 1880, p. 21, p. 199. Guertler, Metallographie, Vol. I, 1912, p. 513.

[2] Kalmus, Electro-plating with Cobalt, Bulletin No. 334, Department of Mines, Canada, 1915. Becquerel, Comp. Rend., Vol. LVIII, 1862, pp. 18-20.

[3] United States Patent, No. 1,119,588, Mineral Industry, Vol. XXIII, 1914, p. 548.

[4] Careis, Berg-u. huttenm. Zeitung, Vol. XL, No. 23, 1881, pp. 215, 216.

until 1908 Europe practically controlled the world's production. In 1908 cobalt products from Canadian and American smelters were placed on the market, and this caused the price of cobalt oxide to fall from $2.00 to $1.00 a pound. Cobalt oxide is at present (1917) selling for $1.50 per pound.

Progress in Ore Dressing

The progress in ore dressing at Cobalt has been brought about by the diminution in the grade of the ore and the attempt to obtain increased recoveries. At first the high-grade ore (2,000 oz. or more) was readily hand-picked from the low-grade and shipped as such. In order to keep up the grade of the shipments, concentration methods were introduced extensively during 1907-1908. For the coarser crushing it is customary to use one of the following combinations: stamps crushing to approximately 20-mesh; crushing in stamps to 0.25-inch, followed by sizing and concentrating, the fine tailing going to waste, the coarse being reground in pebble mills; and crushing in rolls or in ball mills to about 0.25-inch, concentrating, and regrinding the tailing in pebble mills. In 1914 about 75 per cent. of the ore milled was crushed by stamps to 14 to 20-mesh.

Classification is used extensively to separate the sand from slime. In the concentrating mills hindered-settling types of classifiers are employed, while in the cyaniding plants the Dorr classifier is common. For sand concentration the Wilfley, James, and Deister tables are mostly used, while for treating slime the James and Deister tables are preferred, although canvas tables were employed to some extent. The sand tailing averages 3 to 4 ounces and the slime tailing 6 to 8 ounces of silver per ton, but it is not possible to recover the silver from these products by the ordinary gravity concentration methods. The average ratio of concentration in the Cobalt mills is 50 to 1.

The recovery of the silver from the tailing dumps and low-grade ores has been one of the problems that has confronted the metallurgists at Cobalt for some time. At present there are about 2,500,000 tons of tailing, averaging 4 to 6 ounces of silver. To treat these accumulated residues and the low-grade ores, flotation methods seem most suitable. In October, 1915, the first experimental flotation plant was erected by the Buffalo Mines, Limited. This plant consisted of a two-compartment, standard length Callow rougher cell, and a one-half size Callow cleaner cell. The results obtained by flotation were so encouraging that a flotation plant to handle 600 tons daily was erected and put into operation in September, 1916. At present the Buffalo Mines, McKinley-Darragh-Savage Mines, Nipissing Mines, Coniagas Mines, Dominion Reduction Co., Northern Customs Concentrators, and National Mines (King Edward) employ the Callow system of flotation.

To prepare the tailings and low-grade ores for flotation, fine grinding to 100-mesh is necessary. Pebble mills are commonly used for this purpose. The oil used consists of a mixture of 15 per cent. pine oil, 75 per cent. coal tar creosote, and 10 per cent. coal tar. Further experiments have shown that an oil obtained from the distillation of hard wood in charcoal plants is well suited for flotation. The results obtained by flotation are about as follows: feed 6 to 10 oz. of silver, concentrate 250 to 1,000 oz., tailing 0.8 to 2.5 oz., and a recovery of 80 to 90 per cent.

The recovery of the silver from the flotation concentrate has been accompanied with difficulties, and at present most of the concentrate is shipped to the smelters in the United States. Under present conditions the freight and treatment charges on the flotation concentrate amounts to about 20 per cent. of the value of the product. The flotation concentrate produced at the Buffalo Mines was treated at Cobalt. The method employed is to give the concentrate a roast with salt, a leach with hydrochloric acid, and a treatment with salt solution, the silver being finally recovered by precipitation on scrap copper, and the copper by passing the solution over scrap iron. The above treatment has been discontinued by the Buffalo Mines company, but is still being practised by the Dominion Reduction company.

Progress in the Metallurgy of Silver

In the early operation of the Cobalt camp, most of the silver was recovered by smelting methods, the ore shipped averaging 2,000 ounces or more per ton. The presence of large quantities of arsenic caused trouble in the smelting and refining processes, and it was necessary for the smelters to levy a penalty on excessive quantities. There was also a high treatment charge because of the difficulty in smelting the high-grade silver ores. The freight rate on the high-grade ore was also heavier.

In order to obtain a better return from the silver contents of the high-grade ore, experiments were undertaken to devise a process for treating the high-grade ores at Cobalt and obtaining the silver as bullion. The Nova Scotia mill, now the Dominion Reduction, was the first to recover bullion by amalgamation and cyanidation. This mill treated the run-of-mine ore, which included the high-grade, and produced bullion and a residue assaying about 150 ounces of silver per ton. The Nipissing improved on the process by substituting a tube mill for the amalgamating pan. The combination process of amalgamation and cyanidation is used at three mills, viz., the Nipissing and Buffalo on high-grade ore and concentrates, and the Dominion Reduction on concentrates only. The process is usually carried out as follows: With 2,500 oz. ore, a charge would be 6,500 pounds of 20-mesh ore, 8,500 pounds of mercury, 3,800 pounds of 5 per cent. cyanide solution, and 6 tons of pebbles. After 9 to 10 hours' treatment the pulp will all pass a 200-mesh screen, and contain about 50 oz. of silver per ton. It is given a further agitation for 36 hours in a 0.75 per cent. cyanide solution when the silver is reduced to 30 ounces.

The treatment of low-grade ores at Cobalt has for a number of years presented a difficult but interesting problem. It is possible to treat the low-grade ores by concentration methods, by a combination of concentration and cyaniding, and by flotation. It appeared as if flotation in combination with concentration or cyanidation was the most suitable, but recent developments tend in some cases to favor concentration and cyanidation. Very little cobalt and nickel are recovered in the flotation concentrate.

Amalgamation was not practicable on low-grade ores, so attention was turned toward cyanidation. After extensive experiments it was found that it was not possible to treat the low-grade complex ores by the ordinary cyanide process, because the solutions quickly became foul, thereby diminishing the dissolving

power; besides, the cyanide consumption was excessive. To overcome these difficulties a process known as the "Wet Desulphurizing Process" was devised by the Nipissing Mining Company.

Briefly, this process consists in giving the ground ore a treatment with alkali and aluminium. The preliminary treatment is given in tube mills, and the final treatment in tanks. In the preliminary treatment the ore is ground in an 0.25 per cent. caustic soda solution with an addition of 5 pounds of lime per ton of ore. The lime is added to hasten settling. In the process the refractory minerals, especially pyrargyrite and proustite, are decomposed, the sulphur, arsenic, and antimony being reduced to the elemental or metallic state. The reduced sulphur, arsenic, and antimony have practically no action on cyanide. The reactions involved may be expressed as follows:

$$2Al+2\ NaOH+2H_2O=Na_2Al_2O_4+6H.$$
$$6H+3\ Ag_2S+6NaOH=3Na_2S+6H_2O+6Ag.$$
$$6H+Ag_3SbS_3+6NaOH=3Na_2S+6H_2O+3Ag+Sb.$$
$$6H+Ag_3AsS_3+6NaOH=3Na_2S+6H_2O+3Ag+As.$$

With fine grinding and after treating the ore by the wet desulphurizing process, the silver may be readily extracted in 48 hours by treatment with a 0.25 per cent. cyanide solution. By the desulphurizing treatment a saving of one to four ounces of silver is obtained at an additional cost of 54 cents per ton of ore. On a 20-ounce feed a saving of four ounces means an increased extraction of 20 per cent.

The precipitation of the silver from the cyanide solutions by zinc presented a further difficulty, but the substitution of aluminium dust overcame this. The advantages of the aluminium dust in precipitation may be stated as follows: a high-grade precipitate is obtained, there is little fouling of the cyanide solutions, and during the precipitation an amount of cyanide proportional to the silver precipitated is regenerated. One part of aluminium dust will precipitate about three parts of silver. Aluminium dust was used until 1916, but owing to the difficulty of obtaining it and also to the increased cost, other precipitants are being tried. At present at the Nipissing mill sodium sulphide is used to precipitate the silver, and the sulphide precipitate is desulphurized by treatment with caustic soda and aluminium, metallic silver being produced.

Aluminium dust precipitation was first used by the Deloro Smelting and Refining Company, then by the O'Brien mine, and later by the Nipissing and Buffalo and other mines at Cobalt.

Progress in the Metallurgy of Cobalt and Nickel

Before the discovery of the large silver-cobalt-nickel deposits at Cobalt, very little was known in Canada of the properties and metallurgy of the metal cobalt and its compounds, except that cobalt silicate possessed a beautiful colour and was used in the ceramic industries. Cobalt was considered one of the rarer metals.

Cobalt ores had been treated in Europe for centuries, but the treatment was conducted on a small scale, and the methods were what might be called large laboratory methods. There were about 25 plants operating in Europe, and these

were producing about one-half the quantity of cobalt that is now being turned out annually by the three Canadian smelters. The method formerly employed was to dissolve the ore, matte or speiss in either hydrochloric or sulphuric acid, and remove the impurities by chemical methods. The copper was often removed by hydrogen sulphide gas, and after eliminating any gas in solution by boiling, the iron, cobalt, and nickel were precipitated. The high price of cobalt oxide enabled the operators to work on a small scale, even though the grade of the ore would not average over 3 per cent. cobalt.

After the discovery of the cobalt deposits in Canada, it soon became evident that they were of sufficient extent to justify the attempt to establish a cobalt smelting industry in Canada. It was soon seen that new processes would have to be devised, or the old methods improved. The cost of acids and chemicals, the operating difficulties, and the higher cost of labour made the old processes prohibitive in Canada, and at the same time it was not possible to operate them on a considerable scale. The larger proportion of cobalt and the presence of large quantities of arsenic in the Canadian ores, also made it necessary to modify the older processes.

In the processes in use in Canada at present, the gangue minerals, and most of the arsenic and iron are removed in blast furnaces. The products of the blast furnace are: metallic silver, an argentiferous speiss containing cobalt, nickel, and iron as arsenides, also slag and flue dust. The large quantities of silver and arsenic in the cobalt-nickel ores are a source of revenue to the smelters. The argentiferous speiss made in the blast furnace is roasted to about 10 per cent. arsenic, given a chloridizing roast, and the product cyanided. The successful cyanidation of such a complex furnace product was a new departure in cyaniding. The residue is sulphated with sulphuric acid, and the iron is rendered insoluble by heating. In this treatment with acid the cobalt and nickel dissolve, as well as some of the iron and arsenic. The iron and arsenic must be removed before the precipitation of the cobalt and nickel, with solutions of bleaching powder. The grade of cobalt oxide produced by the Canadian smelters is considerably better than that produced by the European refineries. The production of a higher grade oxide at a lower price was necessary to compete with and secure the closely controlled trade of Europe. Both these difficulties were finally overcome by the improvements in and the efficiency of the Canadian processes.

In summarizing, it may be stated that the progress in the metallurgy of cobalt and nickel has not been owing so much to the introduction of new methods as to the development of the old ones on a larger and more efficient scale.

The general progress in the development of the metallurgy and ore dressing of the silver-cobalt-nickel ores has been due to the grade and value of the ore, and to the co-operation of the operators. It would be impossible to mention all those who have contributed to the success of the Cobalt camp, but special mention should be made of the work of Reid and Moffat in ore dressing; of Denny, Fairlie, Jones, and Clevenger in the metallurgy of silver; and of Kirkpatrick and Peek in the metallurgy of cobalt and nickel.

The wet desulphurizing process used in connection with the low-grade ores, and the introduction of the use of sodium sulphide to precipitate the silver,

were developed by J. J. Denny, metallurgist of the Nipissing Mining Company. Prof. S. F. Kirkpatrick was the first to introduce the use of aluminium dust for the precipitation of silver, but his chief work has been in the development of the metallurgy of cobalt and nickel. Under his direction the Deloro Smelting and Refining Company has become the largest smelter treating cobalt ores and also, due mostly to his initiative, a plant has been erected to smelt the complex cobalt ores of Missouri. Difficulties have constantly arisen in the treatment of ores of cobalt, but these have always been solved. The excellent work of Prof. Kirkpatrick in the development of the metallurgy of cobalt-nickel ores has been recognized by the profession, since in 1917 he was awarded the McCharles medal of the University of Toronto.

CHAPTER III

THE CHEMISTRY OF COBALT

The word cobalt is synonymous with "kobold," meaning goblin, which was a term given by the early miners to those ores which did not yield metal on smelting. It is stated[1] that an early form of the word cobalt appears in the writings of Basilius Valentinus about the end of the 15th century. Berthelot[2] states that the word is of Graeco-Egyptian origin. In Hoover's translation of Agricola's De Re Metallica, mention is made of the word cobalt as being from the Greek, cobalos.

The use of cobalt compounds for colouring glass was known to the ancients and, since 1600, cobalt minerals have been used for the preparation of smalt. In 1735 Brandt prepared some metallic cobalt by reduction from the ore.

Polished cobalt metal is silvery white in colour, but when reduced from the oxide, it is in the form of gray powder. The specific gravity varies from 8.79 on an unannealed sample to 8.92 on a swaged sample. The melting point of cobalt is given as 1478°C., and the tensile strength at about 34,400 pounds per square inch.[3] Metallic cobalt is magnetic. The atomic weight is 58.97.

Cobalt is soluble in dilute acids. The metal forms three oxides: cobaltous oxide (CoO) greenish gray; cobaltous cobaltic oxide (Co_3O_4) black; and cobaltic oxide (Co_2O_3) brownish. Cobaltous oxide is obtained from Co_3O_4 by heating at a high temperature. The usual method of preparing the oxides is to calcine, at a red heat, the hydroxide obtained by precipitation in one of the processes mentioned under the Metallurgy of Cobalt.

Cobalt forms with acids two compounds, cobaltous and cobaltic. Cobaltous compounds are pink in the crystallized state or in aqueous solutions, but yellow or green in the anhydrous condition, and blue when in aqueous solutions in the presence of hydrochloric acid.

By dissolving any of the three oxides in acids, salts derived from cobaltous oxide are always obtained, containing bivalent cobalt:

$$CoO+2HCl=H_2O+CoCl_2.$$
$$Co_2O_3+6HCl=3H_2O+2CoCl_2+Cl_2.$$
$$Co_3O_4+8HCl=4H_2O+3CoCl_2+Cl_2.$$

Simple cobaltic salts are unknown, but many complex compounds exist with trivalent cobalt, as, for example, potassium cobaltinitrite, potassium cobalticyanide, and numerous cobalti-ammonia derivatives.

Reactions of Cobalt Salts[4]

Potassium or sodium hydroxide precipitates in the cold a blue basic salt:

$$CoCl_2+KOH=KCl+Co(OH)Cl,$$

which on warming is further decomposed by hydroxyl ions, forming pink cobaltous hydroxide:

$$Co(OH)Cl+KOH=KCl+Co(OH)_2.$$

[1] Gmelin Kraut, Handbuch der anorganischen Chemie, Band V, 1, 1909, p. 190.
[2] Idem, p. 190.
[3] Kalmus, The Physical Properties of Cobalt, Bulletin 309, Department of Mines, Ottawa, Canada, 1914.
[4] A number of the following reactions are taken from Treadwell Hall, Analytical Chemistry, Vol. I, fourth edition, 1916.

In the case of a moderately concentrated solution of the alkali the precipitate of pink cobaltous hydroxide is often produced in the cold, sometimes only after standing for some time. The rapidity of the reaction depends entirely upon the concentration of the alkali.

Cobaltous hydroxide gradually turns brown in contact with the air, forming cobaltic hydroxide:

$$2Co(OH)_2+H_2O+O=2Co(OH)_3.$$

In this respect cobalt behaves similarly to iron and manganese, but differs from nickel, for the hydroxide of the latter is not oxidized by atmospheric oxygen.

On adding chlorine, bromine, hypochlorites, hydrogen peroxide, etc., to an alkaline solution containing cobaltous hydroxide, cobaltic hydroxide is immediately formed, as with nickel and manganese:

$$2Co(OH)_2+2NaOH+Cl_2=2NaCl+2Co(OH)_3.$$

$$2Co(OH)_2+H_2O+NaOCl=NaCl+2Co(OH)_3.$$

From ammoniacal cobalt solutions the above oxidizing agents cause no precipitation, but merely a red colouration; the addition of potassium hydroxide then causes no precipitation, whereas in the case of nickel, a precipitate is formed.

Cobaltous hydroxide—$Co(OH)_2$, behaves under some conditions as a weak acid, for on adding to a cobaltous solution a very concentrated solution of KOH or NaOH the precipitate at first produced dissolves with a blue colour similar to that formed with copper compounds. By the addition of Rochelle salts, $KNaC_4H_4O_6$, to this blue cobalt solution the colour either disappears almost entirely or becomes a pale pink, while the similarly treated copper solution becomes more intensely blue. By the addition of potassium cyanide to the blue cobalt solution it becomes yellow, and in contact with air turns intensely brown. A copper solution would be decolourized by the addition of potassium cyanide.

By pouring a little cobalt solution (or adding a little solid cobalt carbonate) into a concentrated solution of caustic soda or potash, to which a little glycerol has been added, a blue solution is formed (the colour being intensified by warming), which after standing some time in the air, or immediately on the addition of hydrogen peroxide, becomes a beautiful green.

Ammonia precipitates, in the absence of ammonium salts, a blue basic salt, soluble, however, in excess of ammonium chloride. Ammonia, therefore, produces no precipitate in solutions which contain sufficient ammonium chloride. The dirty yellow ammoniacal solution is little by little turned reddish on exposure to the air, owing to the formation of stable cobalti-ammonia derivatives:

$$Co(OH)_2+2NH_4Cl+2NH_3=Co(NH_3)_4Cl_2+2H_2O.$$

Alkali carbonates produce a reddish precipitate of basic salt of varying composition.

Ammonium carbonate also precipitates a reddish basic salt, soluble, however, in excess.

Barium carbonate does not precipitate cobalt in the cold and out of contact with air, but on exposure to the air cobaltic hydroxide is gradually thrown down. The precipitation takes place much more quickly on the addition of hypochlorites or hydrogen peroxide:

$$2CoCl_2+2BaCO_3+3H_2O+NaOCl=NaCl+2BaCl_2+2CO_2+2Co(OH)_3.$$

If the solution is heated to boiling, all of the cobalt is precipitated as a basic salt, even out of contact with the air.

Hydrogen sulphide produces no precipitate in solutions containing mineral acids. In neutral solutions containing an alkali acetate, all of the cobalt is precipitated as black sulphide.

Ammonium sulphide precipitates a black sulphide,

$$CoCl_2+(NH_4)_2S=2NH_4Cl+CoS,$$

insoluble in ammonium sulphide, acetic acid, and very dilute hydrochloric acid; soluble in concentrated nitric acid and aqua regia, with the separation of sulphur:

$$3CoS+8HNO_3=4H_2O+2NO+3S+3Co(NO_3)_2.$$

By continued action of strong nitric acid all the sulphur goes into solution as sulphuric acid.

Potassium cyanide produces in neutral solutions a reddish brown precipitate, soluble in excess of potassium cyanide in the cold, forming brown potassium cobaltocyanide:

$$CoCl_2+2KCN=Co(CN)_2+2KCl.$$

$$Co(CN)_2+4KCN=K_4[Co(CN)_6].$$

On warming the brown solution for some time it becomes bright yellow and gives an alkaline reaction. It now contains potassium cobalticyanide, of analogous composition to potassium ferricyanide.

The formation of the cobaltic salt takes place in the presence of atmospheric oxygen:

$$2K_4Co(CN)_6+O+H_2O=2KOH+2K_3Co(CN)_6.$$

The reaction takes place more quickly in the presence of chlorine, bromine, hypochlorites, etc.:

$$2K_4Co(CN)_6+Cl_2=2KCl+2K_3Co(CN)_6.$$

An excess of chlorine, bromine, etc., does not decompose the cobaltic salt; in this particular it differs from nickel.

The cobalticyanide anion is much more stable than the cobaltocyanide anion. By adding hydrochloric acid to the brown solution of potassium cobaltocyanide, hydrogen cyanide (prussic acid) will be set free and yellow cobaltous cyanide formed,

$$K_4Co(CN)_6+4HCl=4HCN+4KCl+Co(CN)_2,$$

while potassium cobalticyanide is not decomposed by hydrochloric acid.

Potassium cobalticyanide forms, with most of the heavy metals, difficulty soluble or insoluble salts possessing characteristic colours. Thus, it produces with cobaltous salts pink cobaltous cobalticyanide:

$$2K_3[Co(CN)_6]+3CoCl_2=6KCl+Co_3[Co(CN)_6]_2,$$

and with nickel salts greenish nickel cobalticyanide. If, therefore, a cobalt solution contains nickel it forms, when treated with sufficient potassium cyanide to redissolve the cobalt precipitate, boiled, and acidified with hydrochloric acid, a greenish precipitate of nickelous cobalticyanide:

$$2K_3[Co(CN)_6]+3K_2[Ni(CN)_4]+12HCl=12HCN+12KCl+Ni_3[Co(CN)_6]_2.$$

Potassium nitrite produces in concentrated solutions of cobalt salts, in the presence of acetic acid, an immediate precipitation of yellow crystalline potassium cobaltic nitrite. If the solution is dilute, the precipitate appears only after standing for some time, but more quickly on rubbing the sides of the beaker.

The reaction takes place in the following stages:

$$CoCl_2+2KNO_2 \rightleftarrows Co(NO_2)_2+2KCl.$$

$$2KNO_2+2HC_2H_3O_2=2KC_2H_3O_2+2HNO_2.$$

The free nitrous acid oxidizes the cobaltous nitrite to cobaltic nitrite,

$$Co(NO_2)_2+2HNO_2=H_2O+NO+Co(NO_2)_3,$$

which now combines with more potassium nitrite:

$$Co(NO_2)_3+3KNO_2=K_3Co(NO_2)_6.$$

This reaction offers an excellent means of detecting the presence of cobalt in nickel salts.

Potassium nitrite produces in dilute nickel solutions no precipitate. In very concentrated solutions a brownish-red precipitate of $Ni(NO)_2.4KNO_2$ is thrown down; in the presence of alkaline earth salts a yellow crystalline precipitate is formed; e.g., $Ni(NO_2)_2.Ba(NO_2)_2.2KNO_2$, which is very difficultly soluble in cold water, but readily soluble in boiling water, with a green colour.

Ammonium thiocyanate (Vogel's reaction): If a concentrated solution of ammonium thiocyanate is added to a cobaltous solution, the latter becomes a beautiful blue, owing to the formation of ammonium cobaltous thiocyanate:

$$CoCl_2+2NH_4CNS=2NH_4Cl+Co(CNS)_2.$$

$$Co(CNS)_2+2NH_4CNS=(NH_4)_2[Co(CNS)_4].$$

On adding water the blue colour disappears and the pink colour of the cobaltous salt takes its place. If, now, amyl alcohol is added (or a mixture of equal parts of amyl alcohol and ether), and the solution shaken, the upper alcoholic layer is coloured blue. This reaction is so sensitive that the blue colour is recognizable when the solution contains only 0.02 milligrams of cobalt. The blue solution also shows a characteristic absorption spectrum. Nickel salts produce no colouration of the amyl alcohol. If, however, iron is present, the red $Fe(CNS)_3$ is formed, which likewise colours the amyl alcohol, making the blue colour due to the cobalt, indistinct, so that, under some conditions, it cannot be detected. If, a little sodium carbonate solution or a few c.c. of concentrated ammonium acetate and 2 or 3 drops of 50 per cent. tartaric acid are added, the iron will be precipitated, the red colour produced by $Fe(CNS)_3$ will disappear, and the blue colour produced by the cobalt will be seen.

The above reaction serves as an excellent means of detecting cobalt in the presence of nickel.

Ether saturated with hydrochloric acid does not precipitate an anhydrous cobaltous salt, as in the case of nickel, but will dissolve the blue, anhydrous cobaltous chloride. This furnishes the basis of a method for separating nickel and cobalt.

α-Nitroso-β-naphthol, $C_{10}H_6(NO)OH$, produces a voluminous, purple red precipitate of cobalti-nitroso-β-naphthol, $[C_{10}H_6(NO)O]_3Co$, which is insoluble in cold, dilute nitric or hydrochloric acid.

This reagent serves not only for qualitative purposes, but can also be used for the quantitative determination of cobalt in the presence of nickel. The test may be applied conveniently to the solution obtained in the usual qualitative scheme after the removal of all metals except nickel and cobalt. A part of the solution may be used for the sensitive nickel test with dimethylglyoxime, and the

remainder used for the cobalt test. To test for cobalt dilute the solution to about 50 c.c., add 4 c.c. of 6N hydrochloric acid and 20 c.c. of 6N acetic acid. Heat and add 50 c.c. of a saturated solution of nitroso-β-naphthol and boil in 50 per cent. acetic acid. If as much as 0.1 mg. of cobalt is present, a red precipitate or turbidity is obtained even in the presence of 250 mg. of nickel. When more than 150 mg. of nickel are present, however, some of the brownish-yellow nickel compound, $[C_{10}H_6(NO)O]_2Ni$, will precipitate after the solution cools.

The reagent used in this test should be freshly prepared. Nitroso-β-naphthol gradually decomposes on standing in the air, and changes from yellow to brown or even black in colour. It can be purified by dissolving in hot sodium carbonate, filtering, and reprecipitating with sulphuric acid. For ordinary purposes the saturated solution in 50 per cent. acetic acid is most suitable. The cobalt test can be made more delicate by adding an equal volume of alcohol to the test and, for detecting traces of cobalt, an aqueous solution of the organic substance can be used, but as 5,000 c.c. of water are required to dissolve 1 gram of the nitroso-β-naphthol, it is evident that the aqueous solution is not suitable when much cobalt is present. An excess of the reagent is required, as a part of it is used to oxidize the cobalt to the trivalent condition.

Copper gives a characteristic coffee-brown precipitate with the reagent, and it is possible to separate copper from lead, cadmium, etc., by means of it. Ferric iron gives a brownish-black precipitate which serves as a means of separating iron from aluminium, manganese, etc. Ferrous iron also gives a greenish precipitate in neutral solutions. Of all these precipitates, however, the cobalt compound is the most characteristic and the least influenced by the presence of acid. Thus with the acidity recommended above, the presence of a little ferric or ferrous iron causes no disturbance.

Reactions in the Dry Way

The bead produced by borax or sodium metaphosphate with cobalt salts is blue in both the oxidizing and reducing flames. By holding the bead in a reducing flame for a long time it is possible to reduce the cobalt to metal, when it appears, like nickel, gray.

On charcoal, cobalt compounds yield gray metallic cobalt, which can be removed by means of a magnet. The metal is placed on filter-paper, dissolved in hydrochloric acid and dried. The paper is then coloured blue by cobalt. If, now, sodium hydroxide is added and the paper exposed to the action of bromine vapours, black cobaltic hydroxide, $Co(OH)_3$, is formed.

Salts of cobalt when strongly heated with alumina give a blue-coloured compound, Thenard's blue, possibly $CoOAl_2O_3$.

Quantitative Determination of Cobalt and Nickel

In Oxidized Ores

The colorimetric method outlined below was used to determine cobalt and nickel in the ores of New Caledonia.

A 10 gram sample of the finely ground mineral was treated with hydrochloric acid and boiled to obtain complete decomposition and also to expel the chlorine

which is set free in the reaction. By this treatment all the metals should be converted to soluble chlorides, leaving a residue of silica.

The solution was diluted to 100 c.c., the iron precipitated by powdered $CaCO_3$ or CaO, and the solution filtered. To the filtrate one or two drops of hydrochloric acid were added to remove any turbidity due to calcium carbonate. The clear solution was then poured into a standard colorimetric flask or tube and compared with standard colours. For the series of standard colours a solution of cobalt chloride was used. To prepare the cobalt chloride, a weighed quantity of cobalt nitrate was calcined, and the oxide obtained dissolved in concentrated hydrochloric acid. After the excess acid was removed, the cobalt chloride was dissolved and diluted to give solutions of the desired strength. Standard solutions containing from 0.25 to 5.0 per cent. cobalt oxide were prepared, the different solutions varying by 0.25 per cent. It was possible to determine the cobalt in New Caledonia ores colorimetrically to within 0.25 per cent.

Care must be taken in the preparation of colorimetric solutions to add a small quantity of nickel chloride (about one-third the contained cobalt chloride), for account must be taken of the nickel which the asbolite contains. The amount usually varies between one-half to one-third of the cobalt. Green nickel chlorides decrease a little the rose colouration of cobalt chloride, hence the addition of nickel chloride to the standards.

Electrolytic Determination of Cobalt and Nickel

In Oxidized Ores

The asbolite of New Caledonia contains silica, alumina, chromium, iron, manganese, nickel, and cobalt.

Thirty grams of finely pulverized mineral were treated with concentrated hydrochloric acid until decomposition was complete. In case the mineral was not completely decomposed, the hydrochloric acid solution was allowed to settle, and the clear liquid decanted through a filter. The residue was then heated with a little hydrochloric acid and a small quantity of nitric acid. After removing the excess acid, the solution was diluted and filtered. The residue was washed several times by decantation and finally it was brought into a filter and washed well with boiling water. The last portions filtered should be free from iron, the filtrate being tested by potassium ferrocyanide or sulphocyanide. The filtrates were combined and diluted to 900 c.c.

The residue contained the silica, silicates of alumina, chromite, etc.

To 150 c.c. corresponding to 5 grams of ore, a little sulphuric acid was added and the solution boiled. If any nitric acid was present the solution was evaporated to sulphuric fumes. If the evaporation was necessary, the solution was afterwards diluted to 100 c.c. In either case the iron was reduced by zinc or cadmium shavings, and titrated with standard potassium permanganate. Before titrating it was customary to test for any unreduced iron with potassium ferrocyanide.

From another 150 c.c., the iron, aluminium, and chromium were precipitated. The greater part of the acid was neutralized by sodium carbonate and then a quantity of ammonium chloride was added, followed by additions of barium or

calcium carbonate. The solution was allowed to stand, with frequent stirring, to permit the oxide of chromium to be completely decomposed. After filtering, the precipitate was washed until the wash water did not show a precipitate on the addition of ammonium sulphide. The precipitate was dissolved in hydrochloric acid. From the diluted solution the iron, aluminium, and chromium hydroxides were precipitated by ammonia after the addition of several grams of ammonium chloride. This precipitation is repeated to remove any traces of barium or calcium carbonates.

The precipitate was dried and calcined. By subtracting the weight of iron found previously, the weight of the combined aluminium and chromium oxides was obtained. The precipitate was fused with sodium peroxide and the chromium determined by acidifying the sodium chromate solution, adding a standard ferrous sulphate solution and titrating with permanganate. The alumina was determined by difference.

From the 600 c.c. of solution, the iron, aluminium, and chromium were precipitated by calcium carbonate. After filtering and washing the precipitate, the solution was divided into two parts for the separation of manganese, nickel, and cobalt.

To one-half of the filtrate, which contained the manganese, nickel, and cobalt in 10 grams of ore, sodium carbonate was added in excess, then acetic acid to dissolve the precipitate. Thirty to fifty c.c. of sodium acetate were added to the solution which was afterwards saturated with hydrogen sulphide; the solution being kept at 70°C. The precipitated sulphides of cobalt and nickel were removed by filtering and washed. The filtrate was tested for unprecipitated cobalt and nickel by additions of small quantities of ammonium sulphide which gives a black precipitate with cobalt and nickel salts. Ammonium sulphide was added to the filtrate to precipitate manganese sulphide, a flesh-coloured precipitate. The manganese sulphide was dissolved in hydrochloric acid and the manganese determined as manganese dioxide.

The precipitate of cobalt and nickel sulphides was dissolved in aqua regia and evaporated to dryness. A few c.c. of sulphuric acid were added and the solution heated to remove any volatile acids and destroy any organic matter. The solution of nickel and cobalt sulphates was diluted, neutralized with ammonia, and electrolyzed in a slightly acid solution.

To separate the cobalt and nickel, the metals were dissolved in nitric acid which was removed by evaporation and additions of hydrochloric acid. The almost neutral hydrochloric acid solution was saturated with chlorine gas or bromine, then an excess of calcium or barium carbonate was added. The solution was diluted and allowed to stand.

The cobalt hydrate was precipitated while the nickel remained in solution. Instead of chlorine or bromine, solutions of sodium hypochlorite or hypobromite may be used.

Another method (Rose's method) to separate the cobalt and nickel was to precipitate in a cold neutral solution, the cobalt hydrate by additions of barium or calcium carbonates in the presence of bromine water or chlorine gas. The

use of barium carbonate and bromine was preferred. If the solution became acid, thus delaying and even stopping the precipitation, carbonate was added, the CO_2 expelled, and the solution cooled before adding the bromine water.

Zinc acts like carbonic acid, the smallest quantity retarding the precipitation. The composition of the precipitated black oxide was determined by dissolving in a mixture of HCl, adding potassium iodide and determining the iodine set free.

The above outline of the method of analyzing cobalt ores of New Caledonia was given by Beltzer.[1]

In Arsenical Ores

To 0.5 or 1.0 grams of ore add 10 c.c. of hydrochloric and 5 c.c. of nitric acid. After the action has ceased, add 20 c.c. of (1:1) sulphuric acid, evaporate to sulphuric fumes, and fume for five minutes. In most cases the treatment with hydrochloric and nitric acid may be omitted. To the cool sulphuric acid solution add 10 c.c. of cold water, then 15 c.c. of hydrochloric acid, sp. gr. 1.19 and heat on the hot-plate. Evaporate gently to fumes, then add 5 c.c. of nitric acid and the solution is again heated to fumes. After this operation there should be about 5 c.c. of H_2SO_4 present. About 90 per cent. of the arsenic is volatilized by this treatment.[2] The remainder of the arsenic and any copper are precipitated by H_2S from a hot solution containing 10 c.c. of hydrochloric acid in 100 c.c. of solution. The arsenic sulphide should be completely precipitated and coagulated in five to ten minutes. The solution is filtered using a 15 cm. No. 1 F. Swedish filter paper and the precipitate washed with hot H_2S water. The filtrate may be tested for unprecipitated arsenic by passing H_2S gas through the second time.

The clear filtrate is boiled to expel any H_2S, then 5 c.c. of hydrogen peroxide is added to oxidize the iron. Ammonia is added in excess to precipitate the iron. There is usually a sufficient quantity of ammonium salts present to prevent the precipitation of the cobalt and nickel. After the addition of ammonia, the solution is boiled, and the precipitate allowed to settle, filtered, and washed with hot water. As there is a tendency for the iron precipitate to retain some cobalt and nickel, the precipitate is dissolved in hot (1:4) H_2SO_4, diluted to 200 to 300 c.c., oxidized with hydrogen peroxide, reprecipitated with ammonia and treated as above. The combined filtrates are evaporated to 250 c.c. and electrolyzed. About 40 to 50 c.c. of ammonia should be present in the electrolyte. The addition of 0.5 grams of sodium sulphite before electrolyzing gives a better deposit. For each assay a current of 0.25 amperes running overnight is used with the ordinary stationary platinum electrodes. The best results are usually obtained when there is not more than 0.15 grams of metal on the cathode. With revolving anodes a much shorter time is required.

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[1] Beltzer, La Chimie Industrielle Moderne, 1911.

[2] The writer is indebted to W. L. Rigg, chief chemist of the Deloro Smelting and Refining Company, for the outline of the above method of removing most of the arsenic by volatilization. The volatilization of arsenic chloride is not new, but the writer is advised that T. Melvor, a former chemist at Deloro, was the first to apply the method in the assays for cobalt and nickel.

When the cobalt-nickel solutions contain a large percentage of iron, it is advisable to precipitate cold and afterwards boil the solution. When using a revolving anode, it is not necessary to remove the iron before plating unless present in large quantity.

To test for any cobalt and nickel not deposited, remove a few c.c. of the electrolyte and add a few drops of ammonium sulphide. The formation of a black precipitate shows the presence of cobalt or nickel. The electrolyte may also be tested by removing a few c.c. and adding a few c.c. of dimethylgloxime. Ammonium salts give a yellow colour, cobalt a brown colour, while nickel gives a red precipitate. The last of the nickel appears to be deposited after the cobalt.

After the deposition is complete the electrodes are washed and dried with alcohol and weighed.

The cobalt and nickel is removed from the electrode by placing it in a beaker containing about 7 c.c. of hot nitric acid. The electrodes are allowed to remain in the acid for 10 minutes, any undissolved metal being removed by tilting the beaker and turning the electrode in the acid. The electrode is washed with hot water, and the solution is evaporated to about 1 c.c. or less. Dilute to 10 c.c., neutralize with caustic potash and add sufficient hydrochloric acid from a pipette to dissolve any precipitate and four drops in excess. Then dilute to 50 to 150 c.c., depending on the quantity of nickel, (the larger volume with larger amounts of nickel), and boil the solution. To the hot solution add a sufficient quantity of a 1 per cent. alcoholic solution of dimethylglyoxime to combine with the nickel and cobalt. Nickel requires 5 and cobalt 1.7 times its weight of dimethylgloxime. A few c.c. of the reagent in excess is necessary. When the solution is made slightly alkaline with ammonia a red precipitate of the nickel salt of dimethylglyoxime is formed. An excess of ammonia should be avoided, four drops are usually sufficient. After allowing the precipitate to stand for 30 minutes, filter into a weighed Gooch crucible. The precipitate is washed with hot water, dried at 105°C., and weighed. The weight of the precipitate multiplied by 0.2031 gives the weight of nickel. The weight of cobalt is found by difference. The dimethylglyoxime method of precipitating nickel is especially adapted for determining small amounts of nickel in the presence of large amounts of cobalt. It is satisfactory also when the nickel is high, but the quantity of solution taken should be such that there will not be more than 0.05 grams of nickel present.

The action of dimethylglyoxime on the nickel salt is as follows:

$$2\ \begin{matrix}CH_3—C=NOH\\ CH_3—C=NOH\end{matrix} + NiCl_2 + 2NH_3 = 2NH_4Cl + (C_8H_{14}N_4O_4)Ni.$$

According to L. Tschugaeff,[1] who first proposed this qualitative test, the presence of one part of nickel can be detected in the presence of 400,000 parts of water. The reaction is not influenced by the presence of ten times as much cobalt. When a larger proportion of cobalt is present the following procedure is adopted to detect traces of nickel in cobalt salts. Add strong ammonia to the solution of the cobalt salt until a clear solution is obtained, then add a few cubic centimetres of hydrogen peroxide and boil the solution a few minutes to decompose

[1] Berichte der Deutschen chemischen Gesellschaft, 1905, p. 2520.

the excess of this reagent. Then add the dimethylglyoxime and again bring the solution to a boil. A very small quantity of nickel causes a red scum to form and the sides of the beaker become coated with a film of red crystals. With smaller amounts of nickel the colour is best observed upon the filter through which the solution is poured and the precipitate being washed with hot water.

The above reaction is the most sensitive test known for detecting nickel in the presence of cobalt.

Separation of Cobalt from Nickel by Nitroso-β-Naphthol

Nickel and cobalt may also be separated by the use of Nitroso-β-Naphthol. This separation depends on the solubility of the nickel compound in hydrochloric acid, while the cobalt compound is insoluble.

To proceed with this method the metals are removed from the electrodes as above, 5 c.c. of sulphuric acid added, and the solution evaporated to sulphuric fumes. Cool, dilute and add 5 c.c. of concentrated hydrochloric acid. A freshly prepared hot solution of nitroso-β-naphthol in 50 per cent. acetic acid solution is added to the cobalt-nickel solution as long as a precipitate continues to form. The precipitate is allowed to settle and the solution tested for any cobalt. The solution is filtered, the precipitate washed, first with cold water, then with warm 12 per cent. hydrochloric acid to remove any nickel. Finally wash with hot water until free from acid. The precipitate is dried and heated strongly to convert the cobalt compound to oxide. After the carbon of the filter paper is all consumed, the cobalt is reduced to metal by heating in a current of hydrogen.

The disadvantages of the nitroso-β-naphthol method are, first, the precipitate cannot be converted to oxide and weighed because of the variable composition of the oxide, and second, the operation of reducing the oxide to metal requires more time and attention than the dimethylglyoxime method.

Separation of Cobalt and Nickel by Potassium Nitrite

After dissolving the cobalt and nickel in nitric acid, the solution is evaporated to a thick syrup. From 5 to 10 c.c. of water is added, and the solution neutralized by potassium hydrate. Any precipitate is dissolved in acetic acid, usually adding 8 c.c. of 1:1 acid in excess. The cobalt is precipitated as yellow tri-potassic-cobaltic nitrite by the addition of a 50 per cent. solution of potassium nitrite, the amount depending on the percentage of cobalt present. An excess of potassium nitrite is required, but usually 10 to 15 grams should be present in each assay. The solution is allowed to stand in a warm place for 15 hours, when the precipitate should have settled to the bottom of the beaker. The solution may be tested for unprecipitated cobalt by removing a portion, adding more nitrite, and allowing the solution to stand for an hour.

The solution is filtered and the precipitate washed with a 5 per cent. solution of potassium nitrite acidified with acetic acid, or with a 10 per cent. solution of potassium acetate, until the precipitate is free from nickel. The filter is removed from the funnel and spread on the inside of the beaker in which the precipitation was made. Most of the precipitate may be removed by a stream of hot water, while any remaining on the paper is dissolved by hot dilute sulphuric acid. The cobalt solution is evaporated to sulphuric fumes, cooled, diluted, made ammoniacal, and electrolyzed. The nickel is obtained by difference.

Separation of Zinc from Cobalt and Nickel

The usual method given to separate zinc from cobalt and nickel is to precipitate the two latter metals by hydrogen sulphide in a neutral, acetate, or formic acid solution.[1] Funk suggests neutralizing the solution with sodium carbonate and formic acid, and adding sodium formate equal to approximately three times the weight of the zinc. The quantity of cobalt and nickel present also has an effect on the purity of the precipitate and the completeness of the precipitation.

Zinc may be separated from cobalt by adding to a neutral solution potassium cyanide until any precipitate which forms is redissolved, then 10 c.c. of a 10 per cent. solution of potassium sulphide. After standing for 1-2 hours the zinc sulphide may be removed by filtration.

It is also possible to separate cobalt and nickel from zinc by electrolysis at 2.1-2.2 volts. With higher voltages the zinc is deposited.

Determination of Cobalt and Nickel in Cobalt Metal[2]

One gram of drillings contained in a 150 c.c. conical flask provided with a trap (made of a calcium chloride tube) is treated with 20 c.c. of hydrochloric acid, sp. gr. 1.12. A gentle heat is applied until all action ceases. One c.c. of nitric acid sp. gr. 1.4 is added to dissolve any remaining metallic residue. As soon as the action of the nitric acid is complete, the trap is rinsed, removed, and the solution evaporated to a syrup. The contents of the flask are taken up with 30 c.c. of water and filtered.

The siliceous residue on the filter is washed with water acidulated with a few drops of hydrochloric acid, incinerated, and fused with five times its weight of potassium pyrosulphate. The fusion is dissolved in a little water, and added to the main filtrate. The slightly acid solution of the metal is warmed and saturated with hydrogen sulphide. The sulphides of arsenic, copper, etc., are removed by filtration, thoroughly washed with acidulated hydrogen sulphide water (1 c.c. HCl: $100H_2O$) and the filtrate caught in a 350-c.c. casserole.

To expel the H_2S, the contents of the casserole are evaporated to a small volume. The iron is oxidized with a few drops of bromine, 0.2 grams of ammonium chloride added, and the evaporation continued to dryness at water-bath temperature.

The dry chlorides are dissolved in a little water, 0.1 gram of ammonium formate added, and the whole diluted to 50 c.c. The solution is heated until a precipitate of basic formate of iron separates. Very dilute ammonia is added until the solution is only slightly acid. After further heating for a few minutes, the precipitate of basic iron formate is allowed to settle, filtered, and washed with a hot dilute (0.1 per cent.) solution of ammonium formate.

The washed iron precipitate is dissolved off the filter with hot dilute (1:5) hydrochloric acid, the filtrate being caught in the casserole in which the iron precipitation was made. The solution of the iron precipitate is neutralized with ammonia, ammonium formate added, and the iron precipitation repeated in a volume of about 50 c.c. The precipitate is filtered and washed with the hot dilute ammonium formate solution as before.

The combined filtrates from the two iron separations are evaporated with

[1] These methods are summarized by Funk, Zeitschr. anal. Chemie, Vol. 46, 1907, pp. 93-106.

[2] Knittel, Can. Min. Jour., Vol. 36, 1915, p. 597.

the addition of 8 c.c. of concentrated sulphuric acid until fumes of sulphuric acid are copiously evolved.

The sulphates are dissolved in water and transferred to a 180 c.c. tall beaker, keeping the volume of the solution about 50 c.c. Sixty c.c. of ammonia, sp. gr. 0.9 is gradually added to the solution in the beaker (kept cool in running water) followed by 10 c.c. of 20 per cent. ammonium bisulphite solution.

The cobalt and nickel are deposited together with a current of 2.5 amperes. When the solution is colourless, the cover glass and the sides of the beaker are rinsed with water, and the current, reduced to 0.5 amperes, is allowed to pass until a few c.c. of electrolyte tested with potassium sulphocarbonate show that the cobalt and nickel are completely deposited. The cathode is removed with the usual precautions, dried, and the deposited cobalt and nickel weighed.

The cobalt and nickel are dissolved from the cathode with 30 c.c. of nitric acid (1:3), the cathode rinsed, removed, and the solution of the metals boiled to expel nitrous fumes. The solution is diluted to 500 c.c., neutralized with ammonia, made faintly acid with nitric acid, heated to about 50 to 60°C. and the nickel precipitated with a 1 per cent. alcoholic solution of dimethylglyoxime, followed by 10 c.c. of a 20 per cent. ammonium acetate solution.

The precipitate is allowed to stand for four hours, filtered on asbestos, washed twice with hot water, re-dissolved, and the precipitation repeated in a volume of 200 c.c.

After standing for an hour in a warm place, the nickel precipitate is filtered into a Gooch crucible, washed with hot water, and dried at 130 to 140°C. for forty-five minutes. The weight of the precipitate multiplied by 0.20316 gives the nickel. The amount of cobalt is found by difference.

Notes and Precautions.—Cobalt metal usually contains from 98 to 98.5 per cent. cobalt plus nickel. For this reason the amount of 0.2 to 0.3 grams of material recommended by some for the determination of the cobalt and nickel seems scarcely sufficient, as the weighing errors involved would appreciably affect the results. The use of large quantities of acids for solution and oxidation is to be condemned, as the removal of the excess consumes time and increases the chances of mechanical loss.

The separation of iron as basic formate is preferred on account of the ease with which it can be washed, and the formates are completely decomposed on evaporation with sulphuric acid.

The presence of acetates in the electrolyte seems to retard the complete deposition of the last traces of nickel. In one instance on electrolyzing a solution from metal containing 97.5 per cent. of cobalt and 0.8 per cent. of nickel, in the presence of acetates one milligram of nickel was found in the electrolyte 30 minutes after complete deposition of the cobalt. The volume of the electrolyte should be kept within the limit specified above, as the complete deposition of the metals from dilute solutions is unnecessarily prolonged.

It has been found that the amount of cobalt and nickel remaining in the electrolyte after electrolysis is less than 0.01 per cent. on a one gram sample.

The cathodes used are of the perforated type with an effective surface of 90 square centimetres. The anodes are spirals made of 0.04 inch wire, 0.6 inch diameter, and have about 6 turns.

Dry Assay for Nickel and Cobalt [1]

In this assay advantage is taken (1) of the facility with which nickel and cobalt may be concentrated in combination with arsenic to form a speiss; (2) of the order of oxidation of the metals which the speiss may contain, viz., iron, cobalt, nickel, and copper, and the colours they impart to borax. They are removed in the order named. Iron gives a brownish colour to borax, cobalt a blue, nickel a sherry-brown, and copper a blue. Hence, on scorifying the speiss with borax, the colour imparted by the oxide produced indicates the metal being removed. By careful and frequent examination of the colour resulting and the renewal of the borax it is possible to find the point at which first the iron and then the cobalt and nickel are removed. A greenish tint is imparted to the borax at the moment the cobalt begins to scorify, succeeded by a full blue (with fresh borax), followed by a greenish tint when the nickel commences to pass out. This changes to the full sherry-brown, and is followed by a greenish tint when copper commences to oxidize.

Careful examination and much care are necessary to obtain even fair results. By weighing the button at the various stages, the proportion of its constituents may be determined. If copper be present, 1 gram of gold is added to the button after the removal of the cobalt.

Assay of Ores and Speiss.

From 5 to 25 grams of the ore are finely powdered and passed through an 80-mesh sieve and calcined "sweet." At the end of the roasting some finely ground anthracite must be added, and the calcination continued till the carbon is burnt away, thus reducing the sulphates and arsenates formed in the earlier stages.

The roasted mass is mixed with 0.2 to 0.5 times its weight of arsenic, an equal weight of carbonate of soda, 5 grams of argol, and 2 to 4 grams of borax, melted in a crucible at a moderate temperature, and poured. If iron be absent, 0.5 grams of pure iron filings must be added before fusion.

When cold, the button is detached from the slag and weighed. It should be metallic in appearance, and have a smooth grey surface. Portions weighing 1 gram should be taken for the subsequent scorification.

The scorification with borax is conducted in small shallow dishes ¾ inch in diameter inside and ⅛ inch deep. These may be made of finely-sifted clay and ground pots. The clay should be stiff, and as much pressure as possible used in shaping them. The die may be made of boxwood, and provided with a gun-metal or iron ring. The dishes should be dried carefully and heated to dull redness in a muffle before use.

While preparing the speiss, a small muffle should be made as hot as possible, as the success of the operation depends largely on the temperature. The back of the muffle should be white-hot. Place a number of the small dishes in the muffle. Have at hand some ground borax glass, and a vessel of cold water. Place about a gram (rather less than more) of borax in one of the dishes as far from the front as can be seen. It is convenient to wrap the borax in tissue paper and drop in the speiss, also wrapped in tissue paper.

The muffle should be hot enough to melt the speiss immediately, or the order of oxidation will not be preserved. The borax should not be sufficient to cover the speiss when melted. For a moment the surface is dull, but almost instantly brightens and scorifies, very much like the brightening stage in the cupellation of silver. In a few moments remove the dish and contents, and immediately place the bottom of it in water to cool, and as soon as the bead is solid, submerge it in the water.

If iron only has passed off, the brownish-yellow tint due to that metal will only be observed, but if the smallest amount of cobalt has been removed the slag will be greenish or, if a larger quantity, blue. The correct stage has been reached when a faint green tinge is visible in the slags near the edge and round the button. If this be not observed, the operation is repeated till the point is reached. If it is past, the scorification is re-started with a fresh portion of speiss.

The speiss now only contains cobalt, nickel, and copper. It is weighed, and the operation repeated with every precaution till the cobalt is removed. Less borax is necessary as the bead is reduced in size, and a green cap of arsenate appears when the nickel commences to oxidize, as well as the greenish tinge in the slag near the bottom. The attainment of this point is marked also by the motion of the button momentarily ceasing. The process needs careful watching. The dish is withdrawn, and quenched carefully as before. If, on examination, it is doubtful whether the nickel has commenced to scorify, it is best to weigh the prill and return it to a scorifier with fresh borax, and examine immediately it is melted. The dense blue of the cobalt will not then interfere, and the brownish colour of the nickel (and the green cap) will be apparent. The prill is weighed. If copper were present in the speiss, the prill will now consist of nickel and copper arsenides. If much nickel is present the scorification may be continued in the same manner, but it is better to add 1 gram of pure gold, and continue the scorification so long as nickel continues to be removed. The resulting

[1] Assaying and Metallurgical Analysis, pp. 193-195, Rhead and Sexton; Longmans, Green and Company, 1911.

bead consists of the added gold and copper. It is weighed, and the increase in weight of the gold bead gives the copper. Confirmatory results may be obtained by cupelling the gold-copper bead with 34 times its weight of lead, when the gold only will be left, the loss of weight being copper.

In the above remarks it has been assumed that cobalt is present. If it is absent, it is difficult to ascertain the point at which iron is removed and nickel commences to pass out. Further, in assaying an unknown speiss, which may contain nickel and iron only, the green arsenate of nickel which forms on the surface and under the bead must not be confounded with the green tinge indicated above.

Modified Method.

In order to avoid the difficulty caused by the copper, it is sometimes removed before forming the speiss.

The sample of ore is digested with aqua regia till completely decomposed, hydrochloric acid added, and the nitric acid expelled by evaporation. Water is then added, and the liquor saturated with sulphuretted hydrogen, which precipitates the copper, etc. The liquid is filtered, and the residue washed with water containing sulphuretted hydrogen.

The filtrate is then boiled till sulphuretted hydrogen is completely expelled, oxidized by adding a few drops of nitric acid to the boiling solution and neutralized. To the neutral solution barium carbonate and bromine water are added in excess and well shaken. After boiling, the solution is filtered, and the precipitate washed, dried, and ignited. This precipitate, which contains the whole of the iron, cobalt, and nickel, is converted into a speiss as before, but without roasting.

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CHAPTER IV

THE USES OF COBALT

Cobalt Oxide

Cobalt is used chiefly in the form of oxide in the enamel, porcelain, and glass industries, but within the last few years new uses have been found for the metal which is at present produced in considerable quantity. Cobalt metal is used chiefly in the manufacture of stellite, a cobalt-chromium alloy, used as a cutting tool. The metal is added to some high-speed steels to give improved cutting qualities. It is also used in cobalt plating.

Cobalt oxide and its compounds are used as pigments or colouring agents. It is said that when cobalt oxide is present in the ratio of 1:20,000, it imparts a bluish tinge to clear glass or porcelain. The oxide is black or gray, but when fused with borax or silica it possesses a brilliant blue colour. Cobalt oxide is also used in small proportions to produce white enamels, since any yellow colour due to iron oxide is neutralized by the complementary cobalt blue, producing a pure white. Also by the addition of cobalt oxide, copper oxide, pyrolusite, and even iron oxide, to certain raw mixtures or waste enamels, a beautiful black enamel is obtained. The compounds of cobalt, for example, silicate, aluminate, phosphate, arsenate, and nitrite are used instead of the oxide, because they give better and more uniform colouring. The following table gives a list of the customary brands of cobalt compounds with their cobalt content:—

Brand.	Special Designation.	Chemical Formula.	Percentage Cobalt Content.
F F Ko	Finest cobalt oxide (superior oxide)	CoO	78* per cent.
G K O	Grey cobalt oxide, Ia	CoO	76* "
F K O	Grey cobalt oxide	CoO	75* "
R K O	Black cobalt oxide, Ia	Co_2O_3	70* "
S K O	Black cobalt oxide	Co_3O_4	66* "
A K O	Cobalt arsenate	$Co_3As_2O_8.8H_2O$ ..	29 "
K O H	Cobalt carbonate	$CoCO_3$	50 "
P K O	Cobalt phosphate	$Co_3(PO_4)_2.8H_2O$.	34 "

* Theoretically CoO, Co_2O_3, and Co_3O_4 contain 78.8, 71.1, and 73.4 per cent cobalt, respectively.

The history of the value of cobalt compounds as colouring agents dates back to pre-historic times. However, it may be stated that it was not until the discovery of the silver-cobalt deposits at Schneeberg in 1470, that cobalt was used to any great extent. The preparation of cobalt compounds must have been carried on in a small way because about the year 1790, there were 25 works engaged in the industry, most of which were located in Saxony, and the total production of these works was not more than 300 tons of cobalt annually, which was mostly in the form of smalt. The smalt which contained approximately 6 per cent. cobalt was sold in Venice in 1520 at about 16 cents a pound. There were also a few refineries in Holland which supplied the Irish linen trade almost entirely, as well as a large amount to the linen industries at home. It was also used in Holland in the manufacture of litmus. A complete description of the early history of the cobalt industry in Saxony, is given by Mickle in the Report of the Bureau of Mines of Ontario, vol. XIX, 1913, Pt. II, pp. 234-251.

At present the ceramic industry is carried on chiefly in the United States, Germany, France, and Austria-Hungary. In Germany and Austria-Hungary it gives employment to 50,000 people.

Smalt is used now only in a few enamel works. It is a blue compound which owes its colour to the presence of cobalt silicate. As formerly prepared it contained appreciable quantities of impurities. The oxides of cobalt are preferred to smalt because of their purity, uniformity, and lower cost.

The arsenate is prepared by adding sodium arsenate to a cobalt nitrate solution.

Cobaltous carbonate is obtained by adding soda or potash to a solution of a cobalt salt. The rose coloured precipitate which forms is a basic carbonate, of the formula $CoCO_3+Co(OH)_2$.

Cobalt phosphate is prepared by adding sodium phosphate to a cobalt acetate solution. The precipitate is violet in colour and has the formula $Co_3(PO_4)_2$.

The aluminate is formed by adding sodium carbonate to a mixture of cobalt nitrate and alum. The cobalt and aluminium hydroxides may be precipitated separately and afterwards mixed. The mixed hydroxides are washed, dried, and heated at a red heat. The blue cobalt aluminate which forms is ground and dried.

The colour produced by the aluminate, phosphate, or arsenate has various names, for example, cobalt blue, cobalt ultramarine, king's blue, Thenard's blue, or azure blue. Thenard's blue corresponds to cobalt aluminate. Coeruleum, coeline, or blue celeste, is a blue colour showing a slightly greenish tint. It contains oxide of tin and sometimes calcium sulphate. To prepare such a pigment, sodium stannate is added to a cobalt nitrate solution. The precipitate is washed and heated. Another method to prepare blue celeste is to heat cobalt sulphate, tin oxide, and precipitated silica or chalk.

Mazarine blue[1] is commonly employed as a band on the edges of plates. The colour is prepared by mixing cobalt oxide, with tin oxide, sand, and calcium sulphate.

New blue is a pigment varying in colour from a pale greenish blue to a deep turquoise blue. It is largely used for enamels, and consists of aluminates of cobalt and chromium produced by the action of alum on carbonates and hydrates of cobalt and chromium.

Cobalt green or Rinmann's green is formed by substituting zinc oxide for alumina in cobalt aluminate, giving cobalt zincate. This compound may also be formed by mixing the hydroxides or oxides or by adding soda to a cobalt-zinc solution. In either case the oxides must be heated to form the zinc compound. The darker green colours contain the smaller quantities of zinc. A mixture of calcined cobalt carbonate, chromium oxide, and alumina also produces a green pigment.

Cobalt bronze is a cobalt ammonium phosphate compound. It has a violet colour with a bronze-like metallic lustre.

Cobalt yellow, Indian yellow, aureolin, is the precipitate potassium cobaltic nitrite. It is prepared by adding potassium nitrite to a cobalt solution acidified with acetic acid. It is a bright yellow precipitate which because of its purity produces an excellent colour.

[1] Mellor, Clay and Pottery Industries, 1914, p. 71, Lippincott, Philadelphia.

Cobalt brown is formed by calcining a mixture of ammonium sulphate, cobalt sulphate and ferrous sulphate.

In the burning operation of cobalt compounds, it is important that the temperature should not be too high, as a high temperature produces unsatisfactory colours. Of the cobalt compounds the silicate, carbonate and phosphate are the most important.

Cobalt oxide, up to 0.5 per cent., is used in practically all ground enamels as it possesses the property of causing the enamel to adhere better to sheet iron and at the same time neutralizes any yellow colour due to iron oxide. Although numerous investigations have been undertaken to account for this property, no satisfactory explanation has yet been given.

Blue enamels contain on an average 1 per cent. of cobalt, but when a dark blue colour is desired, cobalt may be present up to 3 per cent.

Red and pink cobalt compounds are of scientific rather than technical interest. If cobalt arsenate is strongly heated and then ground it yields a pinkish-red powder. The precipitate obtained from a solution of a cobalt salt with sodium phosphate is pink, changing to violet when heated. Cobalt magnesia pink is obtained from precipitated magnesium carbonate, mixed to a thin paste with cobalt nitrate solution, dried, and heated in crucibles.

Sympathetic inks.—Many of the salts of cobalt are pink and deliquescent. If a weak aqueous solution of one of them, such as the nitrate or chloride, is used as ink, the writing is practically invisible, but if the paper is held near the fire the combined water is driven off and the writing becomes blue and visible. It will afterwards absorb water from the atmosphere and again disappear.

A few experiments have been made to test the action of cobalt nitrate as an addition agent in flotation but it did not show any advantages.[1]

Uses of Metallic Cobalt

Metallic cobalt is used chiefly in the preparation of alloys and high-speed alloy steels. The cobalt-chromium alloys are the most important. These alloys possess extreme hardness and are being used extensively to replace high-speed steels as cutting tools. The trade name of the cobalt chromium alloys is "stellite." Stellite is not a steel, and its properties are altogether different from those of steel. It cannot be hardened or tempered, nor does it lose any of its hardness even when the edge of the tool is at a red heat. Tests have shown that a stellite cutting tool permits more rapid cutting than when the ordinary high-speed steel is used.

The cobalt-chromium alloys are hard, but the hardness is increased by additions of tungsten and molybdenum. As the hardness increases the brittleness also increases. The addition of iron softens the alloy.

Stellite alloys possess a bright surface, and are very resistant to oxidation. They remain unaltered in the atmosphere, and are not attacked by the ordinary acids. The colour of the alloys, when polished, lies between that of steel and silver.

[1] Metallurgical and Chemical Engineering, Vol. XVIII, 1918, p. 76.

The tools are made by casting the alloy into bars of the desired shape and size. These are afterwards ground to a cutting edge on an emery or carborundum wheel.

Two grades of stellite tools are made, one with moderate hardness and great strength for turning steel, and the other with greater hardness but less strength for turning cast iron. The tool used for cast iron enables a greater amount of work to be accomplished, whereas, if operating at a high speed with the stellite tool for steels, the edge would be immediately destroyed.

Further information on these alloys will be found in the section on alloys.

The use of stellite alloys for cutlery has been suggested but up to the present, it has not been used for this purpose as the demand for the cutting tool has been so great.

Electro-plating with Cobalt

Owing to the success that has attended nickel plating, the question arose as to whether cobalt platings possess any superior qualities to nickel platings. In order to decide this question a number of experiments were undertaken at the School of Mining, Kingston, Canada, for the Mines Branch of the Department of Mines. A report[1] of this investigation has been issued, and in it some interesting conclusions are given. The results of the work were tested and confirmed by disinterested operators.

The advantages claimed for cobalt plating may be summarized as follows:—

1. Cobalt may be plated from four to fifteen times as quickly as nickel.
2. The cobalt plating is harder than the ordinary nickel plating.
3. About one-fourth the weight of cobalt as compared with nickel is required to do the same protective work.

Cobalt may be plated on brass, iron, steel, copper, tin, German silver, lead and Britannia metal.

The composition of the solutions recommended is as follows:—

Solution 1 B.—Cobalt-ammonium-sulphate, $CoSO_4.(NH_4)_2SO_4.6H_2O$—200 grams to the litre of water, which is the equivalent of 145 grams of anhydrous cobalt-ammonium-sulphate, $CoSO_4.(NH_4)_2SO_4$, to the litre of water. Sp. gr.= 1.053 at 15°C.

Solution XIII B:—Cobalt sulphate, $CoSO_4$—312 grams; sodium chloride, NaCl—19.6 grams; boric acid—nearly to saturation; water—1,000 c.c. Sp. gr.= 1.25 at 15°C.

Further experiments are being conducted to test the value of cobalt platings.

Kowalke[2] gives an account of a few experiments made to test the suitability of cobalt for use in thermocouples. He states that cobalt should have an important place among thermo-elements since it does not become brittle like nickel, and it gives a high electromotive force.

An amalgam of cobalt is used in dentistry.

[1] Kalmus, Electro-plating with Cobalt: Bulletin No. 334, Department of Mines, Ottawa, 1915. Trans. Am. Electrochemical Society, Vol. XXVII, 1915, pp. 75-130.

[2] Cobalt as an Element for Thermocouples, Trans. Amer. Electrochem. Soc., Vol. XXIX, 1916, pp. 561-568.

A French patent (No. 460,093, July 7, 1913) covers the preparation of cobalt filaments for incandescent electric lamps. The filament is made from a solution of cellulose with zinc chloride, cobalt oxide, and manganese sulphate. It is heated to incandescence for twenty hours and then coated with carbon.

Additional References

Mellor, Cobalt Blue Colours, Trans. Eng. Ceramic Soc., Vol. VI, 1907, p. 71.

Use of Cobalt in Decorating, Chem. Abst., Vol. VII, 1913, p. 3003.

Why a Greater Colour is produced with Cobalt Solutions than with Mineral Colours, Chem. Abst., Vol. VII, 1913, p. 554.

Old and New Colours with Cobalt as their Base, Chem. Abst., Vol. VII, 1913, p. 874.

The Necessity of Cobalt Oxide in Ground-coat Enamels for Sheet Steel, Trans. Am. Ceramic Soc., Vol. XIV, 1912, pp. 756-764.

Cobalt Uranium Colours, Chem. Abst., Vol. VIII, 1914, p. 3710.

Status of Cobalt in the Ground-coat of Sheet Steel Enamels, Chem. Abst., Vol. VIII, 1914, p. 3847.

Cobalt in Pottery Decoration, Chem. Abst., Vol. VIII, 1914, p. 798.

Cobalt Oxides, Reactions between CoO and Al_2O_3, Chem. Abst., Vol. IX, 1915, p. 2852.

Cobalt Oxides, Reactions between CoO and SnO_2, Chem. Abst., Vol. IX, 1915, p. 2844.

Cobalt Magnesium red, Chem. Abst., Vol. IX, 1915, p. 2853.

Cobalt Colours other than Blue, Trans. Am. Ceramic Soc., Vol. XIV, 1912, pp. 767-777.

The Formation of Isomorphous Mixed Crystals between Cobalt Oxide and Manganese Oxide and between Cobalt Oxide and Nickel Oxide, Chem. Abst., Vol. IX, 1915, p. 3039.

Hedvall, The Determination of Dissociation Temperatures with the Aid of Cooling and Heating Curves, Especially for Cobalto-cobaltic Oxide, Chem. Abst., Vol. XI, 1917, p. 1347.

Hedvall, The formation of Cobalt Aluminate, Cobalt Orthostannate and Rinmann's Green, Chem. Abst., Vol. XI, 1917, p. 1373.

CHAPTER V

BINARY ALLOYS OF COBALT

Cobalt and Aluminium

The equilibrium diagram of the cobalt aluminium alloys[1] is shown in Figure. 1. The liquidus curve[2] consists of 4 branches, viz.: AB, BC, CDE, and EF. The points A and F, shown at 658° and 1492°C., correspond to the melting points of aluminium and cobalt respectively. The point E at 1375°C. and 90.5 per cent. cobalt is a minimum point. Alloys of composition represented by points to the right of E consist when solid of a solid solution of aluminium in cobalt. The point D at 1628°C. and 68.5 per cent. cobalt corresponds to the melting point and composition of the compound CoAl. At C, 1165°C. and 38 per cent. cobalt, there is a reaction between the CoAl crystals and the liquid of composition C to form a new compound Co_2Al_5 containing 46.5 per cent. cobalt. At B, 940°C. and 20 per cent. cobalt, there is a reaction between the previously formed Co_2Al_5 crystals and the liquid of composition B to form the compound Co_3Al_{13}, containing approximately 33.5 per cent. cobalt.

The alloys containing between 100 and 68.5 per cent. cobalt are magnetic, the magnetism decreasing rapidly with increased aluminium content.

Schumeister[3] has studied the mechanical and chemical properties of aluminium cobalt alloys containing from 0 to 20 per cent. cobalt. The tests show that the alloys containing 9 to 12 per cent. cobalt possess the greatest tensile strength. Addition of small quantities of tungsten, 0.8 to 1.2 per cent. raised the tensile strength considerably, while with further additions the strength is lowered. The substitution of molybdenum for tungsten did not show any advantage. The aluminium cobalt alloys were harder, easier to work, more stable and durable in the air than pure aluminium.

Peltery obtained a patent[4] on the addition of silver, gold, cobalt, chromium, iron, manganese, and nickel to aluminium; also the General Electric Company, Berlin, patented a light bearing metal containing aluminium with lead, tin, cobalt, chromium, iron, molybdenum, nickel, and antimony.[5]

The following table gives the results obtained later by Schumeister[6] from additions of cobalt, 0 to 12 per cent., on the tensile strength, elongation, and hardness of aluminium. The fracture of the alloys changes from a coarse to a very fine grain with increased proportion of cobalt. The following table shows the effect of additions of cobalt to aluminium.

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[1] Gwyer, Aluminium and Cobalt: Zeitschr. anorg. Chemie, Vol. LVII, 1908, pp. 140-147.

[2] The liquidus or freezing point curve represents the beginning of freezing or solidification of any alloy.

[3] Schumeister, Investigation of the Mechanical and Chemical Properties of Light Cobalt Aluminium Alloys: Metallurgie, Vol. VIII, 1911, pp. 650-655.

[4] German Patent, No. 230,095, Jan. 16th, 1911.

[5] German Patent, No. 257,868, March 20th, 1913.

[6] Schumeister, Investigation of the Binary Aluminium Alloys: Stahl and Eisen, Vol. XXXV, 1915, pp. 873, 874.

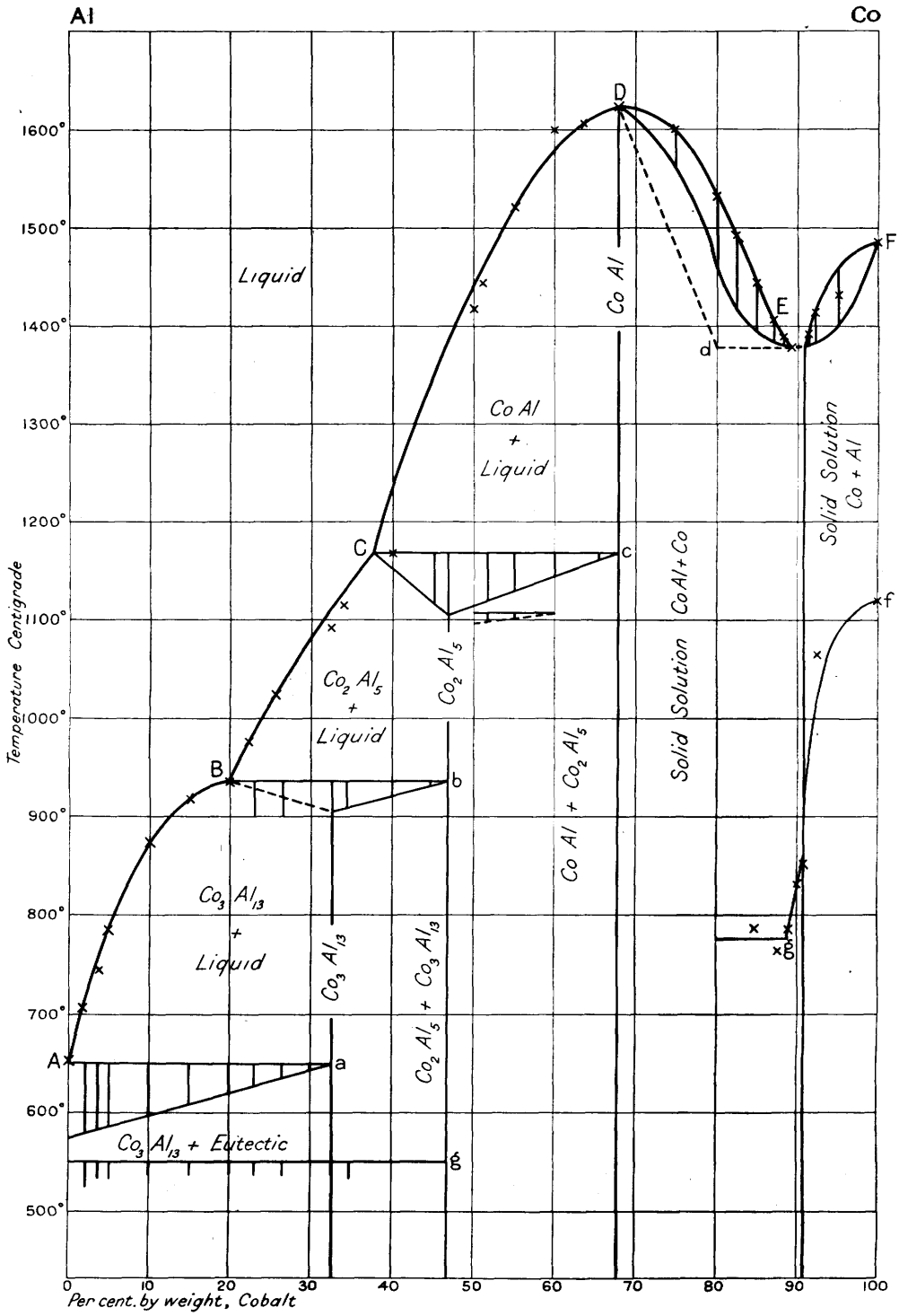


Figure 1.—Equilibrium Diagram of Aluminium-Cobalt Alloys.

Cobalt Content	Tensile strength per sq. m.m.	Elongation per cent.	Hardness
0.0	10.5	34	29
0.6	10.9	35	32
1.6	12.0	28	.....
2.3	12.3	25	.....
3.5	12.9	21	47
5.5	15.5	18	.....
7.5	16.6	14	50
9.4	16.5	11	51
10.5	17.0	11	.....
12.0	18.5	6	61

Additional References

Portevin, Aluminium Alloys: Revue de Metallurgie (Mémoires), Vol. V, 1908, p. 274.
Bornemann, Cobalt and Aluminium: Metallurgie, Vol. VII, 1910, pp. 577, 578.
Kaiser, Metallurgie, Vol. VIII, 1911, p. 300. Analysis of White Bronze (Cu 40-30, Co 50-60, Al 10); p. 305, Analysis of Metalline (Cu 30, Co 35, Al 25, Fe 10).

Cobalt and Antimony

The equilibrium diagram[1] of the cobalt antimony alloys is shown in Figure 2. Both metals are soluble in one another in the liquid state, but only to a small extent in the solid. At 1093°C., cobalt retains 12.5 per cent. by weight of antimony in solid solution; the amount, however, decreases with the temperature. There is no evidence of antimony dissolving cobalt in the solid state.

The addition of antimony lowers the melting point of cobalt, A, until the eutectic point E is reached at 1093°C. and 39 per cent. antimony. The liquidus curve shows a maximum C at 1191°C. and 67 per cent. antimony, corresponding to the compound CoSb. At 897.5°C. there is a reaction between the separated crystals CoSb and the liquid D to form a new compound F. The exact composition of the compound F has not yet been definitely determined. From the eutectic point G, at 615°C. and 98.5 per cent. antimony, the liquidus rises to H at 630°C. the melting point of antimony.

The transformation temperature of cobalt at 1159°C. is lowered to 930°C. by addition of antimony up to 12.5 per cent. For all alloys between 12.5 and 67 per cent. Sb, the transformation takes place at constant temperature, viz., 930°C.

Additional References

Lewkonja, Cobalt-Antimony Alloys: Zeitschr. anorg. Chemie, Vol. LIX, 1908, pp. 305-312.
Ducelliez, Alloys of Cobalt and Antimony: Procès verbaux de la société des sciences physiques et naturelles de Bordeaux, 1908, pp. 183-190; 1908-1909, pp. 131-134. Bulletin Société Chimique de France, Vol. VII, 1910, sec. 4, p. 202.
Ducelliez, Action of Antimony Chloride on Cobalt and its Alloys with Antimony: Compt. Rend., Vol. 147, 1908, pp. 1048-1050.
Ducelliez, Study of the Electromotive Force of the Alloys of Cobalt with Tin, Antimony, Bismuth, Lead, and Copper: Compt. Rend., 1910, Vol. 150, pp. 98-101.
Kurnakow and Podkapajew, Jour. russ. phys. Chem. Ges. 38, 1906, p. 463.
Rammelsberg, Annalen der Physik und Chemie, Vol. 128, 1866, p. 441.
Bornemann, Cobalt and Antimony: Metallurgie, Vol. VIII, 1911, pp. 683-684.

[1] Guertler, Metallographie, Vol. I, 1912, pp. 754-756.

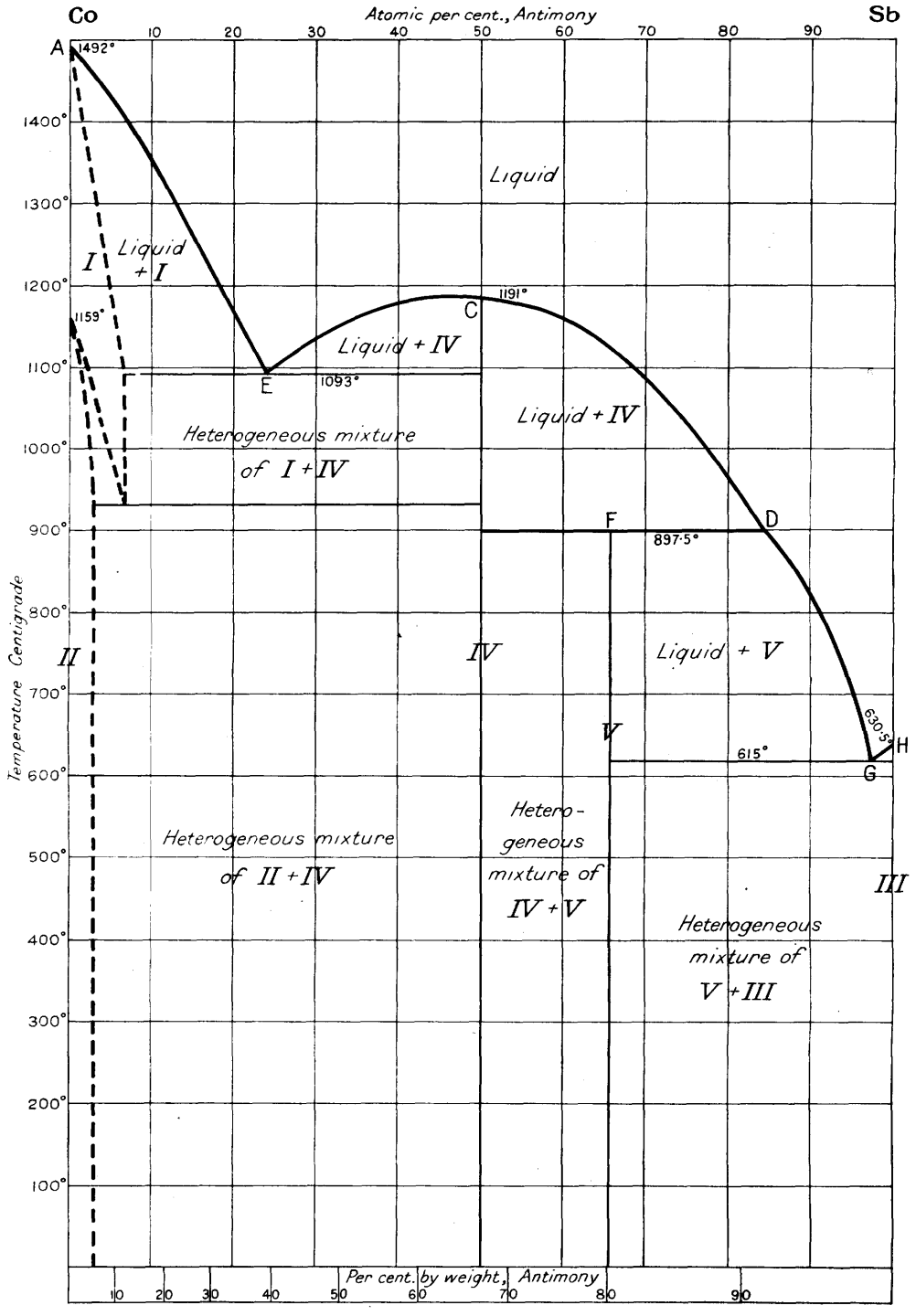


Figure 2.—Equilibrium Diagram of Cobalt-Antimony Alloys.

Cobalt and Arsenic

The cobalt arsenic equilibrium diagram[1] is shown in part in Figure 3. Owing to the volatilization loss of arsenic it has been impossible to investigate concentrations of more than 60 per cent. arsenic.

Cobalt retains about 1 to 2 per cent. arsenic in solid solution. At a temperature of 920°C. and a concentration of 30 per cent. arsenic, there is a eutectic point. With further additions of arsenic, the liquidus curve rises in several successive stages to a maximum at 1175°C. and 57 per cent. arsenic. This maximum corresponds to the compound CoAs. At the temperatures 1014°, 960°, and 930°C., there are three changes in the direction of the liquidus corresponding to the separation of crystals IV, V, VI, of the composition approaching Co_3As_2, Co_2As, and Co_5As_2. Conclusive evidence of the existence of these compounds has as yet not been obtained.

There are also three horizontals in the diagram, at 910°, 830°, and 380°C. The horizontal at 910° between crystals V and III, shows a change in the solid state of crystals IV to crystals VII of similar composition. The horizontal at 830° reaching between crystals I and VI corresponds to a change in the solid crystals VI to IX of the same composition. For compositions containing mixtures of crystals V and VII there appears to be a transformation at 380°, but positive evidence of the exact nature of this change is lacking.

Additional References

Friedrich, Equilibrium Diagram of the Cobalt-Arsenic Alloys: Metallurgie, Vol. V, 1908, pp. 150-157.

The Freezing-point of Cobalt-Nickel Arsenides: Metall und Erz, Vol. X, 1913, pp. 659-671.

Ducelliez, Action of Arsenic Chloride and Arsenic on Cobalt: Compt. Rend., Vol. CXLVII, 1908, p. 424.

Action of Heat on Mixtures of Arsenic and Cobalt: Procès verbaux de la société des sciences physiques et naturelles de Bordeaux, 1908, pp. 57-73.

Cobalt and Bismuth

The equilibrium diagram[2] of the cobalt bismuth system is shown in Figure 4. The metals are only partly soluble in the liquid state. At 1390°C. the concentration of the two layers is 92.7 per cent. cobalt and 7.3 per cent. bismuth; and 93 per cent. bismuth and 7 per cent. cobalt. The first addition of bismuth to cobalt lowers the melting point of the latter by approximately 100°C. The addition of cobalt to bismuth lowers the melting point of bismuth approximately 10° to a eutectic point at 96.7 per cent.

Additional References

Lewkonja, Cobalt-Bismuth Alloys: Zeitschr. anorg. Chemie, Vol. LIX, 1908, pp. 315-318.

Ducelliez, Study of Electromotive Force of Cobalt-Bismuth Alloys: Bulletin Société Chimique de France, Vol. VII, 1910, pp. 199-200.

Cobalt-Bismuth Alloys: Bulletin Société Chimique de France. Vol. V, 1909, pp. 61-62.

Bornemann, Cobalt and Bismuth: Metallurgie, Vol. VIII, 1911, p. 688.

[1] Guertler, Metallographie, Vol. I, 1912, pp. 833-836.

[2] Guertler, Metalloghaphie, Vol. I, 1912, pp. 584-586.

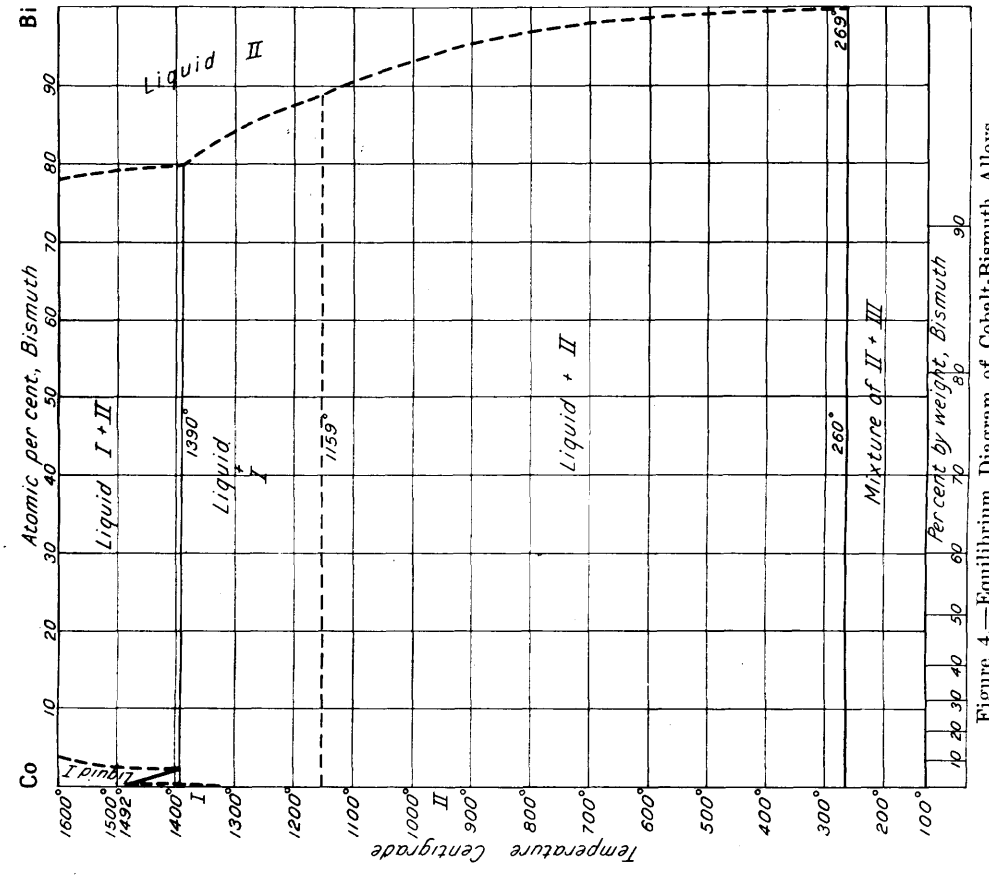


Figure 4.—Equilibrium Diagram of Cobalt-Bismuth Alloys.

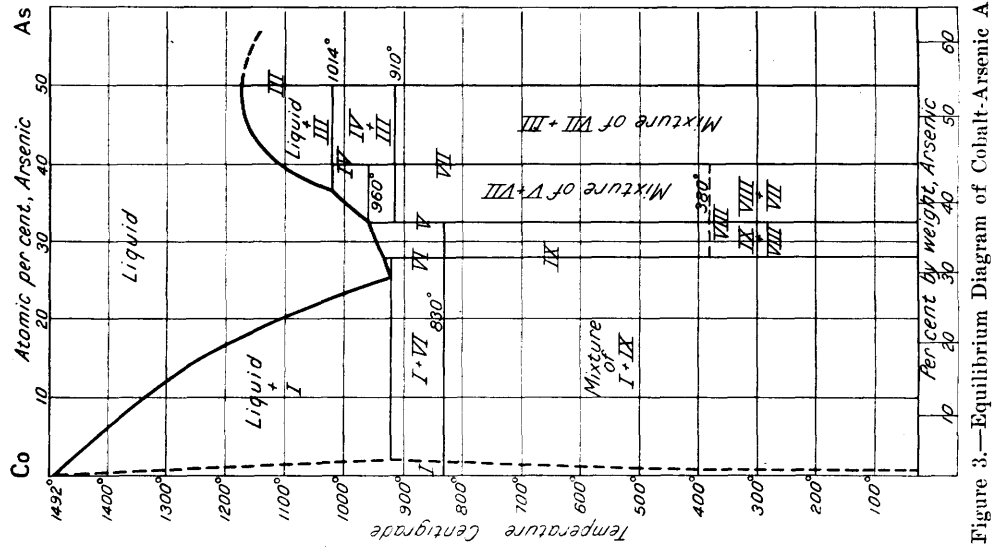


Figure 3.—Equilibrium Diagram of Cobalt-Arsenic Alloys.

Cobalt and Boron

The equilibrium diagram of cobalt and boron alloys or mixtures has not yet been published. However, the compounds Co_2B and CoB_2 have been detected.

The magnetic transformation of Co_2B occurs at 156°C.

References

Jassonneix, The Combination of Nickel and Cobalt with Boron: Compt. Rend., Vol. CXLV, 1907, pp. 240-241.

A Study of the Magnetic Properties of Iron, Cobalt, Nickel, and Manganese with Boron. Report of Eighth International Congress of Applied Chemistry, Vol. 2, 1912, pp. 165-170.

Moissan, A Study of the Borides of Cobalt, Compt. Rend., Vol. CXXII, 1896, pp. 424-426.

Cobalt and Cadmium

A few experiments on the addition of cobalt to cadmium were made by Lewkonja.[1] In all the tests a distinct eutectic point was observed at 316°C., 6° below the melting point of cadmium. None of the alloys were magnetic. It is evident that there must be either a compound formed, or that a solid solution of cadmium in cobalt must exist, as the transition to *a* cobalt was lowered to below the room temperature.

Additional Reference

Guertler, Metallographie, Vol. I, 1912, p. 487.

Cobalt and Carbon

The equilibrium diagram of the cobalt carbon series has been investigated by Boecker,[2] and later by Ruff and Keilig.[3] The diagram of Ruff and Keilig is shown in Figure 5.

Both diagrams show the existence of a eutectic at 1300°C. and 2.8 to 2.4 per cent. carbon. At the eutectic temperature cobalt retains 0.82 per cent. carbon in solid solution, which separates as graphite on cooling, only 0.3 per cent. being retained at 1000°C. Boecker did not carry the experiments above 1700°C., at which temperature he found the maximum solubility of carbon in cobalt to be 3.9 per cent.

The investigations of Ruff and Keilig were conducted at temperatures up to 2415°C., which is the boiling point of the liquid under 30 m.m. pressure. The boiling point of pure cobalt was found to be 2375°C. under these conditions. The existence of a cobalt carbide has not yet been definitely proved.

Additional References

Keilig, The Cobalt-Carbon System for Temperatures above 1500°C. Dissertation, Königliche Technische Hochschule in Danzig, 1915.

Guertler, Metallographie, Vol. 2, 1913, p. 639.

[1] Lewkonja, Cobalt-Cadmium Alloys: Zeitschr. anorg. Chemie, Vol. LIX, 1908, p. 322.

[2] Boecker, Investigation of the Cobalt-Carbon System: Metallurgie, Vol. IX, 1912, pp. 296-303.

[3] Ruff and Keilig, Cobalt and Carbon: Zeitschr. anorg. Chemie, Vol. LXXXVIII, 1914, pp. 410-423.

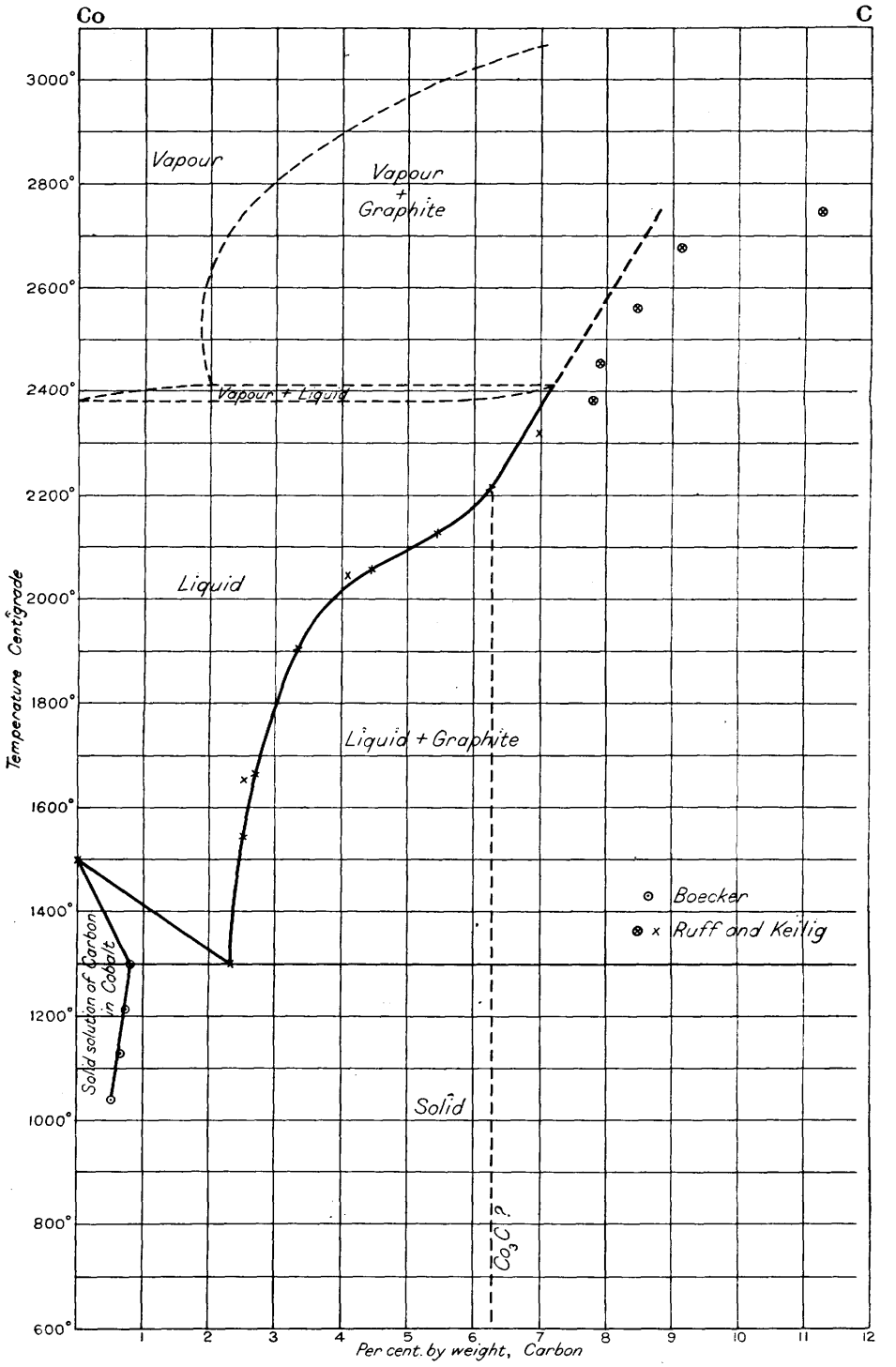


Figure 5.—Equilibrium Diagram of Cobalt-Carbon Alloys.

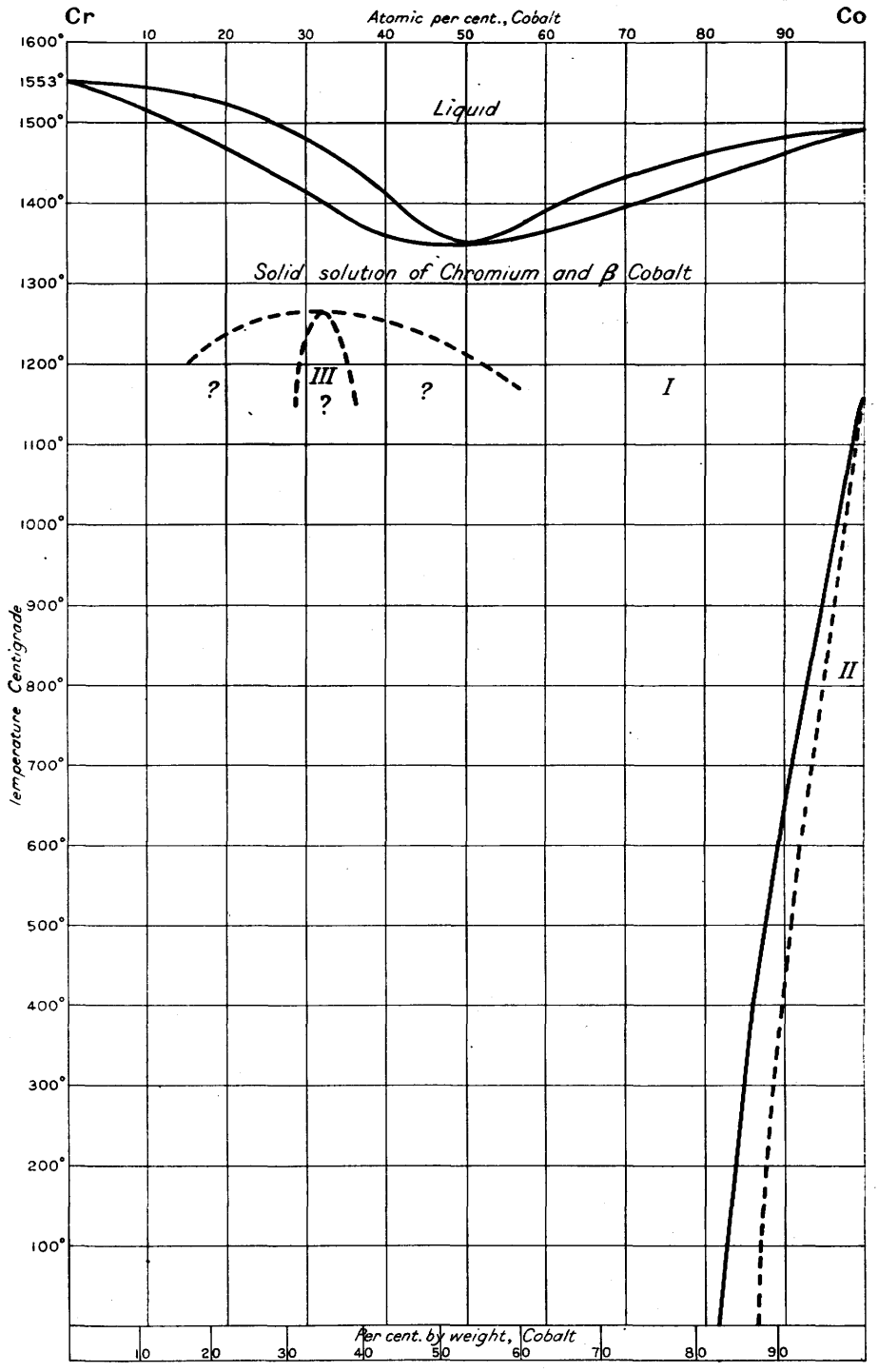


Figure 6.—Equilibrium Diagram of Chromium-Cobalt Alloys.

Cobalt and Chromium

The equilibrium diagram of the cobalt chromium alloys is shown in Figure 6.[1] Both metals are soluble in one another in the liquid and also in the solid state. The liquidus curve shows a minimum at approximately 50 per cent. cobalt and 1340°C. In alloys containing between 45 per cent. and 85 per cent. chromium there is a reaction in the solid state at approximately 1225°C., the homogeneous solid solution above that temperature breaking down into two solid solutions. Alloys with 0 to 45 per cent. chromium show a polygonal structure containing cobalt rich cores, the chromium content increasing from the centre to the outside. In alloys with more than 55 per cent. chromium, the chromium content of the grains decreases from the centre to the outside.

The temperature at which the unmagnetic cobalt chromium alloys become magnetic decreases rapidly with increasing chromium content. The addition of 10 per cent. chromium lowers the transformation point to 685°; 15 per cent. to 300°; while the addition of 25 per cent. lowers the transformation to below room temperature.

Special alloys containing cobalt and chromium are known as "stellite." The word is derived from the Latin, stella, a star, and was chosen because of the brilliant polish these alloys take and retain under atmospheric conditions. An alloy containing 75 per cent. cobalt and 25 per cent. chromium is fairly tough and hard, and may be forged. This alloy is only slightly attacked by nitric acid, and is recommended for cutlery. To increase the hardness of the stellite alloys, varying amounts of either tungsten or molybdenum, or both, are added, the chromium in the alloy remaining about 30 per cent. The addition of 5 per cent. tungsten produces a distinctly harder alloy, which forges readily. With 10 per cent. the metal may be forged, and takes a fine cutting edge. This alloy is suitable for cold-chisels and wood-working tools. With 15 per cent. the metal may still be forged, but only with great care, as it is considerably harder than the 10 per cent. tungsten alloy. With 20 per cent. the alloy is still harder. It may be forged, but only to a limited extent. This alloy is adopted for cutting steel and other metals at a moderate speed. With 25 per cent. a hard alloy is obtained which cannot be forged, but is cast into bars which are ground to a suitable form for lathe tools. These tools are used to cut steel and cast iron, and retain their hardness at high speeds. When the tungsten content reaches 40 per cent. the alloy still retains its cutting qualities, and is preferred to the 25 per cent. alloy for cast iron. Further additions of tungsten produce brittleness. It is claimed these alloys possess an advantage of 20 to 100 per cent. over high-speed tool steels.

Molybdenum produces somewhat the same effect as tungsten, only a smaller proportion is required. An alloy containing 10 per cent. of molybdenum makes an excellent lathe tool. Carbon, silicon, and boron when present impart brittleness.

[1] Guertler, Metallographie, Vol. I, pp. 359-361. Lewkonja, Cobalt-Chromium Alloys: Zeitschr. anorg. Chemie, Vol. LIX, 1908, pp. 323-327.

A few typical analyses[1] of stellite alloys are given below, but it must be remembered that for the successful use of stellite different alloys must be used for different classes of work.

Co	Cr	W	Mo	
75	25	..	..	Original stellite alloy.
70	25	5	..	Forges readily, suitable for wood-cutting tools and cutlery.
60	15	25	..	Suitable for lathe tools for cutting steel and cast iron.
55	35	10	..	
50	30	20	..	
55	15	25	5	High speed cutting tools.
45	15	..	40	Very hard alloy.

Stellite alloys also contain a small percentage of carbon.

The stellite alloys are covered by a number of patents, the numbers of which are given below.

Haynes, U. S. Patent No. 873,745, Dec. 17, 1907. Alloys containing 10-60 per cent. chromium, and 90-40 per cent. cobalt.

U. S. Patent No. 873,746, Dec. 17, 1907. Alloy of 30-60 per cent. chromium and 70-40 per cent. nickel.

U. S. Patent 1,057,423, and 1,057,828, April 1, 1913. The addition of tungsten and molybdenum to the cobalt-chromium alloy is specified in these patents to produce greater hardness and toughness.

U. S. Patent No. 1,150,113, Aug. 17, 1915. Alloy for tools containing approximately cobalt 25 per cent., chromium 20, and iron 55. Molybdenum may be added to vary the colour. More chromium increases the hardness and iron renders the alloy more fusible, malleable and softer.

British Patent 2,487, August 17, 1915 (similar to U. S. Patent 1,057,423).

British Patent No. 100,434, Jan. 5, 1916. Cobalt-chromium alloys containing sufficient iron or nickel to soften the metal. This alloy is known as "festal metal."

Tamman, German Patent 270,750, August 14, 1909. A cobalt-chromium alloy for machine parts, containing 20.23 per cent. chromium and 80-77 per cent. cobalt.

Alloys of nickel and copper or cobalt and one of the following metals, namely, chromium, tungsten, molybdenum, vanadium, aluminium and uranium are used extensively for thermo-electric couples and resistance elements. These are covered by a number of patents granted to Albert L. Marsh, the dates and numbers of most of them being given below.

U.S. Patents Nos. 779,090, Jan. 3, 1905; 781,288, Jan. 31, 1905; 781,289, Jan. 31, 1905; 781,290, Jan. 31, 1905; 786,577, April 4, 1905; 811,859, Feb. 6, 1906; 853,891, May 14, 1907; 859,608, July 9, 1907; 874,780, Dec. 24, 1907; 971,767, Oct. 4, 1910.

Shortly after Marsh's patents were published the General Electric Company manufactured a similar alloy, "calorite," of the composition given below. The validity of Marsh's patents has been affirmed, and at present the Hoskins Electric Company are producing nickel-chromium alloys under the Marsh patents.

[1] Haynes, Alloys of Nickel and Cobalt with Chromium: Jour. Ind. and Eng. Chem., Vol. II, 1910, pp. 397-401.

In the patent suit defence the General Electric Company cited Placet's patent (Br. pat. 202, 1896) as antedating the Marsh patents. It appears that Placet found that the addition of chromium to other metals increased the hardness, toughness, and electrical resistance, but was not aware of the durability of the alloy, which latter property is one of the main advantages of nickel-chromium alloys.

The Driver Harris Company manufactured a nickel-chromium alloy containing 25 per cent. iron shortly after the General Electric Company made calorite. At the present time it is understood that the Hoskins Manufacturing Company control the Marsh patents, and all nickel-chromium alloys are made under a license from them.

The analyses of the various nickel-chromium alloys are given below.

	Ni	Cr	Fe	Mn	Specific Resistance.
Calorite	65	12	15	8	110
Nichrome	60	11	25	4	105
Nichrome 2	75	11	12	2	110
Excello	85	14	0.5	0.5	92
Tophet	61	10	26	3	107
Calido	64	8	25	3	106
Chromel A.	80	20	..	2	102
Chromel B.	85	15	..	2	88
Chromel C.	60	12	25	4	106

With regard to the use of nickel-chromium alloys,[1] it may be stated that the addition of iron makes the working of the alloys much easier, but lowers the resistance of the alloy to oxidation. The great resistance to oxidation of the nickel chromium alloys is not due to the nickel or the chromium but to the scale formed. The addition of iron also lowers the resistance of the scale, especially with temperatures above 1350°F. The lower the iron content, the higher temperature at which it is possible to operate.

Nichrome "2" is manufactured to compete with chromel "A," but owing to the iron content cannot be operated successfully above 1700°F., whereas chromel A may be used successfully at 2000°F.

Chromel "C" was placed on the market to supply a cheap alloy that could be successfully used for small heating apparatus, e.g., electric stoves, irons, etc., where the wire is exposed to the air and not allowed to heat above 1350°F.

A report has been made that a cobalt-chromium alloy, cochrome, may be swaged into wires which are in some respects superior to nichrome wires in electric heating elements. They are less readily oxidized at high temperatures and have a higher melting point.

Additional References

Hibbard, Manufacture and Uses of Alloy Steels, Bulletin 100, 1915, p. 60. Bureau of Mines, Washington.

Haynes, Stellite, Met. Chem. Eng., Vol. 18, 1918, pp. 541-542.

Haynes, The Development of Stellite, Iron Age, Vol. 102, 1918, pp. 886-888.

Guillet and Godfroid, Some Observations on Stellite, Revue de Métallurgie (Mémoires), Vol. 15, 1918, pp. 339-346.

Stellite, Canadian Machinery, Vol. XIX, 1918, pp. 231-235.

[1] Private communication.

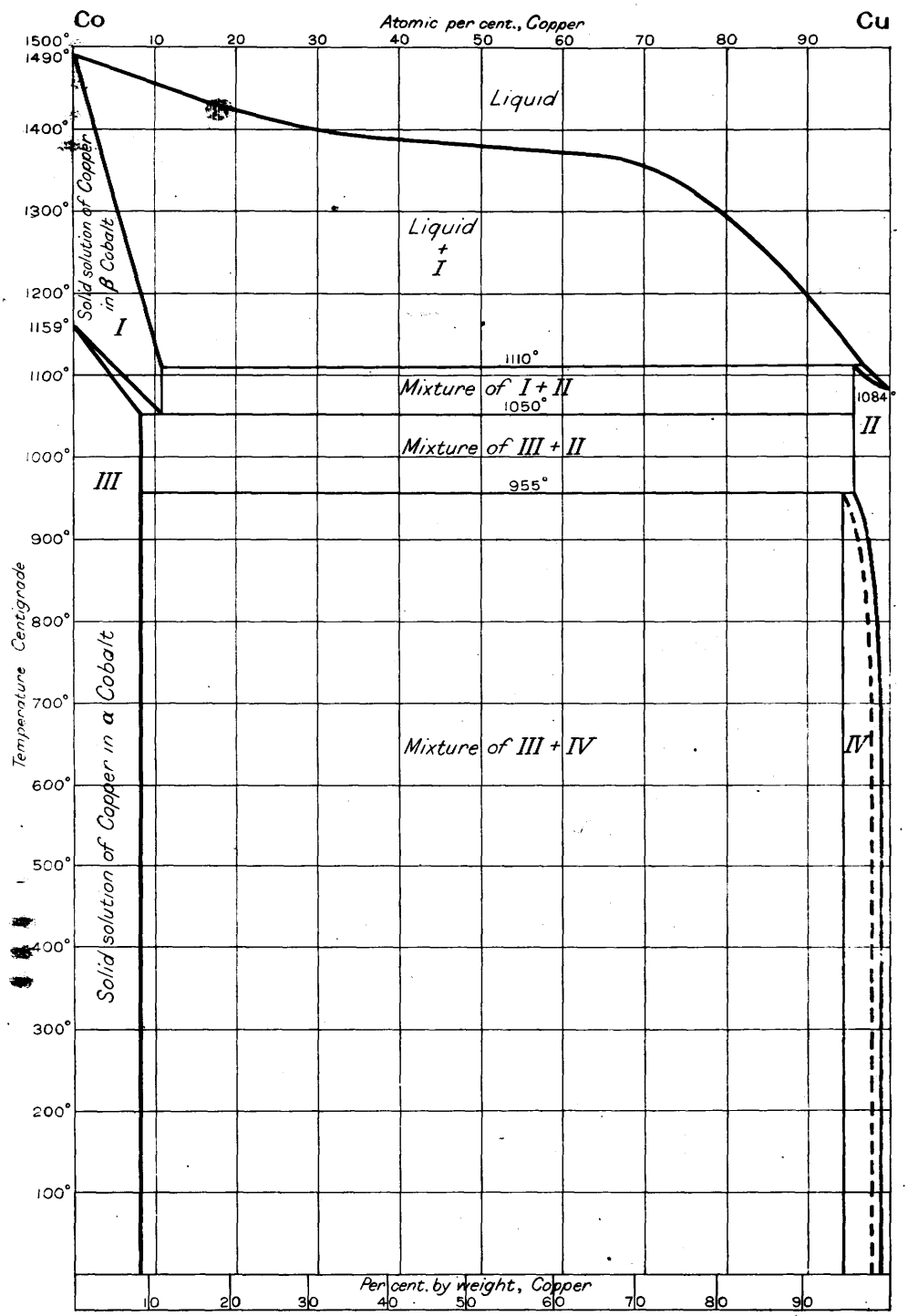


Figure 7.—Equilibrium Diagram of Cobalt-Copper Alloys.

Cobalt and Copper

The equilibrium diagram[1] of the cobalt-copper system is shown in Figure 7. The metals are completely soluble in the liquid state, but form two solid solutions in the solid. The cobalt-rich solid solution contains from 0 to 10 per cent. of copper, and the copper-rich solid solution 0 to 4 per cent. of cobalt. At 1110°C. with mixtures containing between 10 and 96 per cent. copper, there is a reaction, with the formation of the solid solution II. Below 955°C. a new solution IV containing, at room temperature, from 95 to 98 per cent. of copper, separates. This solid solution is remarkably magnetizable. The temperature of the transformation of the β cobalt solution to the α form is lowered with increase of copper from 1159° to 1050°C., where it remains constant for mixtures between 10 and 96 per cent. copper. The hardness of copper-cobalt alloys increases directly with the cobalt. Addition of either metal to the other rapidly decreases the electrical conductivity.

Additional References

Konstantinow, Alloys of Cobalt and Copper: Revue de Métallurgie (Mémoires), Vol. IV, 1907, p. 983.

Ducelliez, Studies of the Alloys of Cobalt and Copper: Procès verbaux de la société des sciences physiques et naturelles de Bordeaux, 1908-1909, pp. 120-126.

Chemical Study of Alloys of Cobalt and Copper: Bulletin de Société Chimique de France, Vol. VII, 1910, pp. 158-160, 196-198.

Waehlert, Cobalt-Nickel-Copper Alloys: Osterr. Zeitschr. Berg. u. Hüttenwesen, Vol. LXII, 1914, pp. 341, 357, 374, 392, 406.

Guertler, Metallographie, Vol. I, 1912, pp. 83-84.

Rosenhain, Electric Conductivity of Alloys of Cobalt and Copper, Introduction to Physical Metallurgy, 1914, p. 112.

Kaiser, Metallurgie, Vol. 8, 1911, p. 300. Analysis of white bronze (Cu 40-30, Co 50-60, Al 10), p. 305, Analysis of metalline (Cu 30, Co 35, Al 25, Fe 10).

Cobalt and Gold

The equilibrium diagram of the cobalt-gold series is shown in Figure 8.[2] The eutectic point which is given at approximately 90 per cent. gold and 997°C., as well as other parts of the liquidus and solidus, have not been accurately determined. In the experiments with the cobalt-rich alloys there was a marked tendency toward undercooling. Cobalt retains approximately 10 per cent. gold in solid solution, and gold retains several per cent. of cobalt, the solubility varying with the temperature. The transformation temperature of β into α cobalt has not been determined accurately.

Additional Reference

Guertler, Metallographie, Vol. I, 1912, pp. 345-348.

[1] Sahmen, Alloys of Copper and Cobalt: Zeitschr. anorg. Chemie, Vol. LVII, 1908, pp. 1-9.

[2] Wahl, Cobalt-Gold Alloys: Zeitschr. anorg. Chemie, Vol. LXVI, 1910, pp. 60-72.

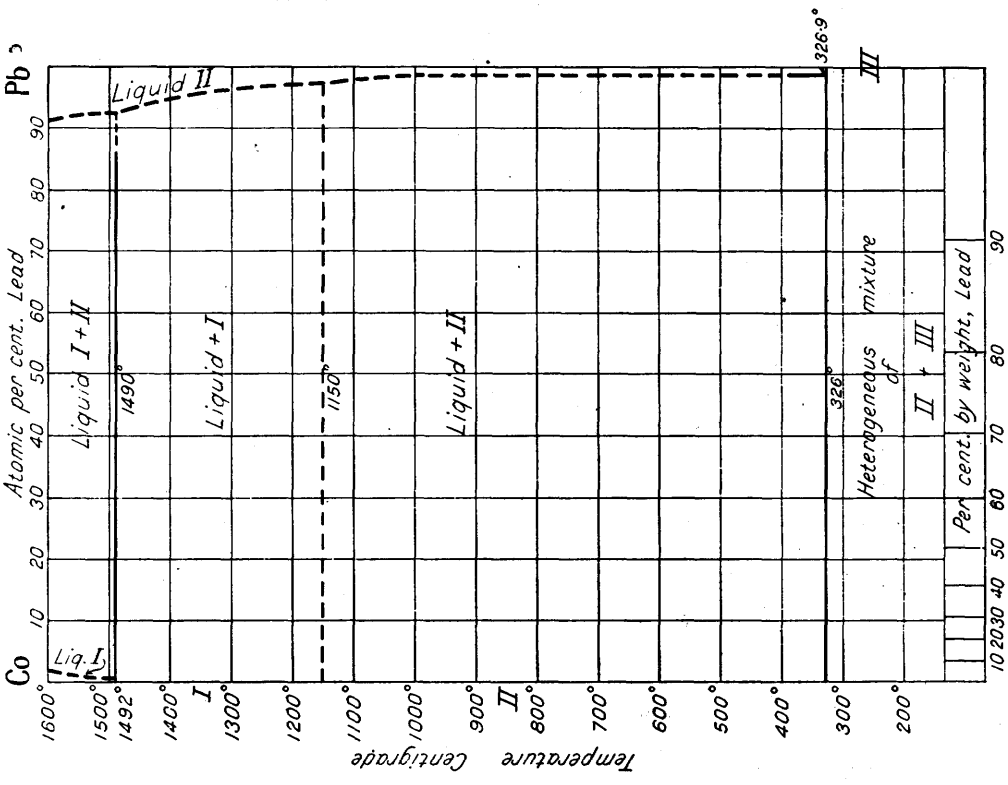


Figure 9.—Equilibrium Diagram of Cobalt-Lead Alloys.

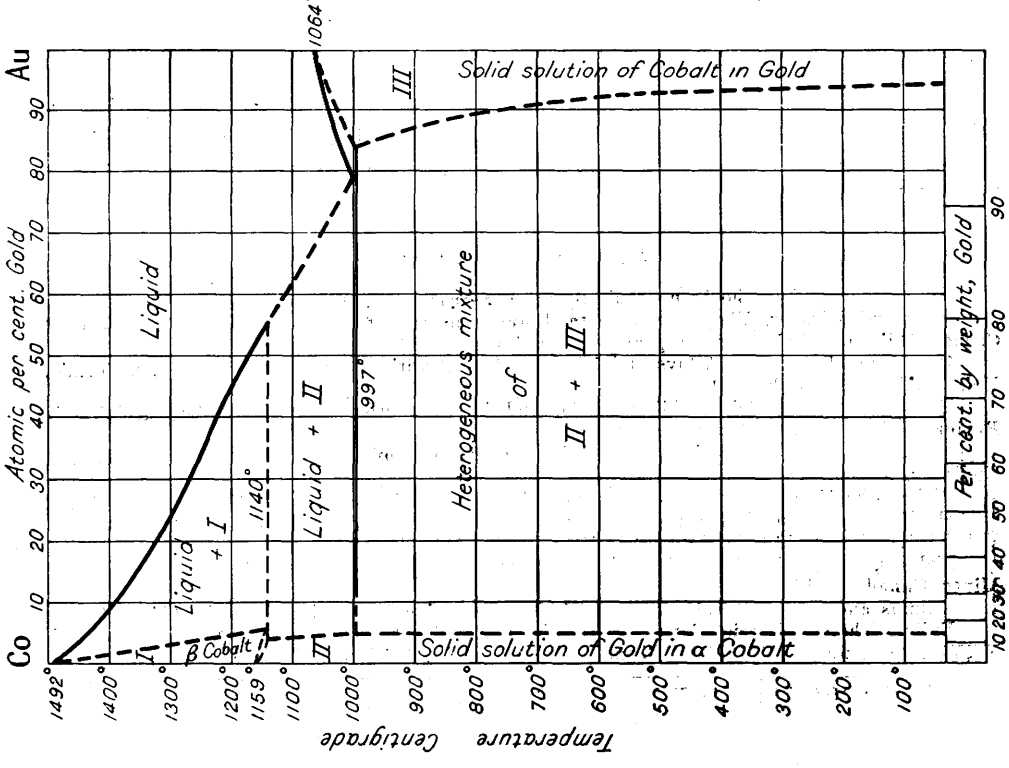


Figure 8.—Equilibrium Diagram of the Cobalt-Gold Alloys.

Cobalt and Iron

The equilibrium diagram of the cobalt-iron alloys is shown in Figure 12.[1] The two metals form a complete series of solid solutions.

A more complete diagram has been published by Ruer and Kaneko. In this diagram the two metals form a series of solid solutions with a minimum between 30 and 40 per cent. of iron and at about 1450°C. By the addition of cobalt the melting point of iron is lowered. The branch of the curve on the iron side of the diagram shows a reaction between the solid solution containing 15.5 per cent. of cobalt with the liquid containing 22 per cent. of cobalt to form a solid solution containing 19 per cent. of cobalt. The two branches of the iron curve then rise, intersecting at 1520°C., the melting point of iron.

In the same diagram the curve of magnetic transformation of iron alloys is also shown. The curve shows a maximum at 55 per cent. of iron and 985°C., which composition approaches very closely that of the compound Fe_4Co. With alloys containing less than 85 per cent. iron, the unmagnetic γ iron changes directly to the α magnetic form. With alloys containing between 100 and 85 per cent. of iron, the γ iron passes through the β form. A curve showing the transformation of β to α cobalt is also shown.

An alloy of iron, nickel, and cobalt with additions of chromium, molybdenum, tungsten, and other metals has been patented by Borchers. (For a more complete description of this alloy, see under Cobalt and Nickel.)

Yensen has investigated the magnetic properties of the iron-cobalt alloy, Fe_2Co, which contains approximately 30 per cent. of cobalt. He states that in this iron-cobalt combination, an alloy is found that is suitable for use in places where the magnetic density is very high, such as armature teeth of dynamo machinery. While its electrical resistance is low, there is reason to believe that this may be raised by the addition of other alloying elements.

Kalmus undertook a series of experiments to test whether the addition of cobalt to sheet iron had any marked effect on corrosion. The results obtained, though not conclusive, showed that cobalt in amounts up to 3 per cent. had a beneficial effect.

Additional References

Ruer and Kaneko, The Iron-Cobalt System: Ferrum, Vol. XI, 1913, p. 33.

Ruer and Klesper, The Gamma-Delta Transformation of Pure Iron, and the Effect of Carbon, Silicon, Cobalt, and Copper: Ferrum, Vol. XI, 1913, pp. 259-261.

Guertler and Tamman, Alloys of Nickel and Cobalt with Iron: Zeitschr. anorgan. Chemie, Vol. XLV, 1905, pp. 205-224.

Yensen, The Iron-Cobalt Alloy Fe_2Co, and its Magnetic Properties: General Electric Review, Vol. XVIII, 1915, pp. 881-887.

Mathews, Metallic Conduction and the Constitution of Alloys: Electrical World and Engineer, Vol. XL, 1902, pp. 531-533.

Weiss, The Magnetic Properties of the Alloys of the Ferro-Magnetic Metals, Iron-Nickel, Nickel-Cobalt, and Cobalt-Iron: mention is made of Fe_2Co. Transactions Faraday Society, Vol. VIII, 1912, pp. 149-156. Revue de Metallurgie (Memoires) Tome IX, 1912, pp. 1135-1143.

Kalmus, Magnetic Properties of Cobalt and of Fe_2Co, Bulletin 413, Department of Mines, Canada, 1916.

Kalmus and Blake, Cobalt Alloys with Non-Corrosive Properties. Bulletin 411, 1916.

Fuller, Thermo-electric Force of Certain Iron Alloys: Amer. Electrochem. Soc., Vol. XXVII, 1915, pp. 241-251; Met. Chem. Eng., Vol. XIII, 1915, pp. 318, 319.

[1] Guertler, Metallographie, Vol. I, 1912, pp. 78-81.

Becket, F. M., Manufacture of an alloy of approximately the composition given by Fe_2Co, containing 2 to 6 per cent. silicon. United States Patent, No. 1,247,206, Nov. 20th, 1917.

Honda and Takagi, The Irreversibility of Nickel and Cobalt Steels, Chem. Abst., Vol. XI, 1917, p. 2449.

Effect of Cobalt on Steel

Owing to the importance of nickel steels and because of the close association and similar chemical properties of nickel and cobalt, numerous experiments have been made to ascertain whether cobalt produced any marked effect similar to that of nickel on the properties of steel.

From the tests conducted so far it has been shown that cobalt has a beneficial effect on certain steels and for certain uses, but that its behaviour is very different from that of nickel.

Hadfield,[1] who was about the first to investigate the effect of the addition of cobalt to steel, concluded that cobalt raised the elastic limit and tensile strength. The amount of cobalt added varied from 0.0 to 6.9 per cent., and the steel contained 0.64 to 1.2 per cent. silicon and 0.10 to .14 per cent. sulphur.

Guillet[2] conducted a series of experiments by adding cobalt to a 0.8 per cent. carbon steel, in amounts up to 30 per cent. He also prepared a few samples containing 50 and 60 per cent. cobalt. The tests showed that the tensile strength increased with the proportion of cobalt, but that no sudden change in the mechanical properties occurred.

Arnold and Read[3] investigated the effect of cobalt on steel and concluded that the additions of cobalt increased the tensile strength, but cobalt did not show the same tendency to precipitate carbon in the form of graphite as nickel does.

Although cobalt steels have shown greater strength than the ordinary carbon steels, it is possible that this increased strength may be obtained more cheaply by the addition of other metals. However, the addition of cobalt to high-speed steels appears to produce an improvement in the cutting properties, and considerable quantities are being used at present for this purpose. In some cases it is claimed the life of high-speed steels containing cobalt, is increased several times.

The effect of cobalt on high-speed steels is quite different from that of nickel. The addition of between 5 and 10 per cent. of cobalt to steel produces a good high-speed steel, while the addition of nickel has an altogether different effect, since it produces a metal with a soft edge.

The valuable properties imparted by addition of cobalt to steel appear to be due to an increase in the hardness of the steel when at a red heat, thereby enabling the steel to cut at a higher speed.

A number of comparative cutting tests have been made by Schlesinger,[4] and the results show a distinct advantage in favour of cobalt high speed steels. One of the high-speed cobalt steels tested contained C 0.76, Si 0.28, Co 5.0, Cr. 4.4, W. 16.4, and V. 0.62 per cent. This analysis corresponds very closely with an alloy steel called Rex AAA.

[1] Hadfield, Iron and Steel Alloys: Iron and Steel Magazine, Vol. VII, 1904, p. 10.

[2] Guillet, Cobalt Steels: Revue de Metallurgie (Memoires), Vol. II, 1905, pp. 348-349.

[3] Arnold and Read, The Chemical and Mechanical Relation of Iron, Cobalt and Carbon: Engineering, Vol. XCVIII, 1915, pp. 346-348, 362-364.

[4] Schlesinger, The Improvement of German Steel Works by the production of High-Speed Steel Alloys: Stahl und Eisen, Vol. XXXIII, 1913, pp. 929-939.

Becker[1] has obtained a patent specifying the use of cobalt in high-speed tool steels. The granting of this patent was opposed by a large number of European manufacturers, but the decision[2] was given in favour of Becker.

A later report[3] states that the patent granted to Becker has been revoked by a decision of a British Court.

Darwin and Milner[4] claim to have discovered a cobalt-chromium steel equal to the Becker iridium-cobalt-tungsten steel. One advantage of the new product is that it may be hardened at a temperature 300°C. below that required for the tungsten steel.

Additional References

Hibbard, Manufacture and Uses of Alloy Steels: Bulletin 100, 1915, p. 60, Bureau of Mines, Washington.
Chromium Nickel, and Cobalt in Pig Iron: Iron Age, Vol. LXXX, 1907, p. 488.
Abstract of Schlesinger's tests on Cobalt Steel: Iron Age, Vol. XCII, 1913, p. 33.
Lantsberry, High-Speed Tool Steel: Iron Age, Vol. XCVI, 1915, pp. 238-241.
German High-Speed Steel: Iron Age, Vol. XCVIII, 1916, p. 1111.
Browne, Metals and Alloys in the Steel Industry: Vol. XCVII, 1916, p. 76.

Cobalt and Lead

The equilibrium diagram of the cobalt-lead series is shown in Figure 9.[5] The solubility of the two metals in the liquid state is very small.

The transformation line of cobalt was not determined, but on account of the small solubility of lead it must lie practically at 1159°C.

Additional References

Lewkonja, Cobalt-Lead Alloys: Zeitschr. anorg. Chemie, Vol. LIX, 1908, pp. 312-315.
Ducelliez, Study of the Alloys of Cobalt and Lead: Bulletin Société Chimique, Vol. III, 1908, pp. 621-622.
Chemical Study of the Alloys of Cobalt and Lead: Procès verbaux de la Société des sciences physiques et naturelles de Bordeaux, 1908, pp. 31-34.
A Study of the Electromotive Force of Cobalt-Lead Alloys: Bulletin Société Chimique, Vol. VII, 1910, pp. 201-202.
Bornemann, Cobalt and Lead: Metallurgie, Vol. VIII, 1911, pp. 361-362.

Cobalt and Magnesium

Very few experiments have been made to prepare cobalt-magnesium alloys. Parkinson[6] attempted to prepare a mixture or alloy of these metals by adding magnesium to molten cobalt. However, he obtained only small amounts of magnesium in the solid alloy. The experiments were not carried far enough to warrant any conclusions.

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[1] German Patent, No. 281,386, Aug. 10th, 1912. Manufacture of High-Speed Cobalt Steels. An approximate analysis of a High-Speed Cobalt Steel is given as C 0.7, Cr 5, W 18, V 1, Mo 0.75 and Co 10 per cent.
United States Patent, No. 1,081,263, December 9th, 1913. Also a British patent.
[2] Iron Age, Vol. XCIII, 1914, p. 453.
[3] Iron Age, Vol. 101, 1918, p. 321.
[4] Darwin and Milner, Cobaltchrome Tool Steel: Engineering, Vol. CIV, 1917, p. 22.
[5] Guertler, Metallographie, Vol. I, 1912, p. 582.
[6] Guertler, Metallographie, Vol. I, 1912, p. 415.

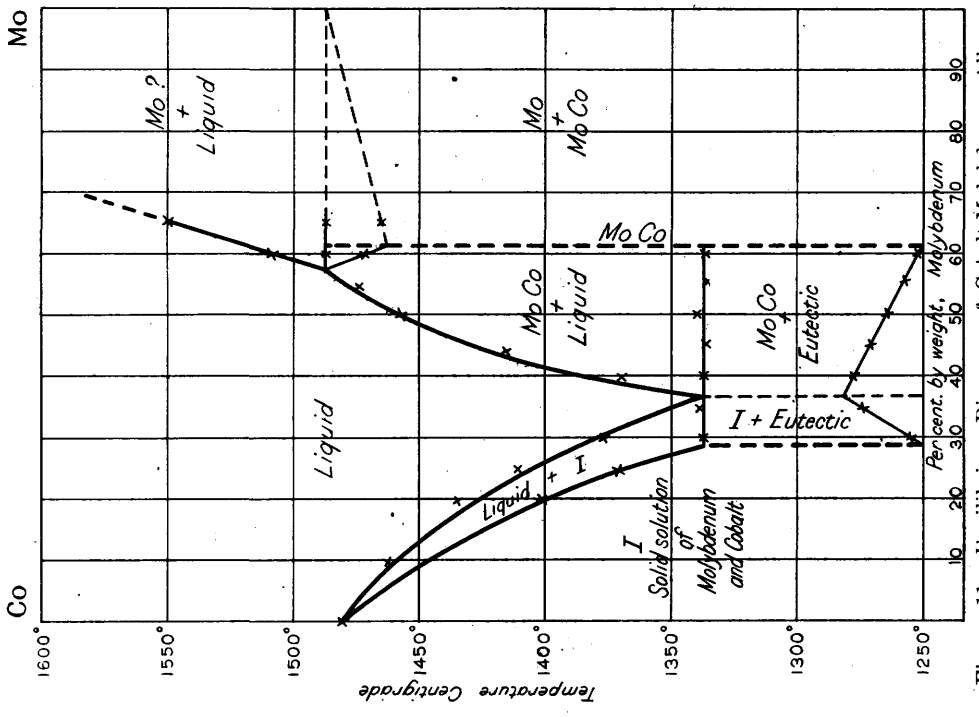


Figure 11.—Equilibrium Diagram of Cobalt-Molybdenum Alloys.

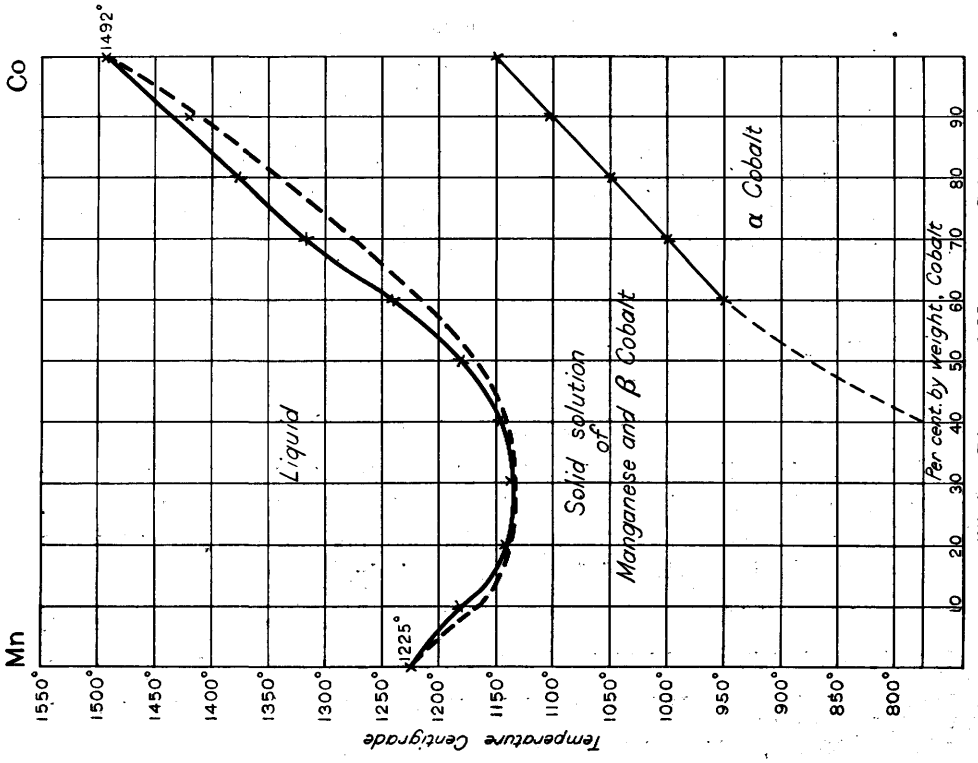


Figure 10.—Equilibrium Diagram of Manganese-Cobalt Alloys.

Cobalt and Manganese

The equilibrium diagram of the cobalt-manganese series is shown in Figure 10.[1] A minimum exists at approximately 30 per cent. cobalt and 1140°C. The alloys in solidifying exhibit a strong tendency toward undercooling. Alloys with more than 40 per cent. cobalt are not homogeneous, but become more nearly so by annealing at 1000°C. for 5 hours. Those alloys containing more than 40 per cent. cobalt were magnetic, the magnetism rising rapidly with increased cobalt content. In the original article Hiege shows the melting points of cobalt and manganese at 1525° and 1250° C. respectively. As this temperature for cobalt is about 25°C. higher than that used in the other diagrams, in reproducing the cobalt-manganese diagram all Hiege's temperatures have been reduced by 25°.

Huntington[2] states the addition of manganese to cobalt renders cobalt malleable.

Additional References

Arrivant, Alloys of Manganese with Nickel, Cobalt, and Vanadium: Procès verbaux de la Société des sciences physiques et naturelles de Bordeaux (Memoires), 1905-1906, pp. 105-114, 152-154.

Guertler, Metallographie, Vol. I, 1912, p. 90.

Guertler, The Magnetizability of the Alloys of the Ferro-Magnetic Metals, Zeitschr. physikal. Chemie, Vol. 65, 1908, pp. 73-83.

Cobalt and Molybdenum

The equilibrium diagram of the cobalt molybdenum alloys is shown in Figure 11.[3] Owing to the difficulty of obtaining homogeneous liquid melts at 1800°C., alloys with more than 65 per cent. molybdenum have not been prepared. A eutectic of a cobalt solid solution and the compound MoCo occurs at 1335°C., and 37 per cent. molybdenum. At the eutectic temperature cobalt retains 28 per cent. molybdenum in solid solution. At 1488°C., the compound MoCo (62 per cent. Mo) is formed by a reaction.

Alloys containing up to 60 per cent. molybdenum are magnetic, but those containing between 50 and 60 per cent. are very feebly so.

Additional Reference

Guertler, Metallographie, Vol. I, 1912, pp. 378-379.

Cobalt-Nickel Alloys

The equilibrium diagram of the cobalt-nickel alloys is shown in Figure 13.[4] The liquidus and solidus lie practically in a straight line between the melting points of the pure metals. The transformation temperatures of pure nickel and cobalt occur at about 320°C., and 1159°C. respectively.

[1] Hiege, Alloys of Manganese with Cobalt: Zeitschr. anorg. Chemie, Vol. LXXXIII, 1913, pp. 253-256.

[2] Huntington, Metallurgy of Nickel and Cobalt, Jour. Soc. of Chem. Ind., Vol. I, 1882, p. 258.

[3] Ravdt and Tamman, Molybdenum-Cobalt Alloys: Zeitschr. anorg. Chemie, Vol. LXXXIII, 1913, pp. 246-252.

[4] Guertler, Metallographie, Vol. I, 1912, p. 81.

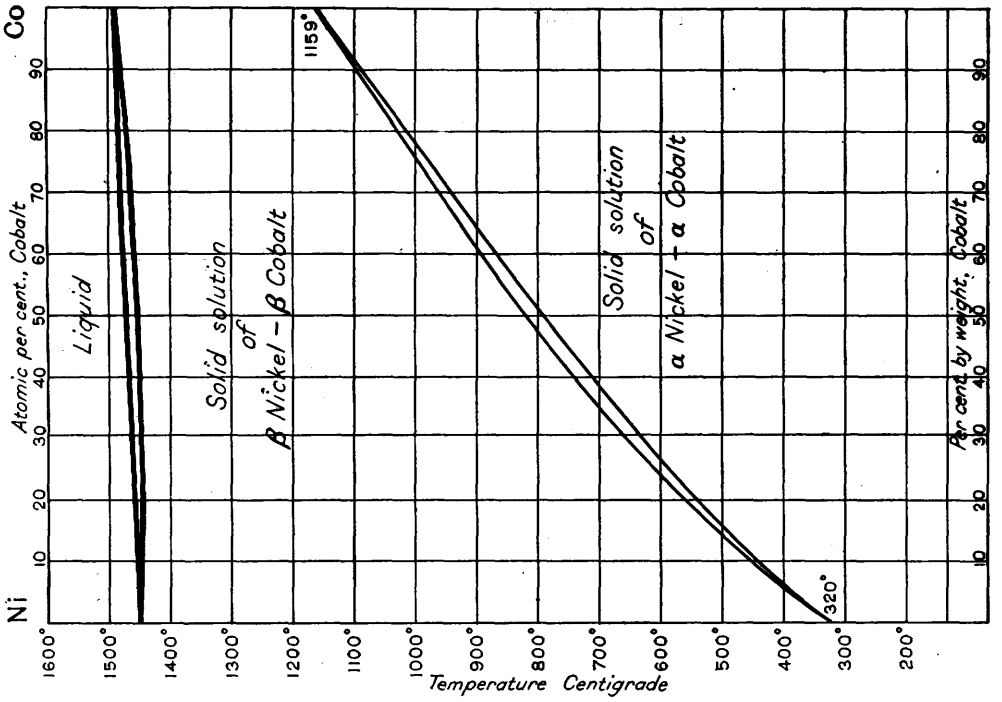


Figure 13.—Equilibrium Diagram of Nickel-Cobalt Alloys.

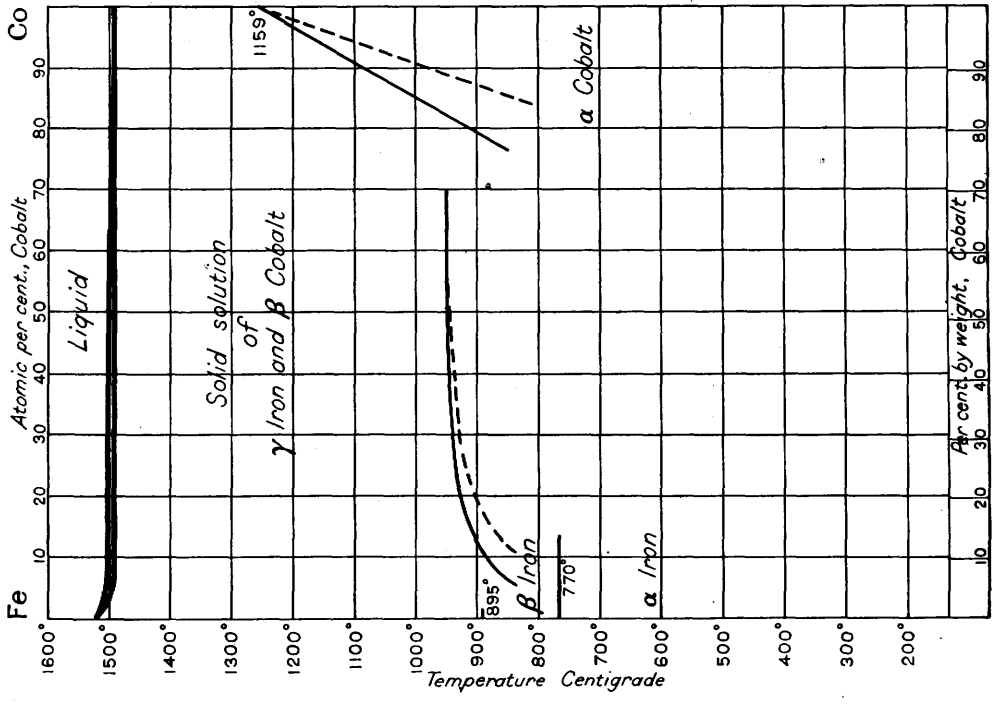


Figure 12.—Equilibrium Diagram of Iron-Cobalt Alloys.

The hardness of the cobalt-nickel alloys remains practically constant until 60 per cent. cobalt is reached, when the hardness increases rapidly with increased percentage of cobalt.

Certain alloys of cobalt and nickel are only slightly attacked by acids, and a number of patents have been granted for acid-resistant cobalt-nickel alloys with the addition of a third or fourth metal for certain other properties.

The first patent[1] was granted to Borchers for an alloy of high chemical resistance, combined with good mechanical properties. It contained approximately 67.5 per cent. nickel, 30 chromium, and 2.5 silver. The addition of silver is said to improve the mechanical properties. Later[2] copper was substituted for the silver.

The next patent[3] was for an acid resistant and mechanically workable nickel-cobalt-silver alloy, the proportions being 39.5: 60: 0.5 respectively. It was found later[4] that the nickel in the first patent may be replaced by an equal amount of cobalt, and the silver wholly or partly by copper. Subsequently, the silver and copper mentioned in the previous patent were replaced by molybdenum.

A later patent[5] granted for chemically resistant and mechanically workable alloys specified the substitution of gold, metals of the platinum group, or tungsten, for the molybdenum in the first mentioned patent.

Another patent[6] was granted whereby up to 90 per cent. of the nickel in the previous patents may be replaced by iron. This was followed by a patent[7] covering the alloys of iron, nickel, and cobalt and their alloys with one another, with additions of chromium between 25 and 35 per cent. and below 5 per cent. of one or more of the following metals: molybdenum, tungsten, platinum, iridium, osmium, palladium, rhodium, ruthenium, tin, silver, and copper.

Cobalt-Nickel-Copper Alloys

An extensive investigation of the cobalt-nickel-copper alloys was undertaken by Waehlert.[8] From the tests he concluded that the addition of cobalt to copper-nickel alloys shows an improvement in the tensile strength, hardness, and working properties. The ternary alloys were quite resistant to sulphuric acid (20 per cent. or more) but were attacked more vigorously by nitric acid. The greatest hardness of the series of alloys occurs when the cobalt and nickel are in approximately equal proportions. The colour of the alloys changes from copper-red to white with 50 per cent. of combined cobalt and nickel.

Additional References

Guertler and Tamman, Alloys of Cobalt and Nickel: Zeitschr. anorg. Chemie, Vol. XLII, 1904, pp. 353-363.

Weiss, The Magnetic Properties of the Alloys of the Ferro-Magnetic Metals, Iron-Nickel, Nickel-Cobalt, Cobalt-Iron: Transactions Faraday Society, Vol. VIII, 1912, pp. 149-156.

[1] German Patent, No. 255,919, June 21st, 1912, W. Borchers and R. Borchers.
[2] German Patent, No. 257,380, August 20th, 1912, Gebr. Borchers.
[3] German Patent, No. 256,123, June 21st, 1912, Gebr. Borchers.
[4] German Patent, No. 256,361, August 20th, 1912, W. Borchers and R. Borchers.
[5] German Patent, No. 265,076 and No. 265,328, Feb. 11th, 1913, W. Borchers and R. Borchers.
[6] German Patent, No. 268,516, June 12th, 1913, W. Borchers and R. Borchers.
[7] British Patent, No. 18,212, August 11th, 1913, W. Borchers and R. Borchers.
[8] Waehlert, Cobalt-Nickel-Copper Alloys: Osterr. Zeitschr. Berg. u. Hüttenwesen, Vol. LXII, 1914, pp. 341, 361, 375, and 392-406.

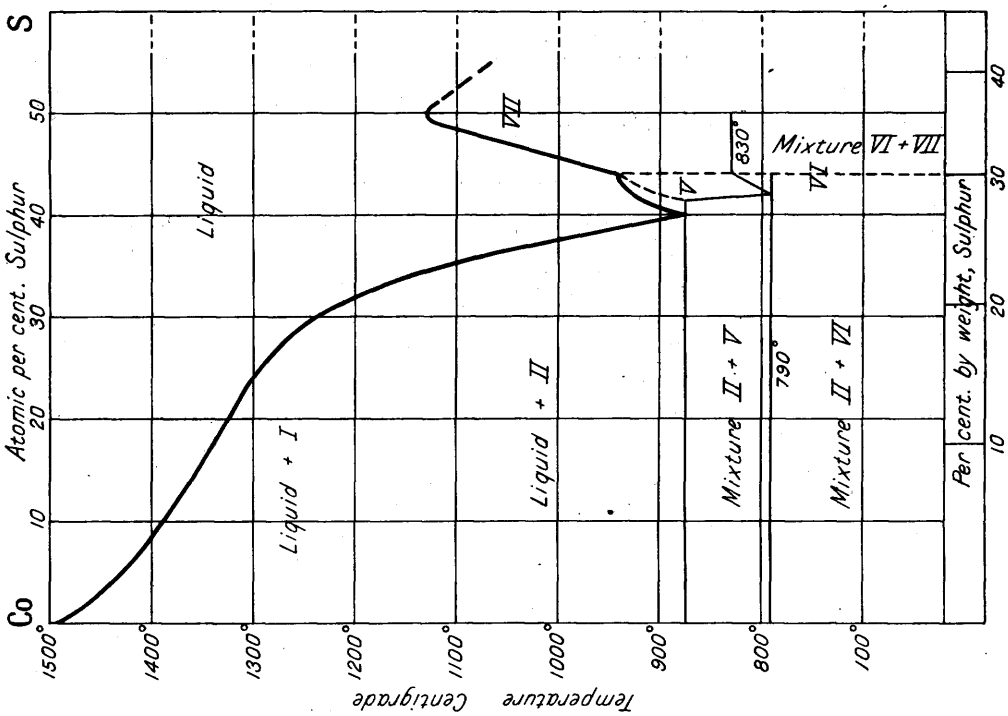


Figure 16.—Equilibrium Diagram of Cobalt-Sulphur Alloys.

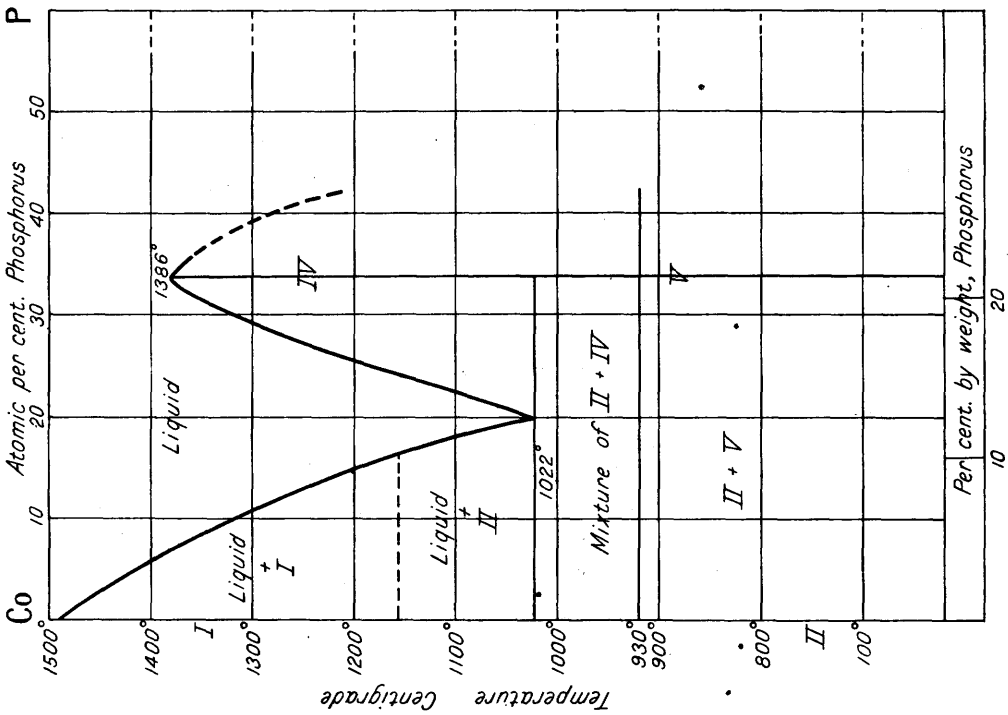


Figure 14.—Equilibrium Diagram of Cobalt-Phosphorus Alloys.

Ruer and Kaneko, The Nickel-Cobalt System: Metallurgie, Vol. IX, 1912, pp. 419-442.
The Specific Resistance and Hardness of Nickel-Cobalt Alloys: Ferrum, Vol. X, 1913, pp. 257-260.
Weiss and Bloch, Magnetism of Nickel and Cobalt and the Alloys of Nickel and Cobalt: Compt. Rend., Vol. CLIII, 1911, pp. 941-943.

Cobalt and Phosphorus

The equilibrium diagram of the cobalt-phosphorus alloys up to 20.7 per cent. phosphorus, is shown in Figure 14.[1] The addition of phosphorus lowers the melting point of cobalt to a eutectic point at 1022°C. and 11.5 per cent. phosphorus. From the eutectic point the curve rises rapidly to a maximum at 1386°C., the melting point of the compound Co_2P. Difficulty was experienced in preparing mixtures containing higher concentrations of phosphorus.

At 920°C. the separated crystals of Co_2P undergo a transformation, forming other crystals of similar composition.

Additional Reference

Guertler, Metallographie, Vol. I, 1912, pp. 888-890.

Cobalt and Selenium

The equilibrium diagram of the cobalt-selenium alloys has not yet been investigated. Partial investigations seem to indicate the formation of the compounds CoSe and Co_3Se_4.[2]

Cobalt and Silicon

The equilibrium diagram of the cobalt-silicon alloys is shown in Figure 15.[3] The curve shows two solid solutions, four eutectic points, and five compounds; one of the compounds, mentioned again below, being formed by a reaction in the solid state, and another by a reaction between separated crystals and liquid. Cobalt retains 7.5 per cent. silicon in solid solution at 1204°C., while silicon retains approximately 9 per cent. cobalt in solid solution at about 1250°C.

The eutectic point B lies at 1204°C. and 15 per cent. silicon. Further additions of silicon cause the melting point curve to rise to C at 19.5 per cent. silicon and 1327°C., corresponding to the compound Co_2Si. With further additions of silicon the melting point curve is lowered to the eutectic point D at 1249°C. and 25.5 per cent. silicon. Below 1249°C. a change occurs in the eutectic, as shown by the line c d e, with the formation of a new compound Co_3Si_2. Further additions of silicon cause another rise in the melting point curve to E, at approximately 1395°C., and 32.5 per cent. silicon, corresponding to the compound CoSi. A lowering of the curve occurs again with increased silicon. At F a reaction occurs between the compound CoSi and liquid F to form a new compound $CoSi_2$, the composition of which is very near that of F. From F the curve drops to the eutectic point G at 1213°C., and approximately 54 per cent. silicon. Again there is a rise in the melting-point curve to H, at 1310°C. and 59 per cent. silicon,

[1] Zemczuzny and Schepelew, Phosphorus Compounds of Cobalt: Zeitschr. anorg. Chemie, Vol. LXIV, 1908, pp. 245-257.
[2] Guertler, Metallographie, Vol. I, 1912, p. 951.
[3] Lewkonja, Cobalt-Silicon Alloys: Zeitschr. anorg. Chemie, Vol. LIX, 1908, pp. 317-338. Revue de Métallurgie, Vol. 8, 1909, p. 954.

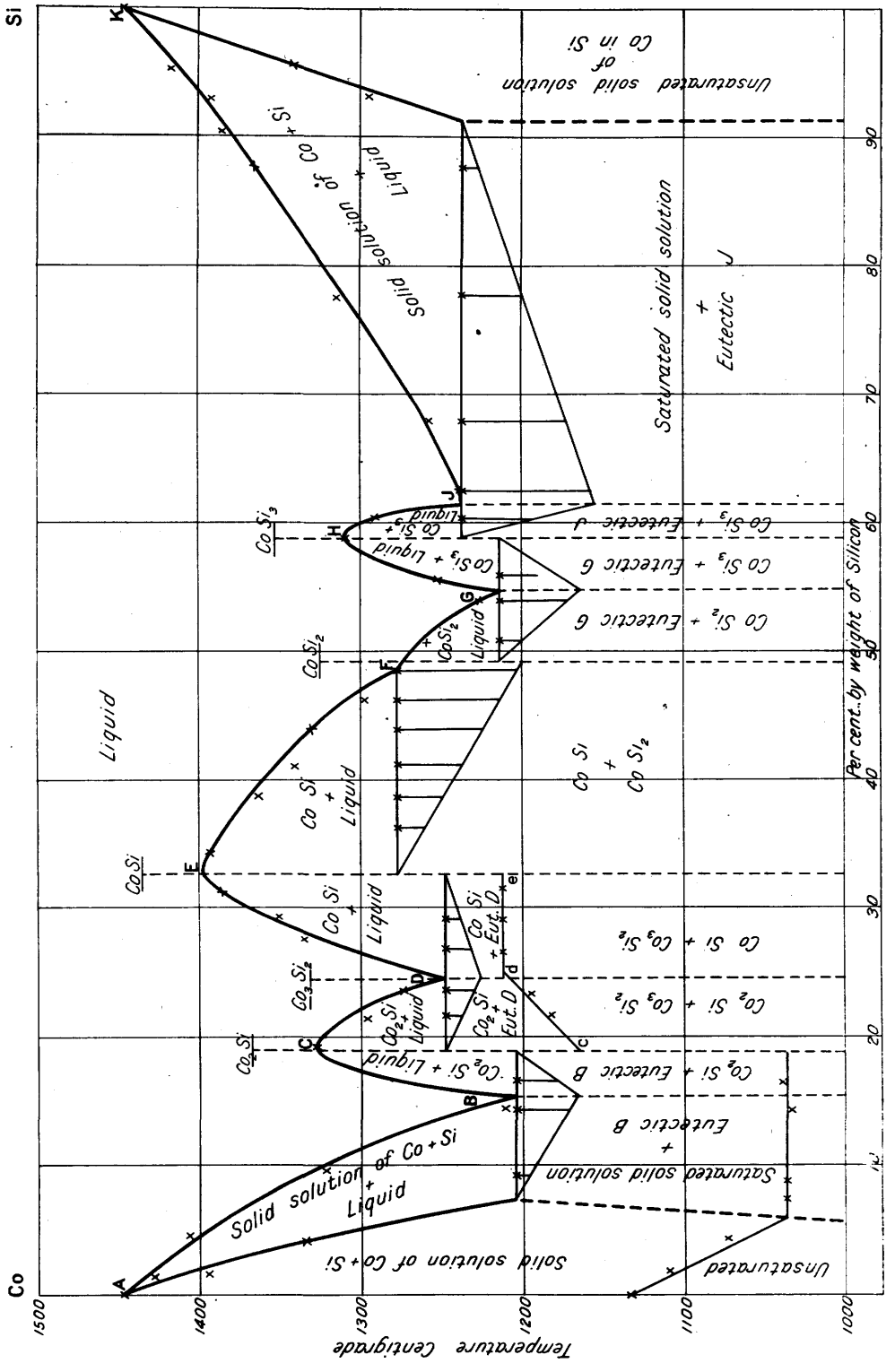


Figure 15.—Equilibrium Diagram of Cobalt-Silicon Alloys.

corresponding to the compound $CoSi_3$. The curve then falls to the eutectic J at 1236°C., and 62 per cent. silicon. From J the melting-point curve rises to K at 1425°C., the melting point of silicon.

Additional References

Lebeau, Silicides of Cobalt: Annales de Chimie et de Physique, Paris, Vol. XXVII, Sér. 7, 1902, pp. 271-277.

Combinations of Silicon with Cobalt and a new Silicide of this Metal: Compt. Rend., Vol. CXXXV, 1902, pp. 475-477.

Vigouroux, Action of Chloride of Silicon on Cobalt: Compt. Rend., Vol. CXLII, 1906, pp. 635-637.

Beckett, F. M., Alloy containing Iron, Cobalt, and Silicon. United States Patent, No. 1,247,206, Nov. 20th, 1917.

Cobalt and Silver

The cobalt-silver alloys have been investigated by Petrenko,[1] who found that cobalt and silver are practically insoluble in one another at temperatures up to 1600°C.

Additional References

Ducelliez, A Study of the Alloys of Cobalt and Silver: Bulletin Société Chimique de France, Vol. VII, 1910, pp. 506-507.

A Study of the Alloys of Cobalt and Silver: Procès verbaux de la Société des sciences physiques et naturelles de Bordeaux, 1909-1910, pp. 46-48.

Guertler, Metallographie, Vol. I, 1912, p. 100.

Cobalt and Sulphur

The equilibrium diagram of the cobalt-sulphur alloys from 0 to 35 per cent. sulphur, is shown in Figure 16.[2] The addition of sulphur to cobalt lowers the melting point from 1490°C. to the eutectic at 879°C. and 73.4 per cent. cobalt. This percentage corresponds closely to that of the formula Co_3S_2, but the eutectic is not a compound. The curve rises with further additions of sulphur to 935°C. and 70.7 per cent. cobalt. At this temperature the compound Co_4S_3 forms, and from 70.7 to 73.4 per cent. cobalt, a solid solution, V, of Co_4S_3 with cobalt exists. The liquidus curve rises finally to a maximum of 1130° and 68 per cent. cobalt, probably approaching the compound CoS.

The formation of the compound Co_4S_3 has not yet been finally accepted. However, there is evidence of a transformation occurring in the solid solution V at 830° and 790°C.

Cobalt and Thallium

The equilibrium diagram for the cobalt-thallium alloys is shown in Figure 17.[3] The metals are only partly soluble in one another in the liquid state. Thallium dissolves 2.8 per cent. cobalt, the melting point thereby being lowered

[1] Petrenko, Alloys of Silver with Iron, Nickel, and Cobalt: Zeitschr. anorg. Chemie, Vol. LIII, 1907, pp. 212-215.

[2] Guertler, Metallographie, Vol. I, pp. 981-982. 1912. Friedrich, Diagram of Cobalt-Sulphur Alloys: Metallurgie, Vol. V, 1908, pp. 212-215.

[3] Lewkonja, Cobalt-Thallium Alloys: Zeitschr. anorg. Chemie, Vol. LIX, 1908, pp. 318-319. Guertler, Metallographie, Vol. I, 1912, pp. 580-582.

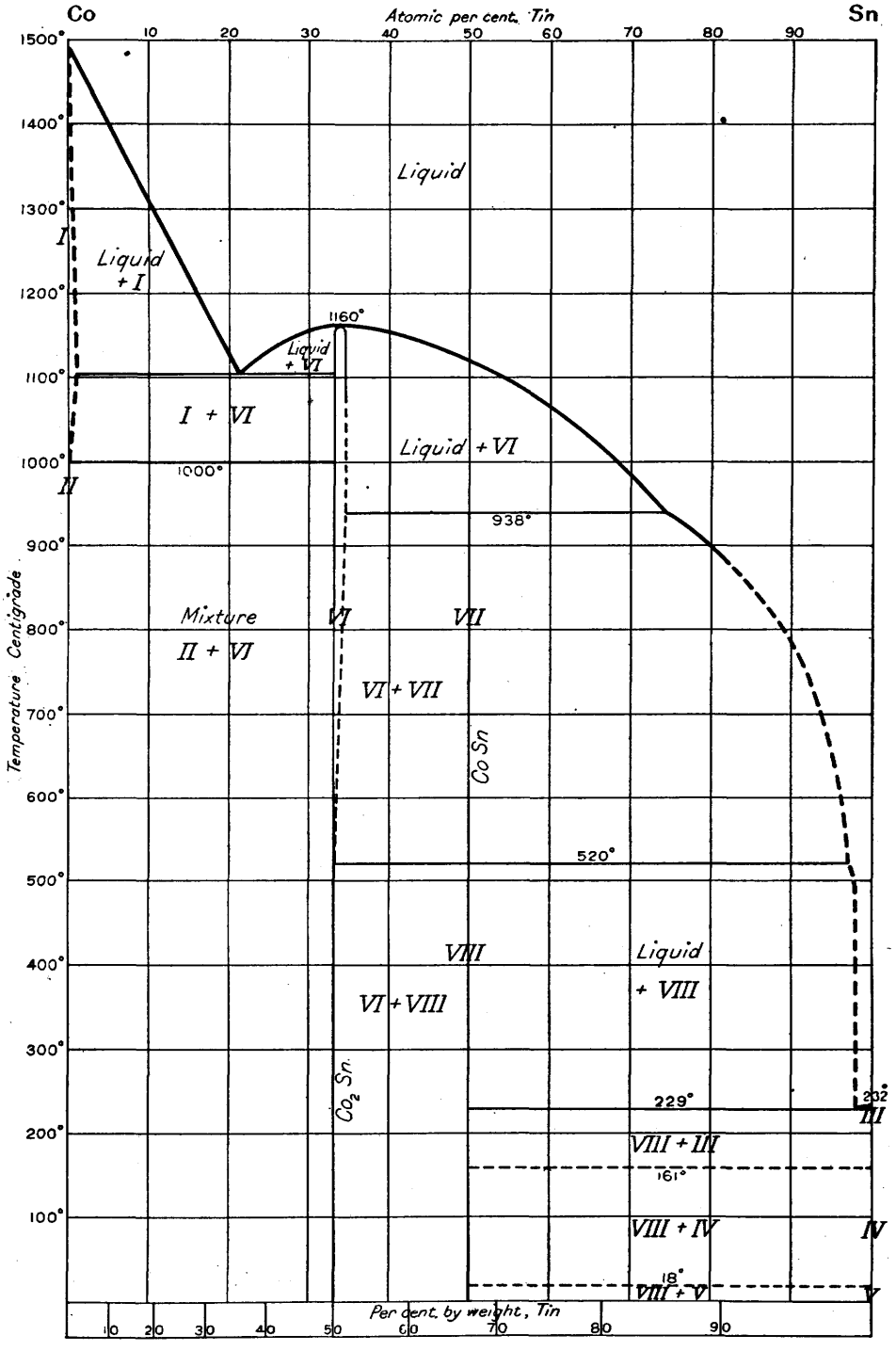


Figure 18.—Equilibrium Diagram of Cobalt-Tin Alloys.

6°C. Alloys with 10 per cent. cobalt show two layers. The boiling point of thallium lies very near the melting point of cobalt. Transformation lines are shown dotted in the diagram at 297° and 224°C.

Cobalt and Tin

The equilibrium diagram of the cobalt-tin alloys is shown in Figure 18.[1] The two metals are soluble in each other in the liquid state, but only to a small extent in the solid, cobalt retaining 2 per cent. tin at 1104°C. The addition of tin to cobalt lowers the melting point of cobalt from 1492° to the eutectic point at 1104°C. and 35 per cent. tin. With further additions of tin, the liquidus rises to a maximum at 1160°C. and 50 per cent. tin, which corresponds to the compound Co_2Sn. The curve falls with further additions of tin to 938°C., where a reaction occurs between the previously separated compound Co_2Sn and the liquid, containing 85 per cent. tin, to form a new compound CoSn. At 520°C., the compound CoSn undergoes a transformation to form a new crystal of similar composition. At 229°C. the eutectic of CoSn and tin occurs. Tin undergoes the usual transformation at 161° and 18°C.

Ducelliez[2] asserts that the compound Co_2Sn of Lewkonja is Co_4Sn_2, and has supported his assertion by numerous experiments.

An investigation of the effect of additions of cobalt on the mechanical and chemical properties of tin and bronze has been undertaken by Barth.[3] He found that adding up to 10 per cent. of cobalt to tin produced an increase in strength and an improvement in the working qualities. With 10 to 20 per cent. cobalt the alloy was a little brittle, about as hard as copper, and gray in colour. With 20 to 30 per cent. cobalt, the alloy had a smooth, bright, glassy fracture and was very hard and brittle. With 40 to 50 per cent. cobalt the hardness and brittleness increased, and the alloys broke into a number of pieces when cooling in the moulds. The alloy with 40 per cent. cobalt showed a conchoidal fracture, while that with 50 per cent. showed a very coarse crystalline structure. The alloys with more than 60 per cent. cobalt showed a finer grained, denser structure. These alloys were very hard and capable of taking a good polish.

The alloys with 20 to 50 per cent. cobalt were only slightly attacked by 60 per cent. nitric acid in five minutes. Molybdenum added to the 50 per cent. alloys did not show any advantage in the chemical tests.

A few experiments were made by Barth to investigate the effect of cobalt on the mechanical properties of bronze, but sufficient tests were not made to draw any definite conclusions.

Browne[4] made a few tests to determine the effect of cobalt (0 to 0.5 per cent.) on an alloy of the following composition: Cu 88, Sn 10, and Zn 2. The results, while encouraging, were not conclusive.

[1] Guertler, Metallographie, Vol. I, 1912, pp. 650-654.

[2] Ducelliez, Studies of the Alloys of Cobalt and Tin: Procès verbaux de la société des sciences physiques et naturelles de Bordeaux, 1907, pp. 51-55, 97-105, 115-119; Compt. Rend. Vol. CXLIV, 1907, pp. 1432-1434; Compt. Rend., Vol. 145, 1907, pp. 431, 502. A Study of the Electromotive Force of Cobalt-Tin Alloys: Bulletin Société Chimique de France, Vol. VII, 1910, pp. 205-206.

[3] Barth, Alloys of Increased Chemical Resistance and Good Mechanical Properties: Metallurgie, Vol. IX, 1911, pp. 261-270.

[4] Browne, Some Recent Applications of Metallic Cobalt: Trans. Amer. Inst. of Metals: Vol. VIII, 1914, pp. 61-67.

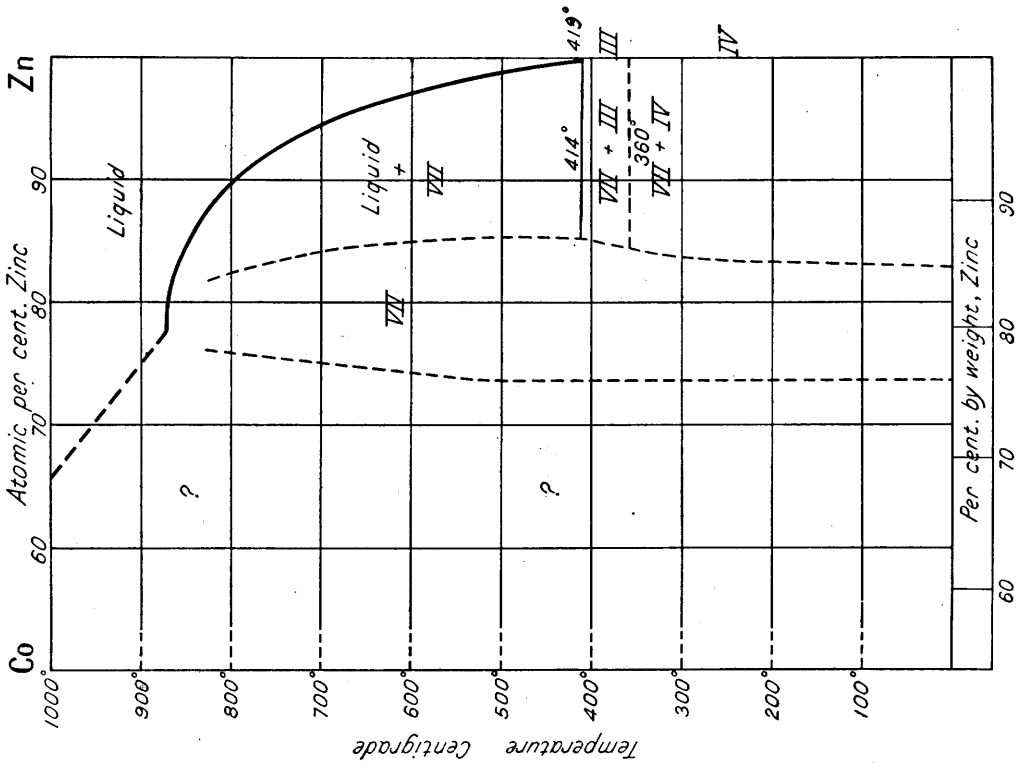


Figure 19.—Equilibrium Diagram of Cobalt-Zinc Alloys.

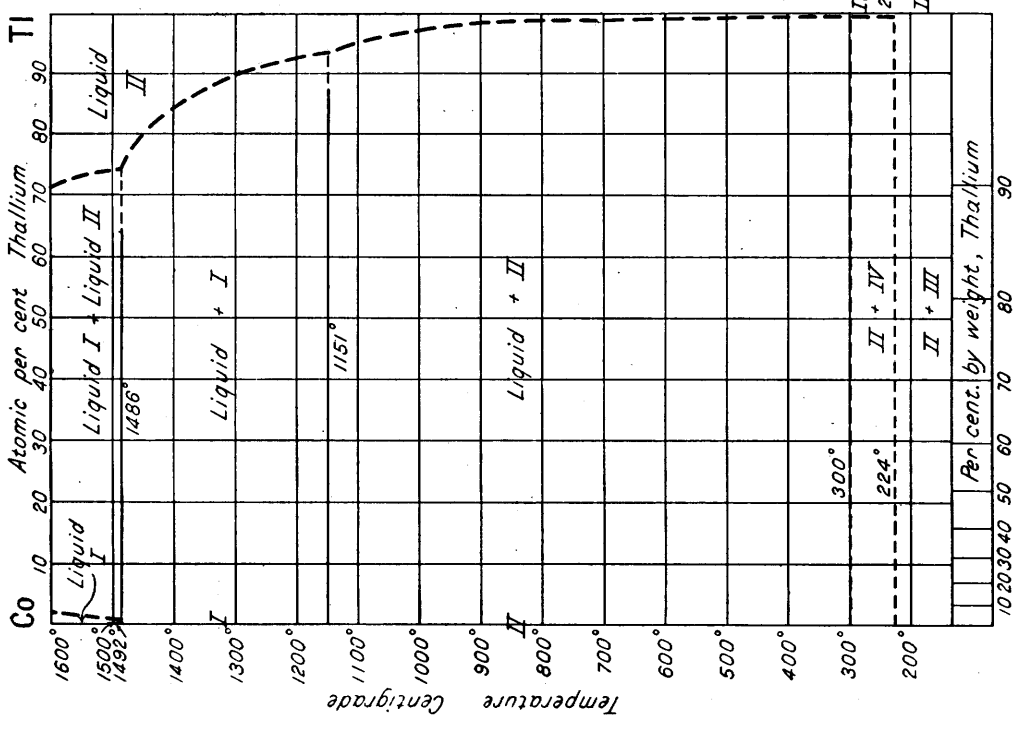


Figure 17.—Equilibrium Diagram of Cobalt-Thallium Alloys.

Additional References

Lewkonja, Cobalt-Tin Alloys: Zeitschr. anorg. Chemie, Vol. LIX, 1908, pp. 294-304.
Zemczuzny and Belynsky, Cobalt-Tin Alloys: Idem, pp. 364-370.
Bornemann, Cobalt and Tin: Metallurgie, Vol. VIII, 1911, pp. 291-292.
Kaiser, Analysis of a Tin Alloy (Sn 37, Ni 26, Bi 26, Co 11): Idem, p. 307.

Cobalt and Tungsten

The equilibrium diagram of the cobalt tungsten alloys has not yet been completely investigated. However, from the various tests that have been made, it appears that cobalt and tungsten form a complete series of solid solutions.

Reference

Guertler, Metallographie, Vol. I, 1912, p. 385.

Cobalt and Zinc

The equilibrium diagram of the cobalt-zinc alloys to 18 per cent. zinc is shown in Figure 19.[1] The addition of a small proportion (0.5 per cent.) of cobalt lowers the melting point of zinc to 414°C., 5° below the melting point. Further additions cause a rise in the liquidus, but melts containing more than 18 per cent. zinc could not be made because of the volatilization of the zinc. The curve even to 18 per cent. zinc has not been completely determined. On cooling alloys between 0.5 and 18 per cent. zinc, a solid solution varying in composition from 18.4 to 13.4 per cent. zinc separates. Melts with more than 12 per cent. zinc showed many rounded holes due to bubbles of zinc vapour.

The alloys from 0 to 18.4 per cent. cobalt were not magnetic.

Browne[2] made a few experiments with the addition of 0.5 per cent. cobalt to manganese bronze and brass containing 80 per cent. copper and 20 per cent. zinc. Sufficient tests were not made to warrant any definite statement as to the advantage of cobalt.

Additional References

Lewkonja, Cobalt-Zinc Alloys: Zeitschr. anorg. Chemie, Vol. LIX, 1908, pp. 319-322.
Ducelliez, Alloys of Cobalt and Zinc: Bulletin Société Chimique de France, Vol. IX, 1911, pp. 1017-1023.
Chemical Study of the Cobalt-Zinc Alloys: Procès verbaux de la société des sciences physiques et naturelles de Bordeaux, 1909-1910, pp. 102-107.
Electromotive Force of Cobalt-Zinc Alloys: Idem, 1909-1910, pp. 108-109.
Preparation and Properties of the Compound $CoZn_4$: Idem, pp. 109-111.

Cobalt and Zirconium

A patent[3] has been granted to H. S. Cooper covering the preparation of an alloy of cobalt and nickel with zirconium. The inventor claims that nickel and cobalt are hardened by additions of zirconium, and that the alloy so obtained is resistant to acids and alkalies, and possesses high electrical resistance. The melting point of nickel and cobalt is lowered by additions of zirconium, but the alloys cannot be forged, drawn, or rolled.

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[1] Guertler, Cobalt and Zinc, Metallographie: Vol. I, 1912, pp. 444, 445.
[2] Browne, Some Recent Applications of Metallic Cobalt, Trans. Amer. Inst. of Metals, Vol. VIII, 1914, pp. 61-67.
[3] United States Patent, No. 1,221,769, April 3rd, 1917. Eng. Min. Jour., Vol. 105, 1918, p. 335.

Ternary Alloys of Cobalt

Very little has been done in the scientific investigation of the ternary alloys of cobalt, except in a few special cases which are mentioned mostly under the binary alloys. Most investigations of the ternary alloys have been done mainly with the object of finding some alloy valuable industrially. Janecke[1] has made an attempt to classify the ternary alloys of the metals, Cu, Ag, Au, Cr, Mn, Fe, Co, Ni, Pd, and Pt, but the classification could not be carried to a conclusion because all the binary diagrams have not been completely determined.

Eight groups are proposed by Janecke, viz., those in which

(*a*) Each of the binary systems possesses complete miscibility in the solid state.

(*b*) One of the binaries forms a eutectic or a transition point.

(*c*) One of the binary systems possesses a limited miscibility in the liquid state.

(*d*) One of the two binary systems possesses a limited miscibility in the liquid state, and the other a eutectic or transition point.

(*e*) Two of the binaries possess eutectic or transition points, or one a eutectic and the other a transition point.

(*f*) Two of the binary systems possess limited miscibility in the liquid state.

(*g*) Of the three binary systems one possesses a limited miscibility in the liquid state, and both the others have either eutectics or a eutectic and a transition point.

(*h*) Of the three binary systems, one possesses a eutectic and two a limited miscibility in the liquid state.

Group A

The ternaries of this group may be subdivided into four groups according as the system shows (1) no minimum, (2) one minimum, (3) two minima or (4) three minima. The CoNiFe and CoFeCr systems belong to the subdivisions 3 and 4 respectively. The different binary systems are briefly summarized below.

Ternary CoNiFe.	Ternary CoFeCr.
Co-Ni, no minimum.	Co-Cr minimum (c) 1340°C. (49p.c.Co).
Co-Fe minimum (a)[2] 1500°C. (50p.c.Co).	Co-Fe minimum (d) 1500°C. (50p.c.Co).

Ni-Fe minimum (b) 1464°C. (70p.c.Ni). Cr-Fe minimum (e) 1440° C. (60p.c.Fe).

The systems CoNiFe may be represented diagramatically as in figure 20, while that of CoFeCr by figure 21.

Group B

The ternaries of this group are divided into two groups b_1 and b_2; b_1 in which one of the binaries shows a eutectic, and b_2 where one of the binaries shows a transition point. To b_1 belongs the system CrNiCo, and figure 22 represents it diagramatically. In the CrNiCo system Janecke gives a eutectic for the CrNi binary system.

[1] Janecke, The Ternary Alloys of the Metals, Cu, Ag, Au, Cr, Mn, Fe, Co, Ni, Pd, and Pt, Metallurgie, Vol. VII, 1910, pp. 510-523.

[2] The letters a, b, c, etc., refer to the points on the ternary diagrams.

System CrNiCo.

Cr-Ni minimum (f) 1300°C. (42p.c.Ni).
Cr-Co minimum (g) 1340°C. (49p.c.Co).
Ni-Co no minimum.

The system CoCuNi belongs under b_2 which is represented by figure 23.

System CoCuNi.

Co-Cu transition point (h) 1110°C. (96p.c.Cu).
Co-Ni no minimum.
Cu-Ni no minimum.

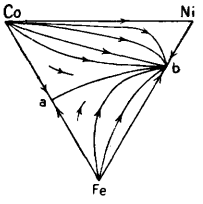


Fig. 20

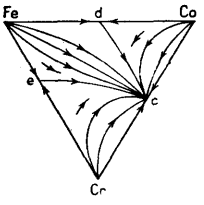


Fig. 21

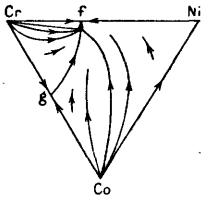


Fig. 22

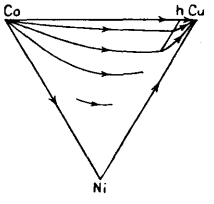


Fig. 23

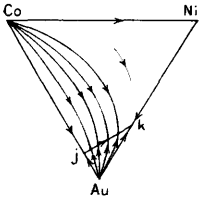


Fig. 24

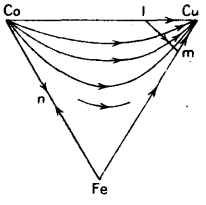


Fig. 25

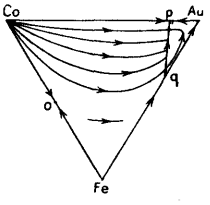


Fig. 26

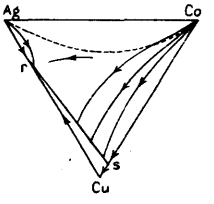


Fig. 27

Type Diagrams of some Ternary Cobalt Alloys

Group C

No system of this group is known in which all three binary mixtures have been investigated.

Group D

In Group D is given those systems in which there is in one of the binary systems a miscibility gap in the solid state, and in one of the others there occurs a gap in the liquid state. This group is subdivided according as to whether there is a eutectic (d_1) or a transition point (d_2) in one of the binary systems. The system AgCoAu belongs to d_1 while CuCrCo belongs to d_2.

System AgCoAu.

Ag-Co two liquids.
Ag-Au no minimum.
Co-Au eutectic 997°C. (90p.c.Au).

System CuCrCo.

Cu-Cr two liquids.
Cu-Co transition point.
Cr-Co minimum 1340°C. (49p.c.Co).

Group E

Group E consists of those systems in which two of the binaries show a miscibility gap in the solid state. There are three subdivisions of this group according as there are two eutectics (e_1); two transition points (e_2); or a eutectic and a transition point (e_3). To e_1 belongs CoNiAu, to e_2, CoFeCu, and to e_3, CoFeAu and AuCuCo.

System CoNiAu. (figure 24).	System CoFeCu. (figure 25).	System AuCuCo.
Co-Ni no minimum.	Co-Fe minimum (n) 1500°C. (50p.c.Co).	Au-Cu minimum 884°C. (20p.c.Cu).
Co-Au eutectic (j) 997°C. (90p.c.Au).	Co-Cu transition point (l) 1110°C. (96p.c.Cu).	Au-Co eutectic 997°C. (90p.c.Au).
Ni-Au eutectic (k) 950°C. (27p.c.Ni).	Fe-Cu transition point (m) 1100°C. (97p.c.Cu).	Cu-Co transition point 1110°C. (96p.c.Cu).

System CoFeAu.
(figure 26).

Co-Fe minimum (o) 1500°C. (50p.c.Co).
Co-Au eutectic (p) 997°C. (90p.c.Au).
Fe-Au transition point (q) 1168°C. (65p.c.Au).

Group F

In this group two of the binary mixtures show a separation into two liquids, and a transition takes place in the ternary system, so that there is not only a gap in the solid state but also one in the liquid state. The mixtures NiCoAg, CoFeAg, and CoCrAg belong to this group.

System NiCoAg.	System CoFeAg.	System CoCrAg.
Ni-Co no minimum.	Co-Fe minimum 1500°C.	Co-Cr minimum 1320°C.
Ni-Ag two liquids.	Co-Ag two liquids.	Co-Ag two liquids.
Co-Ag two liquids.	Fe-Ag two liquids.	Cr-Ag two liquids.

Group G

Of the three binary systems one possesses a limited miscibility in the liquid state, and both the others have either eutectics or a eutectic and a transition point. The ternary mixture of this group may be represented by AgCoCu, figure 27.

System AgCoCu.
(figure 27).

Ag-Co two liquids.
Ag-Cu eutectic (r) 778°C. (28p.c.Cu).
Co-Cu transition point (s) 1110°C. (96p.c.Cu).

Group H

The binary systems of group H are the reverse of those of G. There is one eutectic, and two form two liquid layers in the binary system. No cobalt alloys are given at present under this heading.

In addition to the preceding summary by Janecke, other investigators have made experiments dealing with ternary alloys of cobalt, especially as regards their chemical and mechanical properties. A list of these is given below and a summary of the properties of the various ternaries appears under the description of the binary alloys. In order to enable ready reference to the different binaries for the summary of the ternaries, the metals are arranged in the following list so that by referring to the binary alloy of cobalt with the metal mentioned second, a description of the ternary will be found along with the references to original articles.

Cobalt-chromium-tungsten.
Cobalt-chromium-molybdenum.
Cobalt-copper-aluminium (white bronze).
Cobalt-copper-aluminium-iron (metalline).
Cobalt-iron-carbon. *See* effect of cobalt on steel.
Cobalt-nickel-silver.
Cobalt-nickel-chromium and other metals.
Cobalt-nickel-copper.
Cobalt-tin-copper.
Cobalt-tin-copper. Addition of cobalt to bronze.
Cobalt-zinc-copper. Addition of cobalt to brass.

Additional References to Alloys

Ducelliez. Researches on the Alloys of Cobalt, Thèse, Bordeaux, 1911. (Note.—A copy of this paper could not be obtained in any of the largest libraries on this continent. However, the writer believes most of the separate papers are mentioned under the alloys of cobalt with the different metals.)

Guertler, On the magnetizability of the alloys of ferro-magnetic metals: Zeitschr. physikal. Chemie, Vol. 65, 1908, pp. 73-83.

Fahrenwald, Ternary Alloys of Palladium and Gold with Cobalt, Chem. Abst., Vol. eleven, 1917, p. 1,620.

Acknowledgments

The author wishes to express his appreciation of the assistance received from Dr. William Campbell, Professor of Metallurgy, Columbia University, New York, under whom this investigation was undertaken, but besides acknowledging assistance in direction, the writer wishes to mention that the desire for research was received first from Dr. Campbell. Very few students can work under him without being impressed with his interest in investigation work, and his desire for accuracy and thoroughness in dealing with a given subject.

Acknowledgment is also made to Professor S. F. Kirkpatrick, Queen's University, Kingston, Canada, for suggestions concerning the metallurgy of cobalt, to T. W. Gibson, Deputy Minister of Mines for Ontario, Canada, for assistance in the publication of this review, and to other members of the staff of the Ontario Bureau of Mines.

END OF SECTION I.

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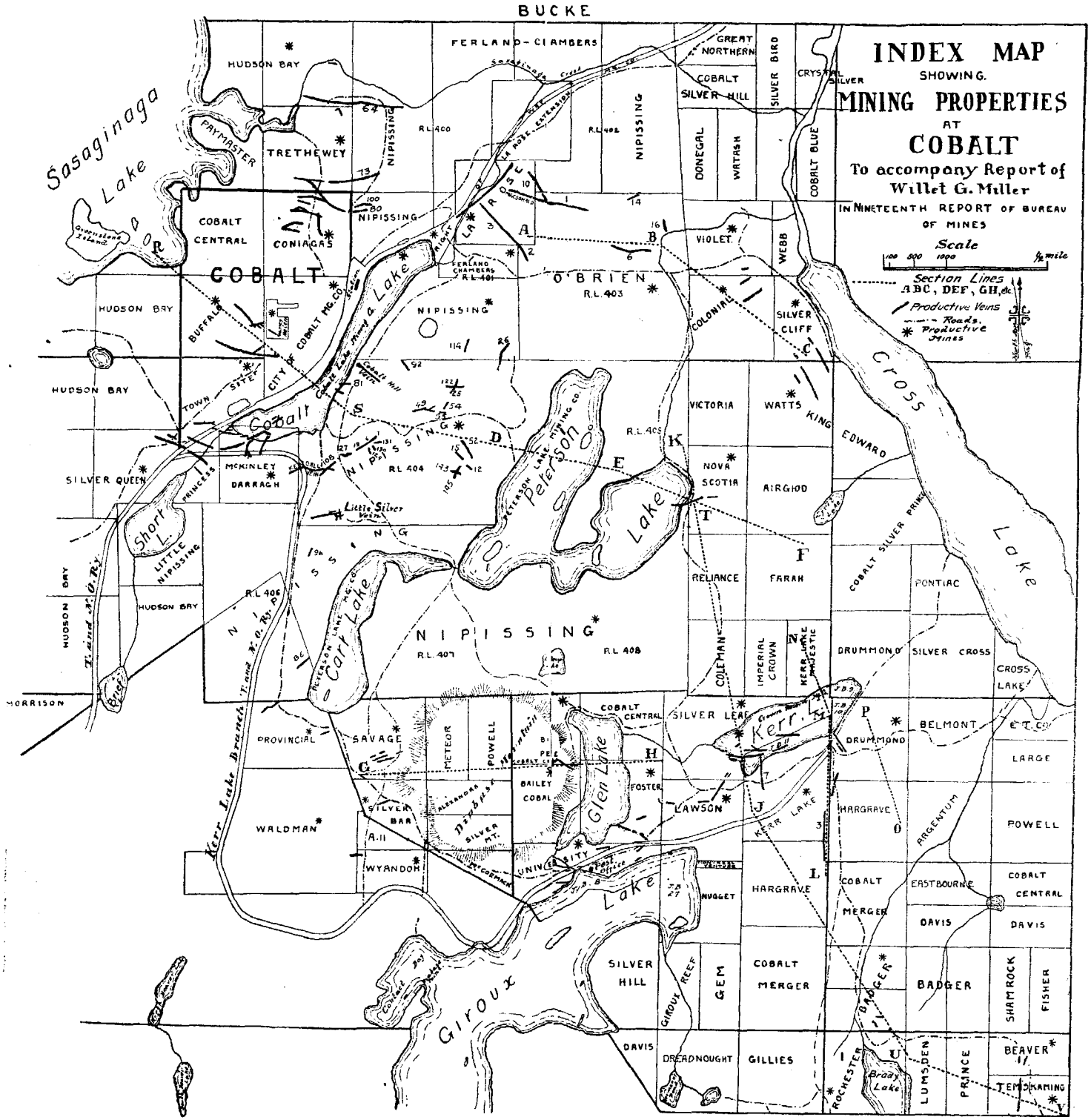
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