THESE TERMS GOVERN YOUR USE OF THIS DOCUMENT

Your use of this Ontario Geological Survey document (the "Content") is governed by the terms set out on this page ("Terms of Use"). By downloading this Content, you (the "User") have accepted, and have agreed to be bound by, the Terms of Use.

Content: This Content is offered by the Province of Ontario's *Ministry of Northern Development and Mines* (MNDM) as a public service, on an "as-is" basis. Recommendations and statements of opinion expressed in the Content are those of the author or authors and are not to be construed as statement of government policy. You are solely responsible for your use of the Content. You should not rely on the Content for legal advice nor as authoritative in your particular circumstances. Users should verify the accuracy and applicability of any Content before acting on it. MNDM does not guarantee, or make any warranty express or implied, that the Content is current, accurate, complete or reliable. MNDM is not responsible for any damage however caused, which results, directly or indirectly, from your use of the Content. MNDM assumes no legal liability or responsibility for the Content whatsoever.

Links to Other Web Sites: This Content may contain links, to Web sites that are not operated by MNDM. Linked Web sites may not be available in French. MNDM neither endorses nor assumes any responsibility for the safety, accuracy or availability of linked Web sites or the information contained on them. The linked Web sites, their operation and content are the responsibility of the person or entity for which they were created or maintained (the "Owner"). Both your use of a linked Web site, and your right to use or reproduce information or materials from a linked Web site, are subject to the terms of use governing that particular Web site. Any comments or inquiries regarding a linked Web site must be directed to its Owner.

Copyright: Canadian and international intellectual property laws protect the Content. Unless otherwise indicated, copyright is held by the Queen's Printer for Ontario.

It is recommended that reference to the Content be made in the following form: <Author's last name>, <Initials> <year of publication>. <Content title>; Ontario Geological Survey, <Content publication series and number>, <total number of pages>p.

Use and Reproduction of Content: The Content may be used and reproduced only in accordance with applicable intellectual property laws. *Non-commercial* use of unsubstantial excerpts of the Content is permitted provided that appropriate credit is given and Crown copyright is acknowledged. Any substantial reproduction of the Content or any *commercial* use of all or part of the Content is prohibited without the prior written permission of MNDM. Substantial reproduction includes the reproduction of any illustration or figure, such as, but not limited to graphs, charts and maps. Commercial use includes commercial distribution of the Content, the reproduction of multiple copies of the Content for any purpose whether or not commercial, use of the Content in commercial publications, and the creation of value-added products using the Content.

Contact:

FOR FURTHER INFORMATION ON	PLEASE CONTACT:	BY TELEPHONE:	BY E-MAIL:
The Reproduction of Content	MNDM Publication Services	Local: (705) 670-5691 Toll Free: 1-888-415-9845, ext. 5691 (inside Canada, United States)	Pubsales@ndm.gov.on.ca
The Purchase of MNDM Publications	MNDM Publication Sales	Local: (705) 670-5691 Toll Free: 1-888-415-9845, ext. 5691 (inside Canada, United States)	Pubsales@ndm.gov.on.ca
Crown Copyright	Queen's Printer	Local: (416) 326-2678 Toll Free: 1-800-668-9938 (inside Canada, United States)	Copyright@gov.on.ca

LES CONDITIONS CI-DESSOUS RÉGISSENT L'UTILISATION DU PRÉSENT DOCUMENT.

Votre utilisation de ce document de la Commission géologique de l'Ontario (le « contenu ») est régie par les conditions décrites sur cette page (« conditions d'utilisation »). En téléchargeant ce contenu, vous (l'« utilisateur ») signifiez que vous avez accepté d'être lié par les présentes conditions d'utilisation.

Contenu : Ce contenu est offert en l'état comme service public par le *ministère du Développement du Nord et des Mines* (MDNM) de la province de l'Ontario. Les recommandations et les opinions exprimées dans le contenu sont celles de l'auteur ou des auteurs et ne doivent pas être interprétées comme des énoncés officiels de politique gouvernementale. Vous êtes entièrement responsable de l'utilisation que vous en faites. Le contenu ne constitue pas une source fiable de conseils juridiques et ne peut en aucun cas faire autorité dans votre situation particulière. Les utilisateurs sont tenus de vérifier l'exactitude et l'applicabilité de tout contenu avant de l'utiliser. Le MDNM n'offre aucune garantie expresse ou implicite relativement à la mise à jour, à l'exactitude, à l'intégralité ou à la fiabilité du contenu. Le MDNM ne peut être tenu responsable de tout dommage, quelle qu'en soit la cause, résultant directement ou indirectement de l'utilisation du contenu. Le MDNM n'assume aucune responsabilité légale de quelque nature que ce soit en ce qui a trait au contenu.

Liens vers d'autres sites Web : Ce contenu peut comporter des liens vers des sites Web qui ne sont pas exploités par le MDNM. Certains de ces sites pourraient ne pas être offerts en français. Le MDNM se dégage de toute responsabilité quant à la sûreté, à l'exactitude ou à la disponibilité des sites Web ainsi reliés ou à l'information qu'ils contiennent. La responsabilité des sites Web ainsi reliés, de leur exploitation et de leur contenu incombe à la personne ou à l'entité pour lesquelles ils ont été créés ou sont entretenus (le « propriétaire »). Votre utilisation de ces sites Web ainsi que votre droit d'utiliser ou de reproduire leur contenu sont assujettis aux conditions d'utilisation propres à chacun de ces sites. Tout commentaire ou toute question concernant l'un de ces sites doivent être adressés au propriétaire du site.

Droits d'auteur : Le contenu est protégé par les lois canadiennes et internationales sur la propriété intellectuelle. Sauf indication contraire, les droits d'auteurs appartiennent à l'Imprimeur de la Reine pour l'Ontario.
Nous recommandons de faire paraître ainsi toute référence au contenu : nom de famille de l'auteur, initiales, année de publication, titre du document, Commission géologique de l'Ontario, série et numéro de publication, nombre de pages.

Utilisation et reproduction du contenu : Le contenu ne peut être utilisé et reproduit qu'en conformité avec les lois sur la propriété intellectuelle applicables. L'utilisation de courts extraits du contenu à des fins *non commerciales* est autorisé, à condition de faire une mention de source appropriée reconnaissant les droits d'auteurs de la Couronne. Toute reproduction importante du contenu ou toute utilisation, en tout ou en partie, du contenu à des fins *commerciales* est interdite sans l'autorisation écrite préalable du MDNM. Une reproduction jugée importante comprend la reproduction de toute illustration ou figure comme les graphiques, les diagrammes, les cartes, etc. L'utilisation commerciale comprend la distribution du contenu à des fins commerciales, la reproduction de copies multiples du contenu à des fins commerciales ou non, l'utilisation du contenu dans des publications commerciales et la création de produits à valeur ajoutée à l'aide du contenu.

Renseignements :

POUR PLUS DE RENSEIGNEMENTS SUR	VEUILLEZ VOUS ADRESSER À :	PAR TÉLÉPHONE :	PAR COURRIEL :
la reproduction du contenu	Services de publication du MDNM	Local : (705) 670-5691 Numéro sans frais : 1 888 415-9845, poste 5691 (au Canada et aux États-Unis)	Pubsales@ndm.gov.on.ca
l'achat des publications du MDNM	Vente de publications du MDNM	Local : (705) 670-5691 Numéro sans frais : 1 888 415-9845, poste 5691 (au Canada et aux États-Unis)	Pubsales@ndm.gov.on.ca
les droits d'auteurs de la Couronne	Imprimeur de la Reine	Local : 416 326-2678 Numéro sans frais : 1 800 668-9938 (au Canada et aux États-Unis)	Copyright@gov.on.ca

PROVINCE OF ONTARIO
DEPARTMENT OF MINES

HON. CHAS. McCREA, *Minister* THOS W. GIBSON, *Deputy Minister*

Bulletin No. 83

TWENTY-FIVE YEARS
OF
ONTARIO'S MINING HISTORY

A Review of Outstanding Developments in the Last Quarter of a Century

Prepared by Officers of the Department of Mines

TORONTO
Printed and Published by Herbert H. Ball, Printer to the King's Most Excellent Majesty
1932

PREFACE

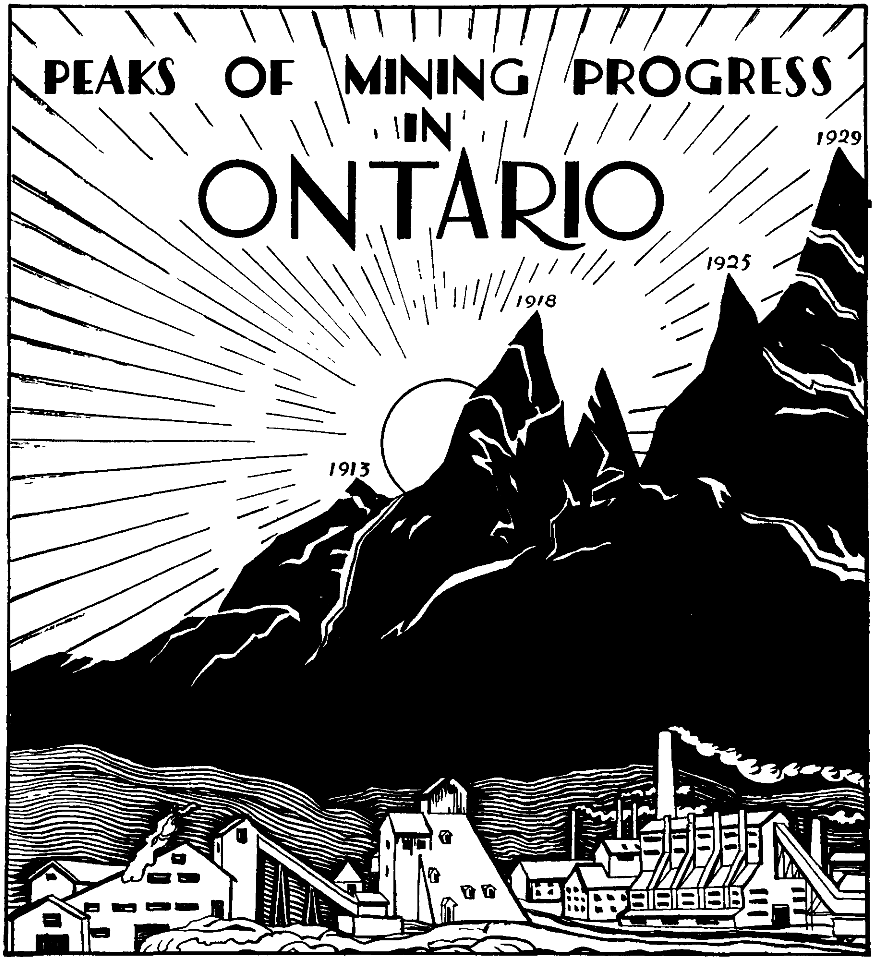
The mining industry of Ontario dates back to the middle of the last century, but for a long time its progress was slow and uncertain. The nickel-copper deposits of Sudbury and the silver-cobalt ores of Cobalt were both discovered and were beginning to reveal their riches more than 25 years ago. "Twenty-five Years" in the title of this Bulletin is therefore not to be interpreted literally, but as covering the period of the greatest and most significant progress which the mineral industry of this Province has yet experienced. It is less than 25 years ago that gold was uncovered in Porcupine and Kirkland Lake, and now the contribution of these fields has lifted Canada into second place among the gold-producing countries of the world. There is every reason to believe that this expansion will continue. The production of base metals has been seriously curtailed during the present stagnation of business, but, on the other hand, the output of gold continues to grow. The 43 million dollars' worth of 1931 will possibly rise to 50 millions in 1932.

Probably under any conceivable mining law, the minerals of a country, if sufficiently valuable, will be exploited. Nevertheless, the attitude of a government and the legislation it provides have a decided influence on the welfare of the mining industry. A brief history of the Mining Act of Ontario and a synopsis of its provisions are therefore included in the following pages.

Bulletin No. 83 supplements a handbook entitled "Ontario's Mines and Mineral Resources," first issued in 1924 for the British Empire Exhibition at Wembley. The handbook has been in such demand that revised editions have been issued every second year. The present Bulletin deals mainly with the metals, but includes also natural gas. Certain statistical data is given for non-metallic substances as a group. Only by looking backward and reviewing the situation that obtained a few years ago is it possible to form an adequate conception of the rapid advances achieved in a comparatively short space of time. This is true not only as regards mining and metallurgical practice, but also as regards the position held to-day by mining among the basic industries of the Province.

T. F. SUTHERLAND,
Acting Deputy Minister of Mines.

DEPARTMENT OF MINES,
Toronto, August, 1932.



Diagrammatic Sketch Showing Growth of Ontario's Mineral Output During the Past Quarter Century

1906	$22,388,383	1920	$73,079,522
1913	$53,232,311	1925	$87,583,306
1918	$80,308,972	1929	$117,960,722

TWENTY-FIVE YEARS OF ONTARIO'S MINING HISTORY

A Review of Outstanding Developments in the Last Quarter of a Century

General Survey

The history of Ontario's mining industry for the past twenty-five years, striking as it is with reference to non-metallics, is dominated almost to the exclusion of other considerations by the dramatic metal-mining development of Northern Ontario. Sudbury produces 85 to 90 per cent. of the world's nickel. Cobalt, in addition to producing 80 per cent. of the world's supply of that metal, has been exceeded in total silver production by only three other camps. Porcupine and Kirkland Lake have raised Canada to second place in annual production amongst gold-producing countries.

The story of this development is the story of the vast pre-Cambrian shield that stretches in a U-shaped belt around Hudson Bay from Labrador to the Arctic ocean. That shield, scarcely 20 per cent. of which has been geologically explored, has already given the province its distinctive position in metal-mining. Including the nickel and copper of Sudbury, the silver of Cobalt, Gowganda and South Lorrain, the gold of Porcupine and Kirkland Lake, the region has provided wealth amounting to over a billion dollars. Much has been written about this immense area in recent years. More and more it has attracted the attention of the mining world, not only for its proved but for its potential riches. It is the firm opinion of most mining men that the wealth it has produced to date is but an indication and a suggestion of the riches that future exploration and discovery may reveal.

Prior to 1900, very little was known of this northern country. Occasional survey and exploration parties traversed the region, but travel was confined to the canoe routes by way of streams, lakes, and portages, while the wide, trackless spruce and jackpine forest areas back from the water routes were seldom visited by any one able to appreciate their mineral possibilities. As the building of the Canadian Pacific railway led to the discovery of the world's greatest nickel deposits in the Sudbury area in 1883, so did the construction of the Temiskaming and Northern Ontario railway lead to the discovery of the famous silver deposits at Cobalt in 1903 and, indirectly, to the great gold deposits at Porcupine in 1909, as well as those at Kirkland Lake in 1912.

The only established centre of mining in Northern Ontario 25 years ago was at Sudbury, which at that time was a small town. Cobalt in the year 1905 was hardly more than a name. The rich gold camps at Porcupine and Kirkland Lake were undreamed of. As a direct result of prospecting and mining development, industrial communities have been established, railways have been extended, water powers have been harnessed, and large areas have been opened up for settlement. Now Sudbury is an incorporated city; Cobalt is a considerable community. The town of Timmins at Porcupine has a population of 14,000 and can be reached by pullman car in 20 hours from Toronto. Kirkland Lake is a thriving centre, and smaller towns and villages throughout the area mark the progressive advance of the prospector, the pioneer of the mining industry. Not only has he been the forerunner of development in Northern Ontario, but the Province's experienced prospectors have gone farther afield and have pioneered in Northern Manitoba, finding the Flin Flon copper deposit and also in Northwestern Quebec, where they located rich auriferous copper occurrences, of which Noranda is the most famous.

It is the prospector who is the true pioneer as he is the backbone of the mining industry. To him, Ontario owes its place in the metal-mining world and the Provincial Department of Mines has been keenly conscious of his value. At best his life is an arduous one, but the past 25 years have seen a great improvement in his general circumstances. The day when prospectors travelled in pairs by canoes to distant places has almost passed. The paddle has been displaced largely by the "kicker" or outboard motor. Remote and almost inaccessible areas are now readily reached by aeroplane in a fraction of the time formerly required. All these aids have speeded up exploration work, and the Government has been constantly active on the prospector's behalf, as on behalf of the industry.

Following the report and recommendation of the Royal Commission investigating the mineral resources of Ontario, a Bureau of Mines was established in 1891 "to aid in promoting the mining interests of the Province." At first the Bureau was under the Crown Lands Department, and later it became a branch of the Department of Lands, Forests, and Mines. In the year 1920, realizing the industry's growth and importance, the Provincial Government established a separate Department of Mines with a Minister of Mines in charge, and the title of Bureau was changed to that of Department. It assists the industry in many ways. A Provincial Assay Office is located in Toronto, at which prospectors are entitled to have a certain number of free assays made, and there is a testing laboratory and sampling works at Cobalt. At the latter, ore is sampled and provision is made for the purchase of shipments of gold ore from prospectors and small operators. Where required, tests are made and advice given as to the best method of treatment of particular ores. Blue prints showing the claims in good standing are supplied at nominal cost. Prospectors' classes are held in the mining centres during the winter months. At these instruction is given in "mineral spotting," elementary chemistry, and geology; and popular lectures are delivered, illustrated with slides, on mining and geological topics. Assistance is given by the Government in trail-cutting and road-building in new mining areas and, where possible, branches of the Government railway (T. and N.O.) are built to provide important and permanent camps with transportation facilities.

Developments in the Geological Branch have kept pace with the other progressive activities of the Department. Previous to 1902, all geological work for what was then the Bureau of Mines was performed by University professors who were engaged for the summer season. Geological maps covering Ontario areas were published by the Dominion Geological Survey. It was not until Dr. W. G. Miller was attached to the Bureau in 1902 as provincial geologist that the permanent character of the branch was established. Now it has a permanent staff of four geologists and employs each year a number of temporary men for field work. When new discoveries of importance are reported, the

Department, where possible, sends a geologist into the field at once to make a preliminary report. Where aeroplanes are available they are used to reach remote areas, and this service has greatly extended the length of the field season. The geologist no longer prepares his own map for the printers as he did in the early days of the survey. The Department to-day has a regular map-making branch, and mapping is done by a staff of expert cartographers for photo-litho reproduction.

The discovery of Cobalt and the mapping of the silver areas was the beginning of a year-to-year campaign of geological exploration of mineralized areas of Northern Ontario. This work has steadily increased until in 1931 eleven geological parties were sent out, and reports, with maps of most of the areas, will be published. Practically the whole of the pre-Cambrian geology of northeastern Ontario has now been mapped as well as many sections of northwestern Ontario. This work has been invaluable to the prospector and the mining industry generally. In addition to the mapping of metalliferous areas, the Department has one geologist who has specialized in rock formations later than the pre-Cambrian, so that the geological possibilities of Paleozoic and more recent deposits, as those near James Bay, can be properly studied.

Among mining men Ontario's mining law is considered one of the best in the world. Lands and minerals belong to the Province and are granted in fee simple, or leased for a term of years in the case of Provincial Forests; consequently title is unassailable.

Disputes arising between individuals, or between an individual and the Crown, are adjudicated first, by the local Mining Recorder, or on appeal, by the Judge of the Mining Court of Ontario. The procedure leading to trial is simple and expeditious. This arrangement avoids the cumbersome delays and heavy expenses of the ordinary law courts. Another provision of *The Mining Act* clothes the Judge of the Mining Court with power to grant rights and easements over other lands required in mining operations, such as the right to construct ditches and flumes, to discharge, drain or divert water and to store and take water, to establish rights of way for roads, tramways, transmission of electricity, and to permit the depositing of tailings and other waste products.

The fairness of its mining laws, as also the regard it has shown for the industry at large and for the man in the field in particular, are characteristic of the Provincial Government's attitude. In all its activities, the Department of Mines has been concerned: first, to protect the man in the field; second, to secure for the people at large some return from mineral discoveries; the first, that human endurance and perseverance and courage might not go unrewarded; the second, that the Province might profit from exploitation of its natural resources. And, as in its fairness to the prospector and in its regard for the public treasury, so it has been considerate in its attitude towards private capital and eager to facilitate the profitable development and operation of mining undertakings born of private initiative and developed by private interests.

So, with public and private effort, initiative, and co-operation, the value of Ontario's metallic mineral production has been raised from some $10,000,000 in 1905 to over $83,000,000 in 1930. The story of this achievement is the story of the nickel, copper, silver, and gold of the North.

Nickel

Copper ore deposits were worked at the Bruce Mines, northeast shore of Lake Superior, before 1848, and from the Bruce, Wellington, and Huron copper group production totalled well over three million dollars by 1875. Nickel, however, is not associated with this area, discovery of it being first recorded in 1848 at the Wallace mine, a short distance west of the entry of Whitefish river into Lake Huron. There is mention of nickel at Michipicoten Island in 1863. But the great nickel-copper story of Northern Ontario dates from 1883 when the Canadian Pacific railway was under construction. Thomas Flanagan, blacksmith, working with a gang on the right-of-way west of Sudbury, discovered copper sulphide. The first mine to open was the Murray. Then came the McConnell discoveries. The Elsie followed. Thomas Frood, a wood-ranger in the employ of the Crown Lands Department, disputed locations with a fellow-prospector. The settlement of the dispute gave Frood the Frood mine, the largest of the great ore bodies of Sudbury. The vast Creighton deposit was re-discovered in 1886 (Government geologists had reported it 30 years earlier). Other discoveries followed. The greatest impetus to the industry was the discovery by James Riley, Glasgow engineer, in 1889, while experimenting with metal alloys, that an addition of 2.5 to 3.5 per cent. of nickel conferred upon steel such a degree of hardness, toughness, and additional strength as to constitute it practically a new material for construction purposes. Years of testing and experiment followed. By 1905, the utilization of the new metal for armament purposes was universal. The navies of the world were armoured with nickel-steel. It was also adopted for heavy ordnance, bullet-casings, and many other forms of military equipment.

FIRST HOUSE IN COPPER CLIFF, BUILT FOR THOS. JOHNSON, 1885

In the year 1906, two nickel mining companies, the Mond and International Nickel, were operating in the Sudbury area. The latter company was formed by an amalgamation of the Canadian Copper Company at Copper Cliff and the Orford Copper Company at Bayonne, N.J. The Mond Company shipped the product of their smelter to Swansea, South Wales, and International Nickel shipped theirs to their plant in New Jersey. The processes of refining employed by these two companies were quite distinct: International Nickel used the Orford process, while the Mond Nickel Company had adopted a process invented by its founder, Dr. Ludwig Mond, one of the foremost industrial chemists of his time.

At the outbreak of the great war in 1914, when the demand for nickel for armaments greatly increased, a demand arose that the complete processing of nickel from the mine to the finished product should be done in Canada. The Ontario Government appointed a Commission in 1915 to investigate the general nickel situation and consider whether there were any insuperable difficulties to the refining of nickel in Canada. This Commission reported in 1917, recommending the establishment of refineries in Ontario, and the following year International Nickel erected a refinery at Port Colborne, on Lake Erie.

Meanwhile, the British American Nickel Corporation was formed for the purpose of assuring a supply of nickel to the British Government. This corporation acquired the Murray mine at Copper Cliff, and a subsidiary company established a nickel-refining plant at Deschênes, on the Quebec side of the Ottawa river. This plant did not come into operation until the year 1920, by which time the demand for nickel had slumped to a low level and the enterprise went to the wall.

Opening the Copper Cliff Mine, 1886

Omitting the figure in the right background, the names of the persons from left to right are Ashmun, Frood, McIntosh, Hooker, and Blue.

With the end of the world war and with international naval restriction agreements, markets were cut in half and for a time nickel mining was reduced to semi-paralysis. The nickel companies of Northern Ontario, the International Nickel Company and the Mond Nickel Company, met the situation with courage and resource. By technical research they discovered new uses for nickel. They instituted an intensive campaign of education and salesmanship, thereby demonstrating to manufacturers of machinery and apparatus the advantages of nickel and its alloys. They furnished the trade with shapes and pieces adapted for immediate use, and so succeeded in restoring nickel mining not only to its pre-war position, but to a production largely in excess of that period. The demand grew to such an extent that the peak production of the war period in 1918 was reached and surpassed in 1928. Nickel has proved as useful in the arts of peace as in the shock of military and naval conflict.

To-day there are no less than sixteen definite classes of nickel in use as compared with nine at the close of the war, and the future holds bright prospects for further expansion of its usefulness. Confident of this expansion and secure in future supplies through the proving of ore reserves, such as the remarkable new ore blocked out in the Frood mine, where an immense mass of nickel-copper, or more properly speaking, copper-nickel, was found at depths of 2,000 and 3,000 feet, the International Nickel Company in 1929 amalgamated its resources and forces with those of the Mond Nickel Company. A gigantic programme of construction was carried out at the mines and plant at Sudbury. This programme embraced additions to the Port Colborne refinery, underground development and erection of a new surface plant at the Frood mine, the construction of a concentrating plant, a new smelter and a copper refinery at Copper Cliff, additions and improvements to the Coniston smelter, and a new surface plant at the Levack mine. Additional work involved the transferring of part of the Port Colborne operations to Copper Cliff.

The nickel-copper ores of the Sudbury area contain in addition to these two chief metals, gold, silver, platinum, palladium, and other rare metals of the platinum group. Their value is considerable, totalling $2,436,683 in 1930. The mattes produced at Sudbury constitute the largest source of the platinum metals in America.

Silver and Cobalt

The silver industry may properly be said to date from the construction of the Temiskaming and Northern Ontario railway from North Bay to the head of Lake Timiskaming. Half a century before Thomas MacFarlane had discovered silver on a diminutive Lake Superior island, 80 feet in diameter, and given the Province its famous Silver Islet mine that yielded silver to the value of $3,500,000 between 1870 and 1884. Other silver discoveries were made in the Port Arthur–Fort William area in 1882, and mines were developed that gave a total production of some $5,000,000 before operations ceased in 1903. It was in this particular year that cobalt bloom was noted in the north and a discovery was made at Long lake near the west shore of Lake Timiskaming that was to mark the development of a silver area of world-wide renown. Long lake subsequently became "Cobalt lake," and the surrounding area became familiar as the famous Cobalt camp with its greatest of all Canadian silver mines, the Nipissing, and with Kerr Lake, Coniagas, Crown Reserve, La Rose, McKinley-Darragh-Savage, and O'Brien, to name only the largest in an area which, to the end of 1930, has produced a total of 364,974,864 ounces out of a total for all Ontario silver mines of 407,279,971 fine ounces. In addition the camp has produced cobalt worth $24,000,000, also arsenic, nickel, copper, lead, and bismuth. Altogether the total output of Ontario silver mines to the end of 1930 is valued at $251,981,892. The value of cobalt adds another $24,093,381 to the silver record, making a grand total of $276,074,273 from this industry.

As a result of the rich Cobalt discoveries, prospectors spread out into the surrounding country and finds were reported in 1906 from Maple mountain and Montreal river to the northwest of Cobalt. In 1907 and 1908, rich silver deposits were uncovered in the Gowganda area, situated some 55 miles northwest of Cobalt and 27 miles west of Elk Lake, a terminal point on the Temiskaming and Northern Ontario railway, since connected with Gowganda by an excellent motor road. In the meantime, silver was found 18 miles southeast of Cobalt at South Lorrain, and the Wettlaufer, Keeley, Frontier, and other mines were opened. Discoveries were also made in Casey township about an equal distance northeast of Cobalt. Actual production began in South Lorrain in 1908. Gowganda, with Miller Lake O'Brien and Castle-Trethewey, developed more slowly, not making shipments of moment until 1910.

General View of the Town of Cobalt as seen from the McKinley-Darragh Hill

At Cobalt, easily extracted high-grade ores lying near the surface and containing from one to twelve thousand ounces of silver per ton were naturally the first to be mined. From 1904 to 1911, silver output jumped rapidly from year to year, the peak of production being reached in 1911. Since that time there has been a general downward trend, but the life of the camp has been prolonged by the finding of "blind" veins, and especially by improvements in metallurgy. There still remains considerable ground lying within or adjacent to the productive area at Cobalt which possesses geological structures favourable for the discovery of silver-bearing veins. Prospecting, however, has largely ceased owing to the prevailing low price of silver. Decline in production in the parent camp has been offset to some degree by an increased production from Gowganda and South Lorrain.

While most of the leading mines have yielded up their treasure, new discoveries being made from time to time in the established camps, together with the probability of new fields being opened up, afford ground for the belief that production will go on for many years to come. This depends, of course, on a fair price for silver. From fifty cents an ounce 25 years ago, it rose to a peak of 111.1 cents in 1919. The average New York price in 1930 was 38.154 cents per fine ounce, the lowest recorded in the history of the Cobalt camp to that date, and in 1931 the price dropped below 30 cents, making profitable operation almost impossible. Only one company, the Nipissing, paid dividends in 1930 and 1931.

The richness of Ontario silver ores has allowed the employment of the most efficient machinery and the best technical skill from the beginning. Probably nowhere in the world has silver mining and the treatment of silver ores been carried on with greater efficiency than at Cobalt. In milling and metallurgical treatment, two systems have been of outstanding importance, gravity concentration and cyanidation. A third process, flotation, has been introduced at a comparatively recent date. Cyanidation of the complex Cobalt ores was a difficult problem, but it was solved with signal success as were other problems encountered when the high-grade ore of the earlier years began to give way to ore of lower value.

At first all ore was shipped out of the country, mostly to the United States, there being no facilities for refining it in Canada; but to-day comparatively little ore goes out of the country. At present the only refinery is that of the Deloro Smelting and Refining Company at Deloro in Eastern Ontario.

Finally, the dividend record has been a remarkable one. Up to the end of 1930, $97,471,281 had been returned to shareholders in dividends and bonuses.

Gold

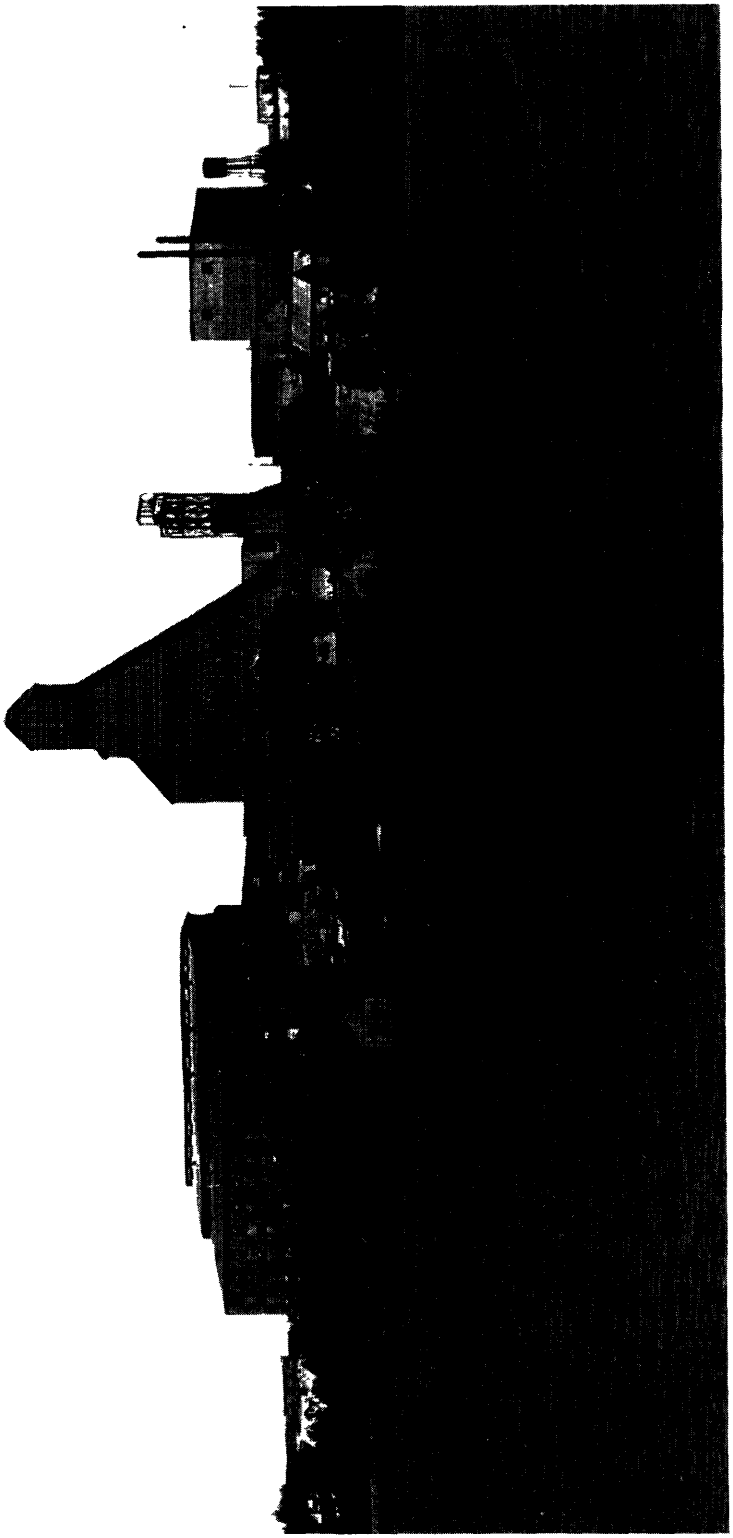
The history of gold mining in Ontario goes back to 1866, when Powell, an old Dutch miner, following a copper seam on the farm of one Richardson in Hastings county in Southeastern Ontario, struck native gold; but the rich deposits of the Richardson farm were not duplicated in neighbouring townships. Five years later attention was centred in the northwest where the Huronia mine was developed, and a mining boom began that was to reach its peak in 1897 and then subside until 1903 when the silver discoveries at Cobalt brought prospectors swarming into Northern Ontario. The truly startling story of gold-mining, however, began with the discovery of Porcupine in 1909. The preceding years had had their value, particularly in improved technique through the application of the cyanide process, which was being steadily developed, and the Province was prepared for major developments.

For almost 20 years, Porcupine dominated the field. It was in 1909 that Ben Hollinger and his companions staked the claims that were the basis of one of the greatest gold mines in the world. Some prospecting had been carried on in the area as early as 1907, but the real gold rush started with the Hollinger, McIntyre, and Dome finds, all of which were made within a few days of one another. There were many pessimists who could see no great future for the new camp; even Hollinger was refused by a leading mining company after careful examination of the property. To Noah Timmins is due the credit of leading the camp into production. He showed his faith in the prospects by erecting a stamp mill on the Hollinger property. This was ready for operation early in 1911. At the same time, a mill was being erected at the Dome. But forest fires in that year devastated the district, burning the Hollinger mill and surface plant to the ground, wiping out the new plant at Dome, and driving miners and prospectors underground or into Lake Porcupine where some perished. Reconstruction started immediately, and the camp moved rapidly forward to its premier position.

HOLLINGER GOLD MINE, 1911

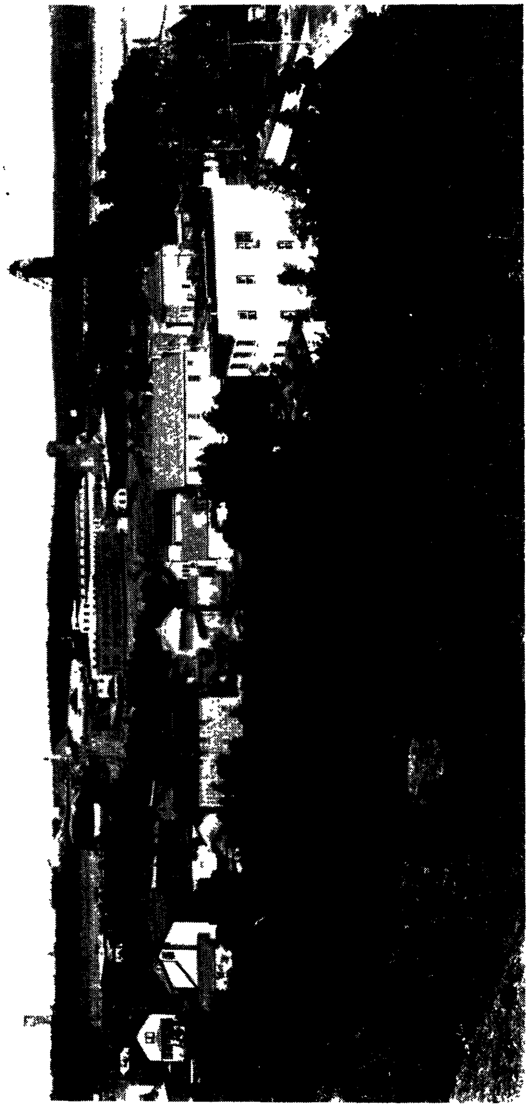
The view shows No. 1 shaft, with original quartz discovery in foreground.

The Kirkland Lake camp came into being quietly. Porcupine had astonished the world. It did not seem possible that there could be another Porcupine in Ontario. Such was the general view. But it was not shared by a few determined prospectors who dropped off the Temiskaming and Northern Ontario railway train at Swastika in the summer of 1911. At that time the Swastika and Lucky Cross were being devloped in the vacinity of the railway station, and some gold was produced later. Despite its optimistic name, the Lucky Cross was not a success; it proved to be but a vest-pocket sample of the larger and richer mines that were discovered later on the shores of Kirkland lake.



McIntyre Porcupine Mine, North Shore of Gillies Lake

The first discovery at Kirkland Lake was made in the autumn of 1911 by W. H. Wright, and the property staked now forms a part of the Wright-Hargreaves mine. Early in 1912 further discoveries were made about a mile east of the lake by the Tough brothers, who were associated with Harry Oakes. In the summer of the same year, Mr. Oakes staked the ground on the lake shore which was destined to develop into one of the richest gold mines in history. But it was not until 1913, when a shipment of high-grade ore was made from the Tough-Oakes claim, that any general interest was displayed in the possibilities of the area. Promising new veins were disclosed on the Burnside, Teck-Hughes, and Sylvanite properties, while Mr. Oakes reported assays as high as $1,000 a ton at the Lake Shore. By the middle of 1914, hydro-electric power was brought



LAKE SHORE MINE AT KIRKLAND LAKE, LOOKING WEST

In the background from left to right are the south shaft of the Teck-Hughes, Kirkland Lake Gold shaft, and Teck-Hughes central shaft.

into the area and underground work was begun on the Lake Shore and Teck-Hughes mines. Development continued in 1915, 1916, 1917, but increasing cost of supplies, labour, and equipment, due to the world war finally interrupted operations on many of the properties, and it was 1920 before the camp was in full swing again and mills were in operation at Kirkland Lake Gold, Lake Shore, and Teck-Hughes. The Tough-Oakes mines, the first producer, closed down in 1918, but is again being developed under the name "Toburn." In 1920 the Kirkland Lake camp production attained the million-dollar mark, and from that time onward its yearly output has advanced until in 1931 it approached $22,000,000.

It was the discoveries at Porcupine and Kirkland Lake that made the gold areas of Northern Ontario world famous. From 1866 to 1891, the Province had only produced gold to the value of $190,258. For the next seventeen years, the total was only $2,504,292. In 1910 the Porcupine mills began producing bullion, and in 1913 Kirkland Lake came into production. In the past 20 years, to the end of 1930, production has totalled $348,420,971, with over $265,000,000 from Porcupine and nearly $80,000,000 from Kirkland Lake. From 1912 to 1930, Ontario's gold mines paid out over $100,000,000 in dividends.

In 1931, when nickel and copper production were greatly affected and the low price of silver and cobalt was disturbing development, gold output showed a marked expansion, increasing more than 20 per cent. over 1930. The responsible factors in this expansion were the abandonment of the gold standard by Great Britain on September 21, the prohibition by the Dominion Government, except under license, of export of Canadian gold, and the purchase by Canada of the product of Canadian gold mines in New York funds. The premium on Canadian gold promoted and intensified the industry both in production and in the development of new areas. From Quebec to the Manitoba boundary, prospectors have been busy, and there has also been renewed activity in many of the older known areas.

The latest developments of interest are the successful operation of the Howey gold mine at Red Lake, 170 miles from the nearest railway, the Parkhill and Minto in Michipicoten, and the opening up of the Moss mine, west of Port Arthur, first worked in 1872. A 200-ton mill was started at the Moss in March, 1932. Promising discoveries have been made in Bannockburn township, about 40 miles west of Kirkland Lake, where the Ashley is rapidly approaching the production stage and a 150-ton mill is in course of construction; the low-grade deposits of the adjacent Matachewan area are now attracting attention. Gold has been found in the Three Ducks Lakes area in Chester and Yeo townships, about 10 miles southwest of Gogama on the Canada National railway, and in Swayze township, northeast of Ridout on the Canadian Pacific railway. Interesting finds have also been made at the north end of Long Lac, east of Lake Nipigon.

Iron

Ontario imports about one million tons of iron ore yearly, chiefly from the United States, but the Province has iron ore deposits of several types and a large volume of rock formation similar to the pre-Cambrian of the Lake Superior region which furnishes about four-fifths of the total American supply; but it has no producing mines at present. To meet present metallurgical requirements, all Ontario ores in large known deposits will require beneficiation. To encourage mining and treatment of these ores, and to assist Ontario producers to compete with United States' shippers, the Ontario Legislature in 1930 passed *The Iron Ore Bounty Act*, granting a bonus for 10 years of one cent for every unit of metallic iron contained in low-grade ore mined or raised in the Province and concentrated, treated, or beneficiated in Ontario; or contained in natural or unbeneficiated ore, raised or mined in Ontario, when delivered at any blast furnace or other works for the production of pig-iron or steel in Ontario, and for use in the same.

With two or three exceptions, all workable ores in the Province are found in the pre-Cambrian formations. The Helen, Magpie, and Moose Mountain are among the better-known mines that have operated in the Province. The Helen, owned by the Algoma Steel Corporation of Sault Ste. Marie, is situated twelve miles from Michipicoten Harbour, on the northeast shore of Lake Superior. The mine was opened in 1899 and continued to operate until 1918, when the hematite deposit was exhausted. It produced in all 2,780,236 tons of hematite and, in addition, 51,930 tons of iron pyrites for the manufacture of sulphuric acid. The ore minerals were hematite, limonite, and gothite. Several thousand feet of diamond-drilling on the adjoining New Helen has indicated over 100,000,000 tons of carbonate ore suitable for sintering, and it is probable that the mining and beneficiation of this ore will be undertaken in the near future. The Magpie, situated in the same area as the New Helen, has produced 1,300,000 tons of sintered ore. It closed down in March, 1921. Moose Mountain is controlled by Moose Mountain, Limited, of Sellwood, Ont., and includes eleven low-grade magnetite deposits lying within an area of about four square miles in Hutton and Kitchener townships. Sellwood, the main centre of operations, is connected by a spur with the Canadian National railway at Sellwood Junction. The mine is 35 miles from Sudbury and 82 miles by rail from Key Harbour on Georgian Bay. Its total area of iron deposits is estimated at 3,256,000 square feet. First shipments from this mine were made in 1908.

Statistical Review

A statistical review for the past quarter of a century (1906-1930) of the mining industry of Ontario by groups: metallics, non-metallics, structural materials, and clay products, while showing a remarkable expansion in value of products is even more impressive from the point of view of particular sections.

The graph of the values of the four main groups of mineral products shows the relative increases in production year by year. In 1906, the total value was $22,388,383. This has steadily increased until a maximum of $117,960,722 was reached in 1929. In 1930, production dropped to $95,272,332, but even this is a growth of over 430 per cent. Prior to 1907, non-metallic, structural materials, and clay products were grouped as one, and the value of the metal production is estimated at $9,520,269 prior to 1891. No estimate has been made of non-metallics previous to that date:—

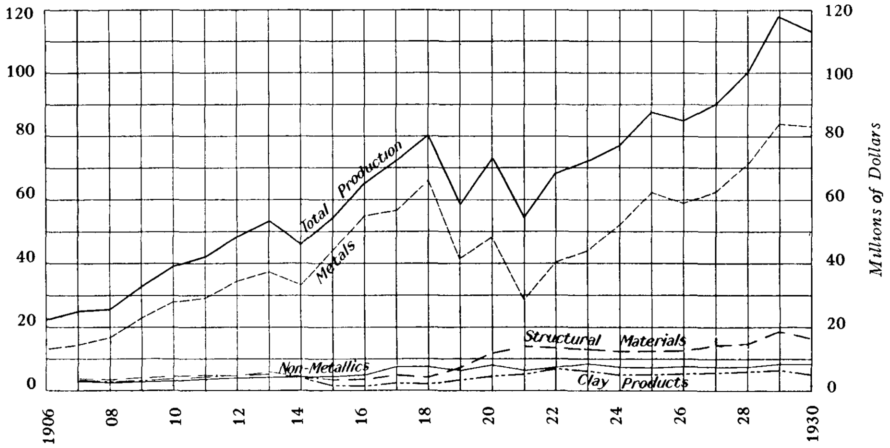
TOTAL MINERAL PRODUCTION OF ONTARIO

Year	Value of Mineral Production				
	Metallic	Non-metallic	Structural Materials	Clay Products	Total
Before 1891	$9,520,269				$9,520,269
1891	388,715	$4,316,958			4,705,673
1892	864,382	4,509,757			5,374,139
1893	614,762	5,505,991			6,120,753
1894	842,750	5,244,008			6,086,758
1895	616,055	4,554,083			5,170,138
1896	963,288	4,271,715			5,235,003
1897	1,038,089	4,480,452			5,518,541
1898	1,689,002	5,546,875			7,235,877
1899	2,055,592	6,361,081			8,416,673
1900	2,565,286	6,733,338			9,298,624
1901	5,016,734	6,814,352			11,831,086
1902	6,257,499	7,134,135			13,391,634
1903	5,242,575	7,628,018			12,870,593
1904	4,906,677	6,665,970			11,572,647
1905	10,201,010	7,653,286			17,854,296
1906	13,353,080	9,035,303			22,388,383
1907	14,550,835	$3,020,537	$3,876,275	$3,571,726	25,019,373
1908	16,754,986	2,629,749	3,396,406	2,856,476	25,637,617
1909	22,928,496	2,825,751	4,028,206	3,198,922	32,981,375
1910	28,161,678	3,141,658	4,380,000	3,630,559	39,313,895
1911	29,102,867	3,674,926	4,935,609	4,263,395	41,976,797
1912	34,799,734	4,009,643	4,701,170	4,831,056	48,341,603
1913	37,507,935	4,296,450	5,866,775	5,561,151	53,232,311
1914	33,345,291	4,339,703	4,505,368	4,105,597	46,295,959
1915	44,109,769	4,655,250	3,609,371	1,871,379	54,245,679
1916	55,002,918	4,982,140	3,734,065	1,584,699	65,303,822
1917	56,831,857	7,702,942	4,962,284	2,596,749	72,093,832
1918	66,178,059	7,815,062	4,297,401	2,018,450	80,308,972
1919	41,590,759	6,308,182	7,208,413	3,776,562	58,883,916
1920	48,281,553	8,141,796	11,921,019	4,735,154	73,079,522
1921	28,777,581	6,636,217	13,967,386	5,183,125	54,564,309
1922	40,290,157	7,591,913	13,640,166	6,944,218	68,466,454
1923	44,076,660	8,511,786	13,139,757	6,269,140	71,997,343
1924	52,130,314	7,555,283	12,398,465	5,137,865	77,221,927
1925	62,495,472	7,488,034	12,451,174	5,148,626	87,583,306
1926	59,218,297	7,842,632	12,681,308	5,356,469	85,098,706
1927	62,631,255	7,638,605	14,160,552	5,853,035	90,283,447
1928	71,267,003	7,822,641	14,815,814	6,177,664	100,083,122
1929	83,967,446	8,621,427	18,541,687	6,830,162	117,960,722
1930	83,356,365	8,492,263	16,571,626	5,221,214	113,641,468
Total	1,183,482,962	562,713,602			1,746,206,504

The graph of total production shows the remarkable contribution of the metallic group, which accounts for more than 67 per cent. of the total value. Clay products and non-metallics have increased more evenly and have remained below the ten million line. Structural materials, which include cement, limestone, and sand and gravel, reflect the activity in highway and other building and construction.

Of much more interest is the curve for the metallic group. A decrease in value of production is observed in 1914, the first year of the war. Then for four years there was a tremendous growth, which halted in 1919, increased again in

1920, only to recede once more in 1921. For the next eight years the value of the metal group shows a steady rise until in 1929 it reached a high point of 83.9 million dollars. While the world-wide depression has caused a temporary drop, which is reflected in the graph, it will be seen that the metallic output, comparatively speaking, has not suffered as severely as in 1919 and 1921.



Graph Showing Production Value of Ontario's Mineral Industry by Groups for 25 Years (1906-1930)

To the end of 1930, the grand total of Ontario's mineral production was almost one and three quarter billions of dollars in value, of which $1,183,492,962 was derived from the metallic section and the remainder, or $562,713,602, from non-metallics, structural materials, and clay products.

In the total production of metals in Ontario, gold moved up from third to first place in 1927:—

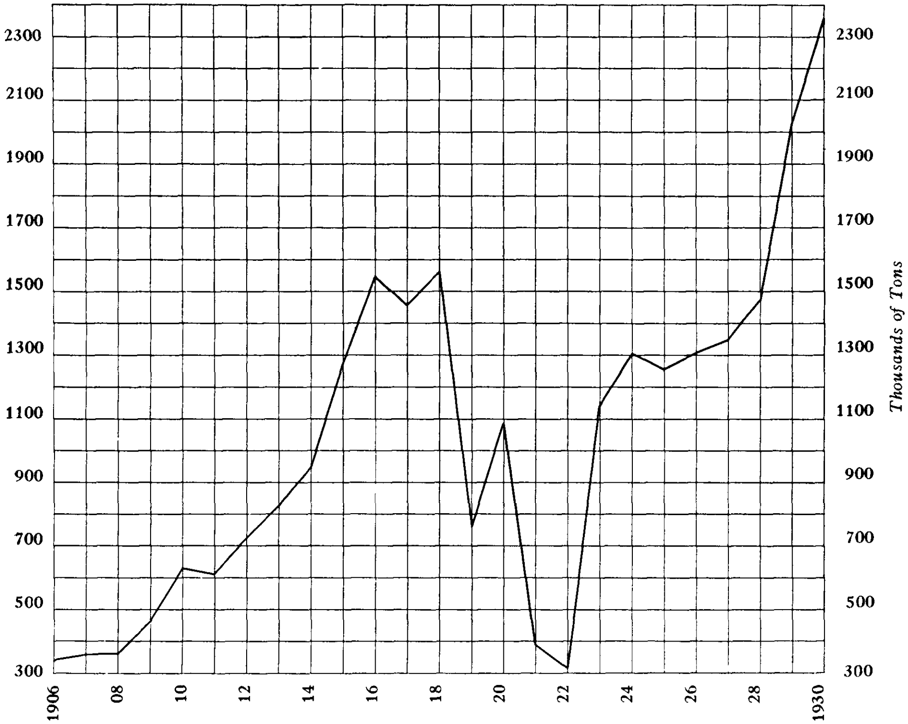
Metal or Product	Production to December 31, 1930
Gold	$351,120,721
Nickel, including nickel oxide and salts	317,068,193
Silver	251,981,892
Copper[1]	121,174,272
Pig iron from domestic ore	84,775,556
Cobalt[2]	24,092,381
Platinum metals	18,493,214
Iron ore[3]	9,463,516
Lead	4,440,879
Zinc, in ore and concentrates	535,696
Molybdenite	209,735
Bismuth	136,907
Selenium (recovered first in 1931 from copper refining)	......
Total	$1,183,492,962

---

[1] Includes small quantities of copper sulphate.
[2] Includes metal, oxide, salts, and cobalt contents of residues exported.
[3] Value of ore shipped out of the Province.

Nickel-Copper

A review of the statistics of production in the nickel industry indicates the rapid increase in consumption of nickel due to newly discovered uses. In 1906, ore smelted totalled 340,159 tons. From that time; with the exception of a slight dropping off in 1911, the increase was continuous until 1916 when 1,521,689 tons of ore were smelted. The war made large demands on the industry, and the peak of production of nickel for war purposes came in 1918 when 1,559,892 tons of ore were smelted. The graph then shows a severe recession, more rapid indeed than the rise in production, until in 1922 the total ore smelted was only 314,120 tons. The total smelted in 1930 was 2,357,154 tons, which was the highest point in the history of the industry, and was due to the newly developed markets for nickel. That year, at its peak of production, the total number of wage-earners, exclusive of some thousands employed in building and construction, was 6,681, to whom $10,134,487 was paid in wages. The total value of nickel and copper to the end of 1930 was $438,242,465, which includes the value of the nickel and copper in matte exported, the metallic nickel and copper produced in Ontario, and also the value of the nickel oxide produced and sold as such.



Nickel-Copper Ore Smelted, 1906-1930

These ores are unique as the producer of Canada's only supply of platinum metals. Exact figures of production have only been available during the past few years; and to the end of 1930 the output was valued at $18,493,214. With the development of refining processes now carried on at Acton in England, the recovery of these rare metals, which include platinum, palladium, osmium, ruthenium, rhodium, and iridium, has made the British Empire practically independent of other sources.

Dividends in the nickel-copper group have been impressive. To the end of 1930, a total of $136,548,804 was paid to shareholders. This industry leads all others in Ontario in earnings in normal years.

Silver-Cobalt

The total output of silver to the end of 1930 was 407,279,971 fine ounces, of which Cobalt furnished 364,974,864 ounces, South Lorrain 22,157,489 ounces, and Gowganda 17,299,320 ounces. In other outlying areas, Casey township, about 15 miles north of Cobalt, accounted for 2,799,740 ounces and isolated locations, 48,558 ounces. The peak of the production occurred in 1911, when 31,507,791 ounces was reported. The graph of yearly output figures shows the rapid rise due to the early discovery of native silver close to the surface and the four-year period during which the production was maintained above 29 million ounces per year, with a price ranging from 53.3 to 60.8 cents per ounce.

With the development of more efficient milling and the introduction of the oil flotation process, ores of lower grade were handled, and the production of silver was well maintained. Despite prices of 81.4 cents in 1917, 96.8 in 1918, 111.1 in 1919, and 100.9 cents per ounce in 1920, the production curve gradually fell. The total value of silver produced to the end of 1930 was $251,981,892.

The total silver shipments by camps from 1904 to 1930 follow:—

SILVER SHIPMENTS BY CAMPS, 1904–1930

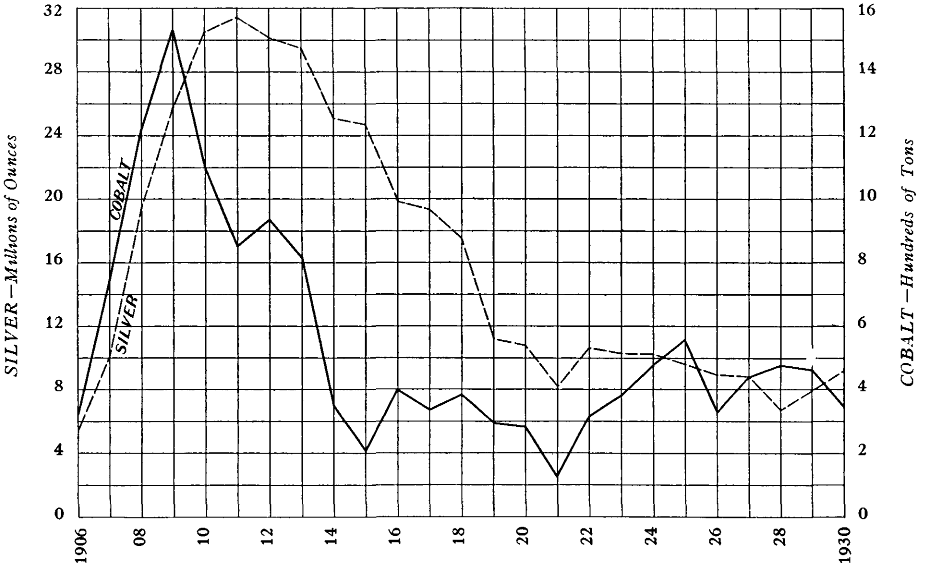
Year	Average price, cents per ounce (New York)	Silver content in troy ounces					
		Total ounces	Cobalt	Casey township	South Lorrain	Gowganda	Montreal River and Maple Mountain
1904	57 221	206,875	206,875	...	....	.....	....
1905	60 352	2,451,356	2,451,356	...	....	.....	....
1906	66 791	5,401,766	5,401,766	.....	......	.....	....
1907	65 237	10,023,311	10,023,311	....	..	....	....
1908	52 864	19,437,875	19,424,251	500	13,124	....	....
1909	51 502	25,897,825	25,658,683	26,185	194,955	.	18,002
1910	53 486	30,645,181	29,849,981	92,544	221,133	471,688	9,835
1911	53 340	31,507,791	29,989,893	114,789	933,912	468,687	510
1912	60 835	30,243,859	28,605,940	253,824	834,119	549,976	....
1913	57 791	29,681,975	28,105,505	825,108	248,992	502,370	....
1914	54 811	25,162,841	24,155,699	499,643	108,199	399,300	....
1915	49 684	24,746,534	24,280,366	223,939	..	242,229	....
1916	65 661	19,915,090	19,008,517	445,900	77,280	383,393	....
1917	81 417	19,401,893	18,327,258	...	10,000	1,064,635	....
1918	96 772	17,661,694	16,807,407	143,901	72,188	638,198	....
1919	111 122	11,214,317	10,314,689	171,278	4,586	723,764	....
1920	100 900	10,846,321	10,402,249	....	8,253	433,352	(a) 2,467
1921	62 654	8,261,931	7,673,535	1,011	328,886	258,292	117
1922	67 528	10,711,127	9,239,147	1,028	1,284,307	170,651	(b) 15,994
1923	64 873	10,377,846	7,259,858	....	2,955,646	160,761	1,581
1924	66 781	9,935,902	6,704,787	....	2,633,058	598,057	....
1925	69 065	10,707,235	6,252,115	.....	3,099,964	1,355,156	....
1926	62 107	10,543,473	6,262,249	.....	3,044,584	1,236,640	....
1927	56 370	8,543,513	4,482,543	......	2,319,356	1,741,614	....
1928	58 176	6,745,401	3,934,020	....	1,133,952	1,677,429	....
1929	52 993	7,781,429	4,823,529	....	876,006	2,081,894	....
1930	38 154	9,225,610	5,329,335	....	1,754,989	2,141,234	(c) 52
Total.	.....	407,279,971	364,974,864	2,799,740	22,157,489	17,299,320	48,558

(a) Includes 885 ounces from Silver Islet, Lake Superior.
(b) Silver Islet, Lake Superior.
(c) Nickel Hill Syndicate in the Sudbury area shipped silver-cobalt ore.

In connection with the production of silver, the metal cobalt has also been recovered, and during almost the whole of the quarter of a century, this industry produced more than 80 per cent. of the world's supply of the metal. In tons of contained metal the high point of production was achieved in 1909, when 1,533 tons of cobalt were marketed. The output of this metal, which is marketed as cobalt oxide, cobalt salts, or metallic cobalt, closely follows the demands of industry and seems to have paralleled the trend of production of silver. The total value to the end of 1930 was $24,092,381, which, with the value of silver makes a grand total of $276,074,273 from this industry.

Cobalt and outlying silver areas in 1920 employed 1,951 workers with a payroll of $2,659,201. Since that year the number has gradually dwindled to 223 in 1930 with $274,668 paid in wages.

Dividends paid to shareholders by the silver mines, for long quite the most important in the Province, have been surpassed by both the nickel-copper and gold mines. To the end of 1930, a total of $94,471,281 by 31 mines was paid to shareholders.



Quantity Production of Silver and Cobalt, 1906-1930

Gold

Total gold production to the end of 1930 was $351,120,721, of which Porcupine produced $265,151,195 and Kirkland Lake $79,548,286, as detailed in the following table:—

In 1930, Canada achieved second place among the gold-producing countries of the world, overtaking the United States (exclusive of the Philipine Islands). The Province of Ontario produced over 80 per cent. of Canada's 1930 output.

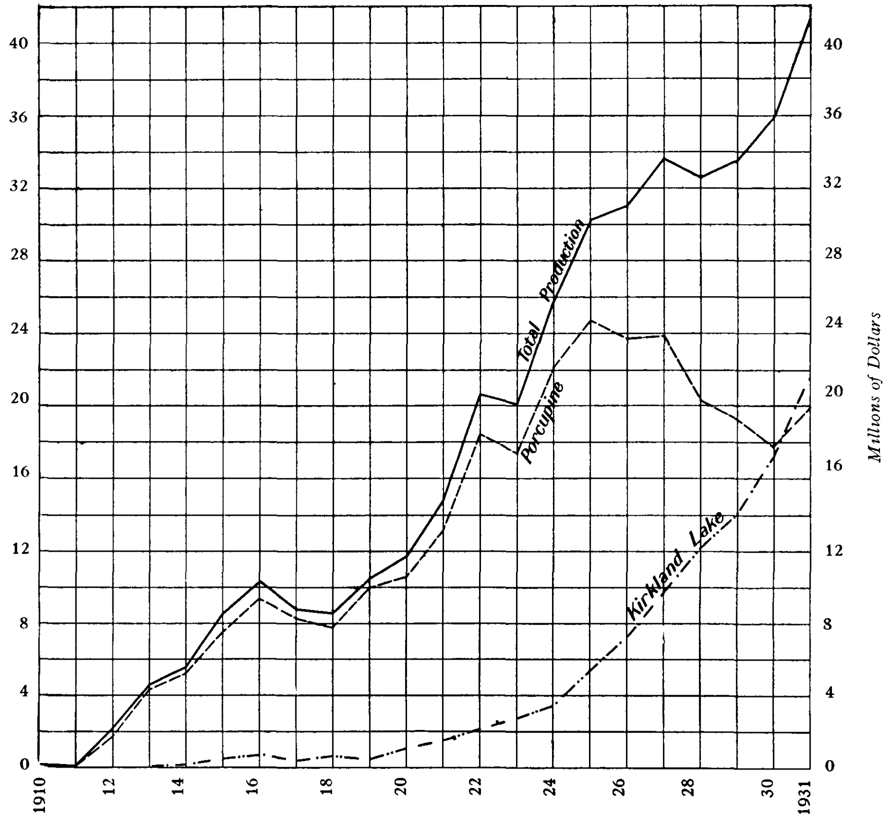
While the gold content of the ore at Porcupine since the beginning averaged about $7.68 per ton, that of Kirkland Lake reached $13.07 per ton. On the other hand the number of employees at Porcupine exceeds the number at Kirkland Lake, since the development and milling facilities are on a much larger scale.

A study of the graph of gold production by these two camps is of interest, and shows that while the Kirkland Lake field has definitely passed Porcupine it has not yet reached the high point achieved by the latter camp in 1925. The

TOTAL GOLD PRODUCTION IN ONTARIO

Year	Total production	Porcupine		Kirkland Lake	
		Value	Per cent.	Value	Per cent.
1866-1891	(*a*) $190,258	....	...	....	....
1892-1909	(*b*) 2,509,492	...	..	....	....
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	$86,316	1 9
1914	5,544,979	5,206,006	93.8	114,154	2 0
1915	8,501,391	7,462,111	88 6	551,069	6.5
1916	10,339,259	9,391,408	90 8	702,761	6 8
1917	8,698,735	8,229,744	94 5	404,346	4 6
1918	8,502,480	7,767,907	91.4	632,007	7.4
1919	10,451,709	9,941,803	95.1	486,809	4 7
1920	11,686,043	10,597,572	90.7	1,033,478	8.8
1921	14,692,357	13,103,526	89.5	1,524,851	10.4
1922	20,579,569	18,374,658	89.3	2,159,581	10 5
1923	20,136,287	17,313,115	85 9	2,719,939	13 5
1924	25,669,303	22,135,534	86 2	3,446,632	13.4
1925	30,206,432	24,733,120	81.8	5,385,256	17.8
1926	30,950,753	23,680,670	76 5	7,174,083	23 2
1927	33,627,040	23,851,857	70.9	9,674,114	28 7
1928	32,629,111	20,246,319	62.0	12,233,524	37 5
1929	33,535,226	19,281,286	57 6	14,046,596	41.8
1930	35,886,558	17,758,842	49 9	17,172,770	47.9
Total to end of 1930	351,120,721	265,151,195	75 5	79,548,286	22 6

(*a*) Estimated. (*b*) Maximum yearly output was $424,568 in 1899.



GOLD PRODUCTION FROM PORCUPINE AND KIRKLAND LAKE, ALSO TOTAL OUTPUT FOR THESE TWO CAMPS, 1910-1931 curve for Porcupine shows the setback in 1916 created by the abnormal conditions during the war when labour, material, and other costs rose to extreme points. A decline in 1922 was due to the lack of power arising during a period of low water in many of the northern streams. The high point of 1925 indicates the period when the percentage of lower-grade ores treated in the largest mill (the Hollinger) was increased; and the rapid drop in value in 1928, 1929, and 1930 may be partly explained by the milling of ore derived from large development operations and the loss of the Dome mill by fire. The output for Porcupine gained in 1931, reflecting the improved milling conditions at the McIntyre and Dome.

The development of the Kirkland Lake area on the other hand was retarded by the lack of capital arising from the war period. After 1924, however, the increase in output was rapid and consistent, and shows the yearly improvement in mill capacity and the continuous supply of high-grade ores.

The record of dividends paid to shareholders by the gold mines during the period 1912 to 1930 is impressive and has been widely reported by the financial press of all countries. A total of $105,018,426 has been paid by six mines in Porcupine and five in Kirkland Lake, the former camp paying $79,148,316 and the latter $25,802,610.

Since the beginning of mining operations at Porcupine in 1910 and Kirkland Lake in 1912, more than 45 million tons of ore have been milled, from which the average recovery per ton was $8.60. A statistical summary of gold mining operations in the major producing areas of Ontario from 1910, the year of first production, to the end of 1931 is given in the following table:

SUMMARY OF GOLD STATISTICS, 1910-31

		Porcupine	Kirkland Lake	Total
Tons milled		37,314,925	7,686,360	45,001,285
Fine gold	$	285,042,910	100,205,819	385,248,729
Fine silver	$	1,579,692	303,291	1,882,983
Value of bullion	$	286,622,602	100,509,110	387,131,712
Average value per ton	$	7 67	13.07	8 60
Premiums	$	1,421,941	1,062,775	2,484,716
Total Value	$	288,044,543	101,571,885	389,616,428
Dividends paid	$	84,411,148	34,678,134	119,089,282
Per cent. of total value		29.5	34.5	30 6
Capital actually invested	$	58,228,630	40,571,341	98,799,971

The gold mining industry, which is now Canada's greatest single producer of new wealth, gives employment in Ontario to more than eight thousand workers of all categories. Salaries and wages are in excess of fourteen million dollars, while capital invested is more than thirteen million dollars. General statistics for the year 1931 were as follows:—

GENERAL STATISTICS OF GOLD MINING, 1931

	Porcupine	Kirkland Lake	N.O. Ontario	Total
Producing mines.......... .No.	8	7	5	20
Capital invested...... .. .. $	58,228,630	40,571,341	5,567,901	104,367,872
Dividends paid.......... . .. $	4,464,834	8,875,124	.. . .	13,339,958
Salaries ....$	838,172	459,495	58,059	1,355,726
Salaried employees...... .. No.	248	126	27	401
Wage-earners: surface .. ... No.	924	755	67	1,746
underground.. "	3,204	2,173	149	5,526
mill.......... "	406	166	47	619
Total number...........	4,534	3,094	263	7,891
Wages............ ... $	7,201,681	5,148,329	411,998	12,762,008
Development work, 1931:				
shafts . ...feet	252	3,800	142	4,194
crosscuts.. ... "	41,846	24,923	543	67,312
drifts.... ... "	101,144	57,437	3,120	161,701
winzes.... .. . "	4,392	7,700	399	12,491
Total.... feet	147,634	93,860	4,204	245,698
Diamond-drilling.... ..... feet	251,614	45,972	2,031	299,617
Cost of fuel and electricity.. .$	1,281,167	1,048,849	95,266	2,425,282

Progress in Mining Methods

The growth of the mining industry in Ontario in the last twenty-five years has been marked by a tremendous increase in the value of mineral production and in the tonnage of ore handled. In the year 1906, the largest tonnage of ore handled at any one mine amounted to between 1,200 and 1,500 tons per day. This was at the Creighton nickel-copper mine in the Sudbury area. The deepest workings in the province were at the Silver Islet silver mine near Port Arthur, where mining had reached a depth of 1,200 feet before it was closed down in 1884. This record was not equalled until 1909.

By the end of 1931, mine workings in Ontario had reached a depth of 4,700 feet, and as much as 6,500 tons of ore a day had been handled at a single mine. Thus the progress has been not only in the discovery of new mines, but in the transition of small-tonnage shallow mines into large-tonnage deep mines. The progress in mining methods since 1906 has been due to this transition, which has been greatly assisted by the paralleled development of mining machinery and blasting materials, and by the application of electricity to mining, all of which have helped to reduce the cost of mining so that ore formerly considered too low grade to handle has now become profitable. Similarly the progressive reduction in the cost of metallurgical treatment and the increase in extraction, through the application of new methods and machinery, has assisted in lowering the cost of metal production, and has extended the limits of ore that can be profitably mined.

Mining Methods

The largest and deepest mining operations in 1906 were at the nickel-copper mines in the Sudbury area, where three mines in that year handled a total of 343,814 tons from a maximum depth of about 800 feet. A considerable part of this production came from a large open pit at the Creighton mine, which was connected at several levels to a shaft. The balance came from underground open stopes at all three mines, where overhand or underhand methods were employed. Electrical power had been introduced into this area during that year and was the only application of electricity to metal mining in the Province.

The next largest group in 1906 were the iron mines with 128,049 tons of ore, the bulk of which was produced by the Helen mine at Michipicoten from open underhand stopes, and the remainder from open pits elsewhere. The same methods of open-cut mining or underground open stopes were in use at the other mines in the province.

At most of the mines the ore was trammed to the shaft by hand in small cars, and the cars were hoisted to surface, though at several of the larger mines they were dumped into small skips.

The first variation in practice took place at the nickel-copper mines in 1908, when two of them adopted dry-wall drifts, stope-filling, and the use of round pillars in stopes where support was needed. By this change cars could be loaded directly from chutes built in the dry walls instead of being loaded by hand, thus increasing the output. The use of fill, with manways and chutes left in it, increased stoping efficiency by keeping the work within reach, thus saving time in setting up the rock-drills as well as permitting closer inspection of the back. At the Crean Hill mine, the dry walls and filling were of waste rock owing to the large percentage of waste contained in the ore, part of which was removed by hand-sorting in the stopes. The balance was separated at the surface sorting-plant and returned to the stopes through fill raises. At the Creighton mine, however, broken ore was used both for dry walls and filling as underground sorting was not necessary. This made possible the building up of a broken ore reserve, as only sufficient ore was drawn from the stopes during stoping operations to give headroom for the miners. The broken ore could then be drawn later as needed. The practice of removing only the excess ore is now known as shrinkage stoping.

The next change occurred at the Helen iron mine when a caving system was adopted in 1915 to mine the ore below the 6th level, while underhand stoping was continued above that horizon. Following this new method, a main drift was driven to the extreme limit of the ore body and sublevels established at 20-foot intervals. The sublevels were blocked out by drifts into rectangles, 20 by 40 feet, then raises were carried up into them at intervals of 20 feet. The rectangular blocks of ore were undercut and caved into the raises to be drawn off through chutes into cars below.

In 1913, a major change in mining methods took place at almost all the larger mines, owing to the attempt to handle larger tonnages through the shafts and haulage ways by concentrating the loading of skips at one or two levels only, and improving transportation on the levels. It was accomplished by connecting the various levels by a system of ore passes, by means of which the ore produced on several levels could be passed down to a single loading-pocket at the shaft. This was augmented by the installation of electric haulage and large self-dumping cars on the main levels, the installation of crushers above the loading pocket to increase the skip load by reducing the voids, and, incidentally, to eliminate the hoisting delay caused by large pieces, and the installation of measuring pockets in order to have an exact skip load ready to load into the skip.

At the same time shrinkage stoping, as used at present, was inaugurated. Instead of cutting out a stope to full size on the level, and then either open stoping or building dry-wall drifts and shrinking, the backs of the drifts only were slashed, timber backs were established, and shrinkage was started above the timber, or box-holes were driven at an incline from the sides of the drift and a stope floor was established 20 to 40 feet above the drift level and shrinkage started from there. Rib pillars were left at regular intervals from foot to hanging wall to support the back and hanging wall of the stope.

The movement of supplies into the stopes was greatly facilitated by the increasing use of compressed-air "tugger" hoists at stope manways. Compressed-air rotary car tipples made their appearance in 1924, though their use, as yet, is confined to a few properties only.

There were no further major changes until 1927, when the deeper workings created new conditions to be coped with. Surface subsidence and the increasing weight of superincumbent rock led to the now wide-spread use of immediate waste filling by means of cut-and-fill stopes, and, where the back is particularly heavy, by filled square-set stopes. In these methods the same general layout of rib pillars, and so on, of the shrinkage stopes is retained. The difference lies in the removal of all ore as broken and, in the case of cut-and-fill stopes, its immediate replacement by waste filling, either broken rock or sand. Temporary support is given the back by posts or timber cribs. In the latter method, timber square-sets are erected to support the back as soon as sufficient ore is broken and removed to make room for one or more sets. These are then filled as stoping progresses.

The Hollinger gold mine, however, had begun filling old empty stopes with waste rock as early as 1924, and at the Creighton nickel-copper mine local conditions had long before permitted the caving of the hanging wall to fill empty stopes. At the Creighton, with the discovery at depth of new ore bodies that did not reach the surface, it became necessary to adopt filled stoping methods there also.

This change to filled stopes has made necessary the driving of numerous raises in order to supply them with fill. As the production underground of waste rock is rarely sufficient to meet requirements, sand is usually obtained from the nearest surface pit and loaded by power-shovels or scrapers into railway cars or aerial tramways for transport to the mines, where it is discharged into main fill passes. The passes are tapped at the various levels and the sand is again loaded into cars for transport to the numerous stope fill raises which feed the stopes below.

An interesting exception to sand filling is found at the Frood nickel-copper mine, which uses waste rock obtained from the old open pit at the Creighton mine, where in past years the discarded waste from the surface sorting plant was dumped, and from the old stopes that were filled by the caved hanging wall.

The handling of timber and fill at the larger mines, where filled stopes are used, has now become as large an operation as the removal of broken ore from the stopes to surface.

In the past few years a new method of handling broken ore or fill in the stopes has appeared. This is the scraping of broken ore into chutes, or the spreading of fill, by means of small double-drum air or electric hoists and dragline scrapers, which is known as "slushing."

At the Frood mine it was found that cut-and-fill methods did not give sufficient support in most of the stopes; but, owing to the fire hazard from using standard square-set methods in a high-sulphide ore body, several intermediate methods were tried out in 1930 and 1931. These were known as semi-shrinkage and long-girt square-set methods. In the former a row of standard square-sets was carried along each rib pillar and tied to it by means of rock bolts and wire cable. The stope was then mined for four or five cuts by shrinkage, and at the same time the square-sets were carried up with the back and tied to the pillars. The ore was then drawn and replaced by waste fill, and the cycle repeated. In the latter method the stope was divided longitudinally into three sections by two rows of standard square-sets. These were connected to each other and the pillars by rectangular sets in which the girts were twice the length of those in standard sets. As filling progressed these long girts were removed in order to create a fire break between the standard sets and the pillars. Neither of these intermediate methods was successful in providing sufficient support for the back, and they were finally abandoned in favour of standard filled square-set methods.

An interesting attempt was made in 1928 at the Porcupine Paymaster to mine a large body of quite low grade gold ore by a modification of sublevel stoping methods. Starting from the various levels, raises were driven through 30-foot rib-pillar sections and stopes opened from a series of sublevels at 33-foot intervals. Between each sublevel a 25-foot bench was formed by side-slabbing a cut 8 feet high and 8 feet wide around a preliminary raise in the stope near the pillar. The stopes were gradually mined by alternate side-slashing and benching, and the broken ore was passed down the raise to the level below. All blasting was done from surface by electricity. The undertaking was not profitable, and the mine was closed down.

Mining Machinery

In 1906, the use of heavy reciprocating or piston drills was general wherever steam or electric power was available. The drills required two or three men to operate and were operated by steam or compressed air. The cutting bit formed an extension of the drill piston and reciprocated with it. Occasionally, light hammer drills, in which the bit did not reciprocate with the piston, were used for very short holes. Gradually the demand for the use of power drills in underground mining led to the reduction in size and weight of the piston drills, and the trend began to be away from steam towards the universal use of compressed air.

By 1914, however, the introduction of hollow drill-steel and water jets, as well as the improvement and modification of the drill itself, had enabled the hammer drill to drill as deep holes as the piston drill. This led to the gradual displacement of piston drills owing to the lightness, greater mobility, and faster cutting speed of the hammer drill.

Piston drills are now obsolete, and the hammer drill has been so much improved by the refinement of valve and piston action and the use of alloy steels, that it now weighs less than half what the early models did, and can drill twice as fast.

A corollary to the development in rock drills has been the progress in drill-steel sharpening from the general use of hand tools and coal forges to that of gas or oil-fired furnaces and compressed-air sharpeners, capable of handling thousands of steel daily.

In 1906, the largest hoist was at the Creighton mine where the first electrical equipment in Ontario metal mines had just been installed to replace steam-driven machinery. It was a 3-drum hoist, having 4½-foot diameter drums, and handled about 800 tons per day from a depth of several hundred feet. It could raise a skip load of 3 tons at a rope speed of 500 feet per minute.

As the mines have increased in depth and production, the hoists have increased in size and capacity. Hoists at present in use at several properties have two 12-foot diameter drums and are capable of handling 6,000 to 8,000 tons per day from depths of more than 3,000 feet, by means of skips handling 9 tons of ore at a rope speed of 3,000 feet per minute.

Compressed-air plants have progressed from a maximum capacity of 1,600 cubic feet per minute in 1906 to a present maximum plant capacity of 25,000 cubic feet per minute. Single units in use have been increased from a maximum capacity of 1,600 cubic feet per minute to 10,200 cubic feet per minute. An interesting compressed-air plant was erected on the Montreal river in 1909 and served the whole Cobalt silver area. It consisted of a single hydraulic compressor, with a capacity of 40,000 cubic feet per minute, which compressed the air by the direct action of falling water.

Twenty-five years ago the forced ventilation of underground workings was unknown in Ontario, as natural ventilation was sufficient for the needs of shallow workings. As the mines became deeper, however, this was not always sufficient to remove the foul air and gases caused by blasting or, in some cases, to remove the heat caused by the oxidation of high-sulphide ores, and in 1914 "booster" fans, operated by electricity or compressed air, were installed underground in some mines.

In the past few years it has been necessary at a few mines to sink special ventilation shafts and equip them with large surface fans, as the "booster" fans alone have not been able to carry the burden. At present the largest surface-fan installation is at the Frood mine, where heat from the oxidation of high-sulphide ore has raised the temperature underground to uncomfortable levels. It consists of two independent reversible units having a total capacity of 440,000 cubic feet of air per minute.

Blasting Materials

Previous to 1908, high explosives used in mining operations in Ontario were what are commonly known as "straight" dynamites. These dynamites were not made specially for underground use; and owing to a deficiency in the oxygen supply, bad fumes, mainly carbon monoxide and nitrous oxides, were often prevalent as a result of their use. They had the further disadvantage of freezing at relatively high temperatures (about 46° F.), and thawing was often necessary to insure safety and efficiency in their use.

Gelignite was introduced into Ontario in 1908. This type of explosive was somewhat similar to blasting gelatin; it contained very little absorbent and resembled para rubber in appearance. It froze readily at temperatures ranging from 40° to 46° F., and when in this condition was extremely liable to detonate from shock and friction. Owing to the large number of accidents occurring from its use, it was soon discarded by the mines. Attempts were made to granulate it, but the powder companies were never successful in this.

About the same time as gelignite was introduced, several companies began manufacture of potassium chlorate explosives, the best known of which was cheddite. These powders were fairly satisfactory from the standpoint of explosive efficiency but had the disadvantage of being very unstable in manufacture. Several disastrous plant explosions took place, and their manufacture was discontinued. Another disadvantage of this type of explosive was that it could not be used in wet holes, as water destroyed it. The powdery nature of the explosive also prohibited its use in holes with an upward slant.

The next step forward in explosives occurred with the development of gelatin dynamite in 1911. This type of powder differs from gelignite because less cotton and more absorbent is used, and it has a plastic nature in contrast to the rubbery nature of the gelignite. Owing to the disastrous results occurring from the use of gelignite in many of the mines, the introduction of gelatin dynamite was attended by a great deal of opposition. However, it rapidly gained favour owing to its ability to stand shock or friction without detonation, its waterproof qualities, and the ease with which it could be handled. Now it is the explosive most favoured by underground miners. Another big factor in its popularity was its freedom from noxious fumes. The importance of this quality was immediately recognized by the mining industry, with the result that gelatin dynamite soon displaced most other powders for underground use.

From 1911 on, extensive experiments were carried on with a view to lowering the freezing point of explosives. Some improvement was made by the introduction of the nitro-substitution compounds, T.N.T. and D.N.T., in small quantities into the explosive mixture. It was not, however, until polymerization, or the elimination of one molecule of water from a molecule of glycerin, that any decided improvement in low-freezing qualities was evident. This polymerized glycerin is nitrated like ordinary glycerin, and the resulting nitroglycerin, when blended with the ordinary product, will not freeze.

A further improvement took place in 1926 by the substitution of glycol for a portion of the nitroglycerin. This resulted in the present "Polar" dynamites and Forcites, which will resist the coldest weather encountered at our mines in the north.

Ammonia dynamites satisfactory for use underground were first developed in 1922. This type of explosive has been a big factor in cutting down the cost of explosives at many mines. Being bulky, a substantial saving is often effected in those working places where it can be loaded stick for stick with denser explosives and still give good results. Its fume qualities are good. The only disadvantage to its use lies in the fact that it cannot be used in wet holes.

At present about 72 per cent. of the high explosives used in Northern Ontario are gelatin dynamites, 22 per cent. ammonia dynamites, and 6 per cent. straight dynamites.

Up to 1912, blasting caps were charged with a mixture of fulminate of mercury and potassium chlorate in the proportion of 80 to 20 or 90 to 10. In 1912, compound blasting caps were introduced having a base charge and a priming charge. Many explosives were tried out in the base charge, but the most satisfactory proved to be tetryl, which is being used at the present time. The priming charge consisted of a mixture of fulminate of mercury and potassium chlorate in the proportion of 90 to 10.

In 1930, the priming charge of fulminate-chlorate was discontinued, and lead-azide and lead-styphnate introduced. The base charge was tetryl as before. Owing to the fact that the lead-azide and lead-styphnate mixtures react with copper in the presence of moisture, it was found necessary to discontinue the use of copper in the shells in favour of aluminum.

In the early days all blasting was done with tape fuse, which had a variable burning speed, gave off large quantities of smoke, was frequently subject to side spitting, and was easily spoiled by water. It has been constantly improved since then, so that it now has a nearly constant burning speed and is water-resisting. Side-spitting, which all too often led to serious accidents, has been practically eliminated, and the volume of smoke given off in burning has been reduced to a minimum.

Some years ago electric blasting caps were introduced in which the detonating charge was exploded almost instantaneously when an electric current was applied to them. Later, delay-action electric blasting caps made their appearance, with which a series of holes could be blasted in rotation by one application of electricity. In this type the electric current ignited a match-head, which in turn set fire to a safety fuse, the length of which varied according to the delay desired, and finally fired the detonating charge. Recently, a new type of delay-action cap has appeared in which the safety fuse delay has been replaced by slow-burning powder.

All shaft-sinking operations and steep raises are now required by Government regulations to be blasted by electricity in order to protect the workmen.

In the last few years several mines have used instantaneous electrical blasting successfully to recover pillars and floor sills with economy, efficiency, and safety. The largest single underground blast by this method to date was one of 9,800 holes, which broke 177,600 tons.

Electricity

During the last twenty-five years electricity has replaced steam and compressed air in supplying the power used in Ontario mines. The air and steam pipes have given place to electric cables. Twenty-five years ago, the total electric load at the mines did not exceed 1,000 horse-power; the accompanying chart shows the increase from that time to the present.

Most of the electric power originally used was for driving air compressors, which supplied the power for hoists and pumps. Rock-drills and a few hoists are practically the only uses to which compressed air is now put—the mine has been electrified. The advances made in the methods of control have made the electric motor adaptable for any operation. The magnetic control, with smooth acceleration and high speed, makes the motor preferable for hoisting.

The safety devices have eliminated many of the hazards of hoisting. Overwind, underwind, and overspeed trips will automatically cut off the power and apply the brakes. The original method was a switch in the headframe, which was opened by the cage if hoisted beyond the required height. This did not provide for overspeed or underwinding. This method has been superseded by controls geared to the hoist, which prevent accidents due to operators' errors. The braking is regulated in such a way that the retarding is gradual, thus causing less shock to the cables and attachments.

The control for other units has also been much improved. At each unit there may be merely push-buttons for starting and stopping, making the operation simple and safe. The control apparatus can be located in a distant compartment accessible only to the electrician.

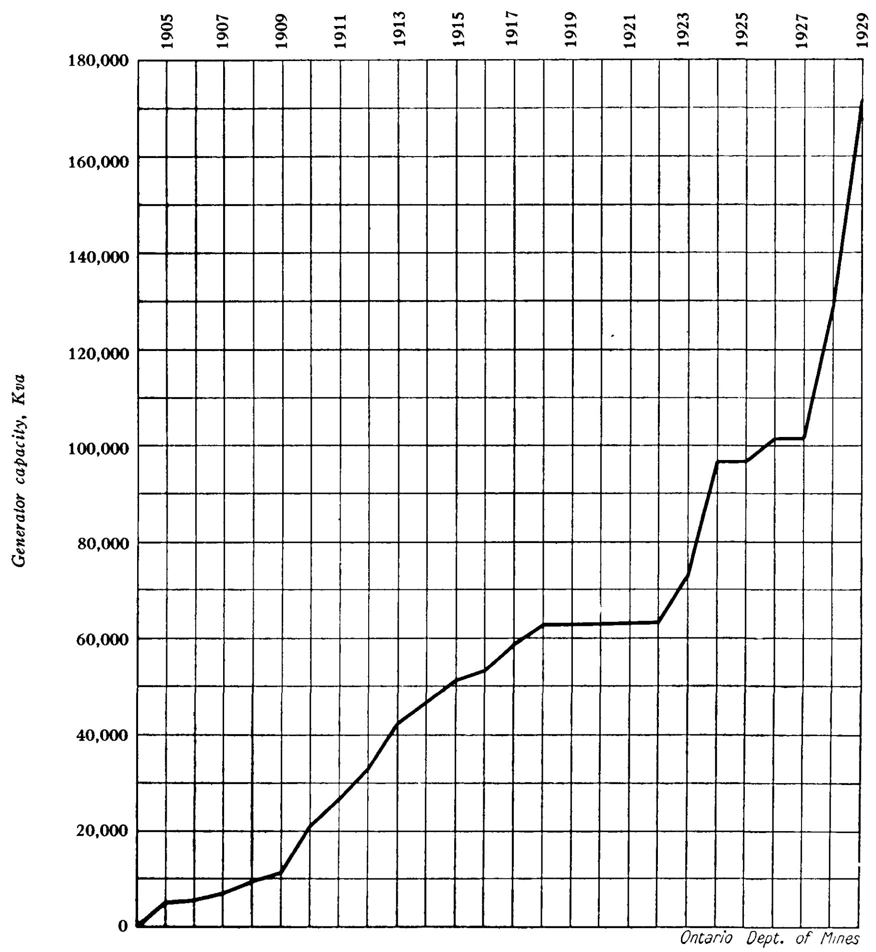
Pumps underground are equipped with controls that enable them to start and stop automatically, depending on the amount of water in the sump. Ore is distributed in bins from belts by motors that stop and reverse without the aid of an operator.

The individual drive for milling has simplified and greatly reduced the costs. About 50 per cent. of the motors at a mine are under 10 horse-power in capacity. The use of high voltage has permitted the transmission of electric power to isolated properties at low cost, and the improvement in line insulators has reduced the interruptions and attendance.

The supply of power is not dependent on one generating station alone. The systems are tied together at a central point and in the event of trouble at one station the capacity of the other stations is sufficient to carry the load.

The rupturing capacity of circuit-breakers has received special attention; it must be governed by the capacity of the supply circuit as well as the load that it carries. The present method of operating several generating stations in parallel and the distribution of heavy loads from substations has resulted in the developing of circuit-breakers capable of breaking an arc of high voltage and amperes.

The transportation of material on the surface and underground is done almost exclusively by electric locomotives. On short hauls storage batteries are used; where the distance to be travelled and the quantity of material to be transported increases, trolley locomotives are used.



Graph Showing Increase in Hydro-Electric Power Installed to Serve the Mining Industry of Northern Ontario

The underground cables have been so developed that the hazards from transmitting power to underground workings are very slight. While the mines were working at comparatively shallow levels, there was little demand for power below the surface, and it was usually transmitted by single-conductor cables in conduit. As the depths increased, there was a demand for larger pumps, crushers, and hoists.

The voltage used underground was increased from 600 to 2,200 volts, and armoured cable was used in the place of the conduit. The cables for delivering this power down the shaft are protected from mechanical injury and are given sufficient strength to be self-supporting by means of steel-wire armour. To prevent the inner core of cable from slipping in the armour wire it is usually served at intervals of 20 to 30 feet with wire the same size as the armour, thus securely locking the core to the armour wire. Where the cable is run horizontally on a level and self-support is not necessary, a steel tape armour may be installed. In both types of armouring, a bedding of jute is applied over the lead sheath. Jute is not used as a covering for the armour in cables underground owing to the fire hazard.

There are three different types of insulation for copper cables: rubber, varnished cambric, and paper. Rubber insulation is used more generally, as the potential does not exceed 2,200 volts and is satisfactory for this pressure. Varnished cambric tape is used in some cable, as it has a slightly higher rupturing capacity, but it is more easily damaged in handling. Paper insulation, although it has a higher rupturing capacity than the others, is not used for vertical installations on account of the possibility of the drainage of the insulating compound used with the paper, which would tend to develop a static head and burst the cable.

A factor of safety of 50 per cent. above the voltage on which they are to be used is required for all cables operating at over 600 volts. Owing to this factor of safety and skilled installation, a reliable service has been provided for the underground apparatus.

Ore Dressing and Metallurgical Methods

As previously stated, the transition of small-tonnage mines into large-tonnage mines has been greatly assisted by the progressive inclusion of ore previously considered of too low a grade to mine.

A considerable factor in this respect has been the parallel expansion and change in ore dressing and metallurgical plants and methods. New or improved methods and equipment have reduced the cost of metal production by increasing the profitable recovery of the metals from their ores. Also the economic treatment of certain complex ores has been made possible. As well as assisting in the above transition, this reduction in the cost of treating ores has helped in the opening up of new mines on ore deposits of a grade previously considered unprofitable.

Nickel-Copper

Twenty-five years ago there were two nickel-copper companies operating in Ontario. Since these two have produced and treated nearly the entire production of nickel and copper in Ontario, this account is confined principally to their operations.

In 1906, the Canadian Copper Company, later the International Nickel Company, operated a smelter at Copper Cliff with a capacity of some 25,000 tons of ore per month. The Mond Nickel Company had in operation a smelter at Victoria Mines with a capacity of 5,000 tons per month. In that year the steam-driven machinery in use at the former was replaced by electrical equipment, but the Mond smelter was not changed over until three years later.

At the various mines operated by them the waste rock in the ore was removed in the surface rock-houses by hand-picking from belts. The ore was crushed in jaw crushers, and sized by means of revolving trommels.

Most of the coarse ore and all the fine ore was shipped separately to roast yards. The balance of the coarse ore was sent directly to the smelters to be mixed with roasted ore. At the roast yards heaps were made up by first laying a bed of split cordwood, 18 to 24 inches deep, then from wheelbarrows piling the coarse ore on it to a depth of 6 or 7 feet, and finally covering it with 6 to 8 inches of fine ore. Once the heaps were fired the combustion of the sulphur in the ore provided the necessary heat for the operation. The object of roasting was to oxidize as much of the iron content in the ore as possible, and also to reduce the sulphur content from 20 to 25 per cent. to from 7 to 12 per cent. The heaps usually contained from 800 to 3,000 tons of ore and took from three to nine months to roast. When roasted the ore was loaded into cars by steam shovels and sent to the smelter bins.

At the smelters the roasted ore was mixed with coke, smelter reverts, silica or limestone flux, and a small proportion of green ore, and then fed to blast furnaces. From the furnaces the molten products were tapped into settlers, where the matte settled out from the slag and was transferred to acid-lined converters. In the converters it was blown to "bessemer" matte containing from 78 to 80 per cent. nickel plus copper. This bessemer matte was exported from Canada for further treatment.

The first important change in treatment occurred in 1911, when a reverberatory-furnace plant was put into service at the Copper Cliff smelter. This was installed to treat the fine ore from the mines, which was being produced in excess of roast heap requirements. The fines produced at the mines were given a further separation and all minus seven-eighths-inch ore was diverted to this new plant. There it was ground dry in Krupp ball mills to pass a 5-mesh screen, then roasted in Wedge 7-hearth roasting furnaces, and finally smelted in the reverberatory furnace, which used pulverized coal as a fuel. It was then treated in the converters with the blast-furnace matte.

About the same time, the acid-lined converters were discarded in favour of basic-lined converters, in which the acid lining of quartz and clay was replaced by one of magnesite brick. With the former type the siliceous flux needed to slag the iron contained in furnace matte was supplied from the lining. This meant that the lining had to be repaired after the converter had produced an average of six or seven tons of bessemer matte. With the new type the flux was not supplied from the lining but was added directly to the charge in the converter from time to time. As a result the converter lining did not need repairs until it had produced an average of six or seven thousand tons of bessemer matte.

The Mond smelter at Victoria Mines was closed down in 1913 and a new smelter erected at Coniston, in which blast furnaces and basic-lined converters were installed. The same problem of handling the excess fines had arisen during the last years of operation at Victoria Mines as at Copper Cliff. However, instead of using a reverberatory-furnace plant as at Copper Cliff, they decided to sinter the fines at Coniston on Dwight-Lloyd straight-line sintering machines, using fuel oil as an igniter. Sintering reduced the sulphur content and oxidized the iron in the ore in the same manner as heap roasting, but in addition converted the fines into cakes suitable for blast furnace feed.

When operations started at Coniston, all material too poor for profitable smelting was discarded as waste. In the following year the Mond Company erected a 50-ton concentrator to experiment with methods of separation and concentration on this low-grade ore on which mining costs had already been paid.

Meanwhile, at Copper Cliff, the previous practice of resmelting converter slag in the blast furnaces was replaced by the more economical practice of pouring it directly into the blast furnace settlers.

The next step forward in nickel-copper metallurgy in Ontario occurred in 1916 when the International Nickel Company started the construction of a nickel refinery at Port Colborne, which was completed and put in operation two years later. Here the nickel-copper bessemer matte from the Copper Cliff smelter, which had previously been exported for treatment, was smelted in cupola and reverberatory furnaces, with nitre cake as a flux, to obtain a "top" high in copper and low in nickel, and a "bottom" high in nickel and low in copper. The latter was crushed in jaw crushers, ground in ball mills, then leached and roasted, after which it was sent to special oil-fired nickel-refining furnaces to produce commercial nickel. The "tops" and the copper obtained in treating the "bottoms" were treated in converters to produce "blister" copper, which was exported for refining.

An important change took place in 1918-19 when the Mond Company discarded heap roasting entirely in favour of sintering. International Nickel continued to use heap roasting but eliminated the use of hand-labour and wheelbarrows in the unloading of the green ore and its distribution on the heaps by installing transfer cars and an unloading bridge.

In 1922, the refining plant at Port Colborne was enlarged. The process was changed and improved by the elimination of the reverberatory furnaces in favour of all-cupola smelting and by the substitution of double-hearth roasting furnaces in place of the earlier hand-operated and mechanical types. At the same time an electrolytic refining plant was added to the refinery. The high-nickel cupola matte after being crushed, ground, and water-leached is sintered on Dwight-Lloyd machines to remove sulphur and convert the nickel sulphide to the oxide. The finished sinter is transferred to oil-fired open-hearth furnaces to produce anodes for the electrolytic tanks. There the pure nickel in the anode sheets is recovered by electrolysis in the form of cathode sheets. These are cut into commercial sizes or sent to the furnace department to be melted and poured as shot or blocks. The precious metals contained in the anodes are recovered from the sludge precipitated in the tanks. This sludge is filtered, calcined, and then smelted with coal in an oil-fired open-hearth furnace to produce anode sheets. These are treated in special electrolytic cells and a second sludge obtained, which is concentrated by acid treatment and exported for precious-metal refining. The copper in the anodes is dissolved in the circulating electrolyte, from which it is recovered by cementation and blown in converters to blister copper, which until recently was exported for refining.

After many trials with magnetic separators, tables, and flotation, a practical separation and concentration method was finally evolved at the Coniston experimental concentrator. By 1924, magnetic separators, of their own patented design, had been added to the mine rock-houses. These utilized the magnetic properties of the pyrrhotite in the ore, which were found to be closely proportionate to the nickel-copper content, to sort the plus three-quarters-inch mine ore into three grades: blast furnace ore, milling ore, and waste. At the enlarged concentrator this milling ore was crushed in a disc crusher and then put through crushing rolls. It was then concentrated on Butchart tables. The table tails were reground in tube mills and sent to M.S. oil-flotation cells. The table and flotation concentrates were sent to the sintering machines with the minus three-quarters-inch ore from the mines.

During 1925, the production of sulphuric acid by the "contact" process from converter gases was commenced at Coniston as a by-product industry.

In the same year International Nickel erected a 50-ton experimental concentrator to attempt the concentration of low-grade Frood ores. However, deep diamond-drilling at the Frood in 1925-26 revealed large resources of high-grade ore at depth, which eliminated the necessity of handling low-grade ore for a considerable time to come. This discovery, and the increase in nickel sales, led International Nickel to decide on a large increase in equipment. Similar high-grade discoveries at depth on the Mond Frood property led them also to plan additional plant capacity.

Then in 1929 came the amalgamation of the two companies with a consequent reorganization of operations and plans for expansion.

The past three years have seen a radical change, not only in plant capacity, but in ore dressing and metallurgical methods.

Improvements made elsewhere in flotation practice, and also in the economic smelting of fine material, have made it feasible to obtain and smelt an ore concentrate even richer than the ore previously treated in the blast furnaces. It was also found that a selective flotation of the copper and nickel minerals was practicable, by which about half the copper content in the ore could be eliminated from the comparatively costly process of copper-nickel furnace separation. Consequently, it was decided to erect at Copper Cliff a concentrator capable of handling 8,000 tons of ore per day and to treat all ore except that used to produce the nickel-copper alloy known as "monel" metal.

At the mine rock-houses the waste mined with the ore is now removed by hand-picking and magnetic separators of the Mond type. Crushing is done by jaw crushers principally, though cone crushers have recently made their appearance. The magnetic separators separate the coarse high-sulphide ore from the coarse low-grade ore. The coarse ore is sized with grizzlies and revolving trommels, and the fine ore is now screened into several sizes by vibrator screens.

At the new concentrator, completed in 1930, the ore from the mine rock-houses is crushed in cone crushers and rolls. It is then ground in rod mills and fed to pneumatic oil-flotation cells. By selective flotation two concentrates are obtained—a copper concentrate and a nickel-copper concentrate. These are dewatered and filtered in Dorr thickeners and filters and sent to the new adjoining smelter, where they are treated separately. The tailings from the flotation cells are fed to a battery of Deister tables and a low-grade nickel-iron-copper concentrate removed, which is added to the nickel-copper flotation concentrate. The over-all ratio of concentration is about 2 to 1, so that in handling 8,000 tons of ore per day about 4,000 tons of concentrates would be produced.

The new Copper Cliff smelter, also completed in 1930, is designed to handle 5,000 tons of ore or concentrates per day. Heap roasting has been entirely abandoned in favour of roasting in multiple-hearth furnaces. Blast-furnace smelting has been replaced by reverberatory-furnace smelting, except for the smelting of smelter reverts, for which three blast furnaces have been retained. Thus the new smelter consists of 10-hearth Herreshoff roasting furnaces, reverberatory furnaces fired by pulverized coal, and basic-lined converters. The copper concentrates from the concentrator are treated in separate furnaces from the nickel-copper concentrates. The copper converter-matte, or blister copper, is cast into slabs and sent to the new Ontario refinery at Copper Cliff. The nickel-copper converter-matte is shipped to the Port Colborne refinery, where the copper content is recovered and returned to the Ontario refinery as blister copper.

The capacity of the Coniston smelter was enlarged to 3,000 tons per day, but sintering and blast-furnace smelting has been retained. At present it is used for the production of nickel-copper converter-matte without the previous separation of part of the copper content as practised at Copper Cliff. This matte is used for the production of "monel" metal, an alloy of nickel and copper in nearly the same proportions as they exist in certain of the mine ores, hence no separation is desired.

Copper Cliff Smelter, International Nickel Company of Canada, Limited

The new stack, completed in 1929, is 510 feet high and 45 feet inside diameter at the base.

The Ontario refinery, the British Empire's largest copper refinery, was erected at Copper Cliff in 1929-30 by the Ontario Refining Company and has an initial capacity of 120,000 tons of refined copper per annum. Here the blister copper is melted in reverberatory furnaces to be cast as anode sheets for electrolytic tanks. The pure copper in the anodes is recovered by electrolysis as cathode sheets, which are melted in another unit of reverberatory furnaces to produce commercial forms, either wire-bars or cakes. The nickel in the anodes is dissolved by the circulating electrolyte, from which it is recovered as nickel sulphate and returned to the nickel company. The precious metals and insoluble impurities in the anodes are precipitated as a sludge or slime in the tanks. This slime is roasted and leached to remove any copper, and then smelted. The resulting matte is treated with acid to remove any silver. The residue is cast into anodes and treated in special electrolytic cells to remove the gold. Provision is also made for the recovery of platinum metals from the gold electrolyte and cell residues. Selenium was recovered for the first time in Ontario in 1931.

In 1929, additional electrolytic units were added to the refinery at Port Colborne, which gave it an annual capacity of 43,200 tons of electrolytic nickel, 18,000 tons of nickel in oxide, and 60,000 tons of blister copper.

A sulphuric-acid plant, capable of producing 150 tons of acid per day, was erected in 1929 at Copper Cliff by Canadian Industries, Limited, to produce acid from the converter gases of the new smelter by the "contact" process. In addition a nitre-cake plant, with a capacity of 225 tons per day, was erected to manufacture the nitre cake used as an essential flux in the furnace separation of nickel and copper. In it sodium sulphate is mixed with sulphuric acid and heated in oil-fired retorts, where a chemical reaction takes place to produce sodium acid sulphate, or nitre cake.

In 1931, a plant for the furnace separation of copper and nickel, similar to the one at Port Colborne, but with many improvements, was erected at Copper Cliff to replace it, in order that the separation could be done there, thus saving the time and expense entailed in shipping the nickel-copper converter-matte to Port Colborne for separation and then returning the blister copper to Copper Cliff for refining. This plant went into operation in March, 1932.

Silver

Previous to the discovery of Cobalt in the fall of 1903, silver-mining in Ontario had been confined to Silver Islet and a group of small mines on the mainland in the Port Arthur area. Their total production to that time is estimated to have been worth $4,700,000. Most of this production came from high-grade ore, which was exported without any treatment other than hand-sorting. The balance was obtained from low-grade ore by simple gravity concentration methods. The most advanced practice used was to crush the ore in jaw crushers and stamps to 30- or 40-mesh, then pass it over Frue vanners with corrugated belts, which concentrated the coarser ore. The tailings were passed into hydraulic classifiers, which sorted them into three sizes. These were treated on Frue vanners with smooth belts, which concentrated the ore. Vanner concentrates were exported for further treatment.

Production from the Lake Superior silver mines ceased in 1903, except that 16,879 ounces was obtained from the old Silver Islet property between 1920 and 1922. Since then, silver-mining in Ontario has been limited principally to the Cobalt, South Lorrain, and Gowganda areas. The mines of the Cobalt area, in addition to producing most of Ontario's silver, have developed almost all of the important changes in silver metallurgy in Ontario in the past 25 years, and this review is confined to the progress of metallurgical methods in that area.

The ores of the Cobalt area were found to be remarkable not only for their high silver content, but also for the assemblage of complex minerals that they contained, cobalt and arsenic being among the valuable elements. About 97 per cent. of the silver was in the form of native silver, in which antimony was the chief impurity.

Twenty-five years ago only high-grade ore was sought at Cobalt, and no attempt was made to extract metal from the low-grade material. Much of the ore was sacked underground, and the remainder hand-sorted in simple washing plants. Ore carrying less than 100 ounces to the ton was usually considered low-grade and consigned to the dump.

It was gradually realized, however, that the high-grade ore was not extensive either in length or depth and would soon be worked out. At the same time it was found that much of the vein matter and wall rock contained low-grade silver values.

At that time all high-grade ore was shipped to outside points for further treatment; but the cost of transportation made the same procedure impossible for low-grade ores, and methods of treatment were soon sought for concentrating it. The success attained led to the treatment of lower-grade ores. Then the natural evolution of practice led to the development of processes to reduce the silver in the high-grade ore and concentrates to the form of fine bullion, which could be cheaply shipped.

Gravity concentration plants for the treatment of low-grade ores were introduced at Cobalt in 1907. The early practice was to crush the ore coarsely and size it in trommels. The oversize was then hand-sorted on picking belts and the high-grade removed. The rejects and the undersize from the trommels were again crushed and sized. They were then treated in jigs or on bumping tables and the concentrate removed. The tailings were again crushed, and the product classified into sands and slimes. The former were concentrated on sand tables and the latter on slime tables or Frue vanners. All concentrates were shipped out for further treatment.

Meanwhile, attempts had been made to cyanide the low-grade ores by the standard practice of silver cyanidation as then used elsewhere, but many difficulties were encountered owing to the complex and refractory nature of the ores. Cyanidation was first used at Cobalt in 1908, in the mill at the Buffalo mine, as an accessory treatment to recover the silver lost in the slime tailings from gravity concentration.

Zinc was used to precipitate the silver from the cyanide solution, as was the general practice elsewhere. The precipitated silver was then melted down and sold as base bullion, and the gravity concentrates were shipped out for further treatment. This method was not particularly successful as it was found that the use of zinc as a precipitant caused a heavy consumption of cyanide and in addition fouled the solution, with the result that there was a marked decrease in dissolving efficiency.

An attempt was also made at the Buffalo mill to recover the silver in the sand tailings by cyanide leaching, but without success.

The first really successful cyanide treatment was developed at the O'Brien mill in 1909, also as an accessory to gravity concentration. The tailings from gravity concentration were sent to a classifier working in closed circuit with Hardinge mills and tables, and a concentrate was obtained on the tables. The overflow from the classifier was thickened and cyanided. The silver in the cyanide solution was precipitated by aluminium dust, which the metallurgists of the O'Brien Company had found to be much superior to zinc, as it did not foul the solution and actually regenerated cyanide instead of consuming it. This practice was later adopted at other properties.

Up to 1911 the high-grade ore and concentrates had been shipped for further treatment either to reduction plants, which had been erected elsewhere in Ontario for the special purpose of treating them, or else exported to outside smelters. The reason for the erection of special plants was the difficulty of treating the ores at the ordinary customs smelter on account of their complex nature and their high arsenic content.

These special plants had been built at Copper Cliff, Deloro, Thorold, and elsewhere in Ontario. The general practice was to smelt the high-grade ore in blast furnaces to recover most of the silver as a base bullion and the balance in a silver-cobalt-nickel speiss. The latter was roasted and treated by wet methods to recover the silver, cobalt, and nickel. The arsenic driven off during roasting was recovered in bag-houses as arsenic trioxide. Concentrates were not usually accepted owing to the difficulty of treating fine material in blast furnaces.

As early as 1908, the Nipissing Mining Company at Cobalt was experimenting with a process for the treatment of both high-grade ore and concentrates that would produce fine bullion and yet be efficient and inexpensive in operation, without requiring large expenditures for plant equipment. These experiments were finally successful and resulted in the construction of a high-grade mill, which began operations in 1911. The process developed was a combination of amalgamation and cyanidation, in which the high-grade material, both high-grade ore and concentrates from the low-grade plant, was ground in a tube-mill with mercury. The mercury amalgamated with about 97 per cent. of the silver in the high-grade material. The residue after the amalgam was removed was then cyanided. The amalgam was retorted in oil-fired retorts to produce sponge silver, which, together with the silver precipitate from cyanidation, was melted and refined in an oil-fired reverberatory furnace to fine bullion. The residue left after cyanidation was sold for silver and cobalt. The skimmings from the reverberatory furnace were treated in a blast furnace to recover any silver remaining in them as base bullion. This was re-treated in the reverberatory furnace to reduce it to fine bullion. The blast furnace slag was sent to the low-grade mill for treatment.

The only low-grade all-cyanidation process used at Cobalt was developed at the Nipissing plant in 1912. Previously the refractory silver combinations in the complex ores had resisted successful treatment by cyanide alone, but the origination of a desulphurizing process there made it possible for these combinations to be broken down and the silver to be reduced to a metallic state, which could be easily treated in the subsequent cyanide process. The general process developed was first to crush the mine ore coarsely in gyratory crushers, then size it in trommels. After this it was given a preliminary treatment by hand-sorting and jigging to remove a high-grade concentrate, which was sent to the high-grade mill. The remainder was crushed in a secondary gyratory and stamped in a caustic soda solution. The stamp product was then subjected to fine grinding in a closed circuit of tube-mills and classifiers. The pulp produced was desulphurized by passing it through a tube-mill charged with aluminium ingots and then mechanically agitating it in tanks lined with aluminium plates. After this it was filtered and sent to the cyanide tanks, where the silver was dissolved in the solution. After thickening, the pulp was filtered and discarded. The silver in the cyanide solution was precipitated by aluminium dust and filtered out. It was then sent to the refinery to be melted down and refined in the reverberatory furnace to fine bullion.

Various attempts were made at the Nipissing high-grade plant to recover the mercury lost in the residues, mostly in the form of floured mercury and a small part as mercuric sulphide. These attempts were not successful. At the Buffalo high-grade plant, where essentially the same process had been adopted on commencing operations in 1912, it was found that the loss of mercury in the form of the sulphide was excessive, owing to the higher sulphur content of the residues. A successful process for recovering the mercuric sulphide was finally developed there in 1914 and consisted essentially of leaching it from the residues by means of a caustic alkaline solution of sodium sulphide, and precipitating the mercury with metallic aluminium.

Early in 1915, changes in the character of the ore at the Nipissing mine made certain changes in metallurgical treatment essential. It was found that the ore then mined contained less of the complex silver minerals than formerly. Thus, with the increased cost of aluminium, the desulphurizing process no longer returned a profit. In addition the cobalt and arsenic contained in the concentrates and residues had become of increasing value to the mines. Hence the desulphurizing process was eliminated.

In the following year the Nipissing Company developed the use of sodium sulphide as a precipitant of silver from cyanide solutions in place of the more costly aluminium. But the sodium sulphide precipitated the silver as silver sulphide, which had still to be desulphurized to produce metallic silver. This process, however, required only a small amount of aluminium in comparison with the former practice. Other companies followed suit, and the new treatment, which is still in use, soon became general at all mills using cyanidation.

About the same time the Cobalt Reduction Company erected a high-grade mill but did not adopt the amalgamation-cyanidation treatment owing to the high cost of mercury. Instead, they evolved a hypochlorite-cyanidation process in which the high-grade material was finely ground in a calcium hypochlorite solution in a tube-mill operated in closed circuit with classifiers. This treatment oxidized most of the base-metal compounds that would otherwise act as reducing agents and interfere with the subsequent cyanide treatment. All the high-grade material was then subjected to cyanidation and the silver precipitated with sodium sulphide as silver sulphide, which was desulphurized and refined to fine bullion by the Nipissing process. This new treatment was substituted for the amalgamation-cyanidation process at the Nipissing plant in 1918.

Meanwhile, in 1915, an experimental flotation plant had been erected at the Buffalo mine to attempt the oil-flotation of the silver contained in gravity concentration rejects. Various small-scale tests had been made previously, but the results of these were largely unsatisfactory, usually because the concentrates produced were too low in grade. The Buffalo plant, however, developed a process of recleaning these low-grade concentrates and made flotation a successful practice at Cobalt. Other mines adopted it, and it soon became a competitor of the cyanidation process for the treatment of gravity concentration tailings. The process developed was to grind the tailings in tube-mills to 80 to 100 mesh, with the addition of flotation oils in the tube-mills to ensure thorough emulsification. After grinding, the tailings were given a final table concentration before being passed to thickeners. The thickened pulp was fed to treble-length pneumatic flotation cells to yield a low-grade concentrate. This concentrate was re-cleaned in single-length flotation cells to produce a final concentrate containing from 300 to 600 ounces of silver. The tailings from the cleaning cells were either returned to the primary cells or else treated in a separate circuit by flotation or cyanidation.

Attempts were made at Cobalt to reduce the silver in flotation concentrates to bullion by means of a chloridizing roast in Holt-Dern furnaces, followed by an acid salt-leach, or by cyanidation. They were not a success, and all flotation concentrates have since been exported for further treatment.

The Nipissing Company abandoned its all-cyanide low-grade practice in 1916 and attempted to recover the silver minerals not dissolved in the cyanide treatment by flotation. This was not a success, and the following year they reverted to gravity concentration followed by cyanidation, but instituted extremely fine grinding prior to cyanidation. This treatment was found to be so satisfactory that in 1921 the preliminary treatment by hand-sorting and jigging was eliminated, and the high-grade ore was sent with the low-grade to the stamps, and later separated on roughing tables.

A preliminary acid-wash treatment was developed at the Nipissing plant in 1921 to replace the hypochlorite treatment in the high-grade process. It had been found that large quantities of cyanide were consumed in the cyanide treatment subsequent to the hypochlorite treatment. This was owing to the presence of decomposed nickel compounds which were not affected by the hypochlorite. In the new treatment a considerable saving in cyanide consumption was effected. The high-grade material was ground as before, but without the addition of hypochlorite. It was then agitated for twelve hours in a solution of sulphuric acid. The pulp was allowed to settle and the liquid decanted, then the pulp was washed with water several times. Finally lime was added to the pulp to neutralize any remaining acid, and the pulp cyanided. The silver was precipitated with sodium sulphide, desulphurized, and refined as formerly. This process was used only at the Nipissing plant, as the ores treated at other plants did not contain as large a proportion of decomposed nickel compounds.

During 1921, an interesting experiment was undertaken at the Nipissing plant in an endeavour to reduce the costs and improve the grinding in tube-mills. The usual metallic or silex liners were replaced by rubber liners, first in a small test tube-mill, then when their superiority was proved, in some of the operating tube-mills. Their installation proved so successful in reducing the cost of liner installation and repairs, as well as in increasing the efficiency of grinding, that during 1924 all the remaining tube-mills at the Nipissing plant were changed over. At the same time the use of flint pebbles as the grinding agent in the tube-mills was discarded in favour of iron balls, as it was found that the latter increased the output as well as permitting a coarser feed. The use of iron balls became general and made possible a large increase in the daily capacity of the mills without the installation of additional equipment. The use of rubber liners, however, was restricted to the originators, as patent rights had been obtained.

As has been noted, all ore treated by cyanidation at Cobalt since the introduction of that process in 1908 has been in the form of slimes, with the exception of the unsuccessful attempt of the Buffalo mine in the early days to treat the sands by cyanide leaching. The cyanide treatment of the slimes has varied but little since 1908, and has generally consisted of their agitation with cyanide solution in agitation tanks using the charge system, followed by thickening and filtering. The latter has been accomplished principally by intermittent slime filters of the vacuum or pressure type, though continuous vacuum filters were used at the high-grade mill of the Cobalt Reduction Company in later years with the hypochlorite-cyanidation process.

For intermediate crushing the general practice has been to retain gravity stamps, though almost all other types of standard equipment for that purpose were tried out at various times. One of the chief advantages of gravity stamps is the fact that they produce a minimum of slimes. This feature has been considered very desirable, as practically all of the plants used gravity concentration before cyanidation.

During recent years silver mining in Ontario has been declining very rapidly owing to the gradual exhaustion of the mines and to the abnormally low market price for silver. In the past seven years there have been no important changes in metallurgical practice at Ontario silver mines.

Gold

Twenty-five years ago gold mining in Ontario was an extremely small industry as judged by present-day production. During 1906, for instance, eight gold mines obtained a total of 3,926 ounces of gold from the treatment of 11,791 tons of ore. This production, however, was not the largest up to that time as the industry was then on a decline from a peak production of 27,594 ounces, established in 1899. This record was not broken until 1912. Since then the industry has grown enormously and during 1931 established a new high record of 2,062,420 ounces, obtained from the treatment of 5,025,725 tons of ore.

Placer gold has not as yet been discovered in economic quantities in Ontario, and all gold produced has been obtained from lode deposits. To separate the gold from waste rock and associated minerals, metallurgical plants have been erected. Twenty-five years ago the largest plant for the treatment of gold ores in Ontario had a capacity of less than 200 tons of ore a day. At present there are four plants capable of handling 2,000 tons or more a day. The largest of these is at the Hollinger mine and has a capacity of 8,000 tons a day, though this tonnage has not as yet been handled.

Before the discovery of Porcupine in 1909, the production of gold came mainly from mines in the Lake of the Woods area in northwestern Ontario, and in Hastings township in southwestern Ontario. In the Lake of the Woods area, the gold was usually found in the native state, commonly called "free" gold, though occasionally in association with pyrite. Some of the mills erected were of the crudest type; others were more elaborate. In the latter, the practice was to crush the ore with stamps, then either to treat it directly by amalgamation or cyanidation or to concentrate it on Frue vanners followed by the cyanidation or chlorination of the concentrates. In the latter treatment, now obsolete, the concentrates were dead roasted then moistened with water and subjected to chlorine gas. After this they were leached with water, from which the gold was precipitated with charcoal or ferrous sulphate. When cyanidation was used, either with or without concentration, the usual practice was to attempt to separate the slimes from the sands prior to cyanidation as the slimes were considered less amenable to treatment than the sands and were usually discarded. The sands were leached with cyanide solution and the gold dissolved in it was precipitated with zinc shavings.

In the Hastings area, the gold was found in intimate association with arsenopyrite at a number of properties. Various methods for the extraction of the gold from the arsenopyrite were tried, in all of which amalgamation in one way or another formed a part. Chlorination and cyanidation by ordinary methods both proved unsuccessful. Finally the bromo-cyanide process, developed in Australia, was tried at the Deloro plant and proved successful in combination with amalgamation and concentration. The ore was first crushed and amalgamated and the residue concentrated on Frue vanners and tables. The concentrates were treated with bromo-cyanide solution, from which the gold was precipitated. The residue was then treated to recover the arsenic.

Since 1912, the production of gold in Ontario has been mainly derived from the Porcupine and Kirkland Lake areas.

When mills were put in operation at Porcupine during 1912, the methods evolved in the development of the cyanidation process elsewhere were used, of which the principal one was an economic method of cyaniding slimes. Cyanidation was first used at Porcupine as an accessory to amalgamation in treating the residues. As most of the ore originally handled contained little gold in association with pyrite, much of it could be recovered by amalgamation. Later work, however, disclosed large deposits of ore in which most of the gold occurred in intimate association with pyrite, and a poor recovery was made with the amalgamation process. In consequence, a straight all-sliming cyanidation process was rapidly adopted at most of the mines. Since then this process has been used almost exclusively at Ontario gold mines. These progressive improvements have made Ontario the leader in the development of the cyanidation process. The most important improvements have been the result of the development of mechanical equipment, including pressure and vacuum filters, continuous thickeners, mechanical classifiers, diaphragm pumps, and crushing and grinding machinery.

In 1912, there were four mills in operation in the Porcupine area, all of which employed amalgamation. They used tube-mills in open circuit for fine grinding, and all except one employed stamps for intermediate crushing. The Vipond mill used rolls and a ball mill for this purpose. The two largest mills, the Hollinger and Dome, which in that year treated 45,195 tons and 75,088 tons, respectively, used all-sliming cyanidation on a large scale in conjunction with amalgamation. These two plants, operated by electrical power, accomplished the same metallurgical result by two different mechanical means.

The Dome mill stamped the ore in water then passed it over amalgam plates. The rejected material was classified into slimes and sands, and the latter were ground in tube-mills, then again passed over amalgam plates. The coarse material that had escaped the tube mills and secondary plates was recovered by means of cone classifiers and returned to the tube mills to be reground.

The Hollinger mill stamped the ore in a cyanide solution, then ground it directly in tube mills, the product of which was separated into slimes and sands. As the ore contained considerable gold in intimate association with pyrite, the sands were treated on concentrating tables, and the concentrate was reground in grinding pans, to which mercury was added to amalgamate the released gold. The residues from the tables and amalgam pans were added to the slime circuit.

At both plants the slimes were thickened, then agitated in a cyanide solution. At the Dome, a series of Pachuca tanks were used for this purpose to give continuous treatment, and mechanical agitators were used at the Hollinger. From the final agitation tank the slimes were run to storage tanks, from which they were drawn off intermittently to vacuum or pressure filters and the cyanide solution recovered. The gold dissolved in this solution was precipitated and recovered in filter presses by the Merrill zinc-dust precipitation process. It was then either smelted directly to give a low-grade bullion, or else treated with acid to remove impurities, water-washed, then fluxed and smelted in an oil-fired furnace to produce fine bullion.

After its mill had been operating for a short time, the Hollinger substituted a strong cyanide solution for mercury in the grinding pans, and the mill became an all-cyanide plant. This method of treating the concentrates was soon abandoned in favour of regrinding them in tube mills, followed by agitation in a strong cyanide solution. Early in 1913, they installed mechanical thickeners after the agitation tanks to obtain two steps of continuous decantation of the cyanide solution. This permitted them to precipitate part of the cyanide solution without filtering.

Later in the year the Porcupine Crown installed at their mill a series of mechanical thickeners after their agitation tanks and instituted complete counter-current decantation. In this system the agitated pulp was sent to the first thickener, and barren cyanide solution was added to the final one. The overflow from each thickener was transferred to the thickener preceding it, and the thickened pulp from each was transferred to the next following one. The pulp from the final thickener was discarded without filtering in slime filters, and the overflow from the first thickener was sent to the precipitation plant. This counter-current treatment permitted a completely continuous operation in contrast to the intermittent operation previously obtained with slime filters. It was shortly afterwards adopted at the Vipond, McIntyre, and Hollinger mills and soon became standard practice in Ontario along with closed-circuit tube-mill grinding in cyanide solution.

Meanwhile, in 1914, the Dome mine adopted a combined sand-leaching and slime process. Instead of reducing all ore to slimes prior to cyanidation, they used the cone classifiers to separate the secondary amalgam plate discharge into slimes, sands, and concentrates. The slimes were treated by cyanidation as before, and the concentrates were reground in a tube mill in closed circuit with a classifier and an amalgam plate, and the classifier overflow was returned to the slime circuit. The sands were leached with cyanide solution separately. This process was later abandoned and all-sliming reverted to, though amalgamation was retained.

Cyanidation was also first used at Kirkland Lake in conjunction with amalgamation, but the general practice there soon changed to all-cyanidation as at Porcupine.

The first installation of the cyanide process in Kirkland Lake was at the Tough-Oakes mill in 1914, where the all-sliming continuous counter-current system was used with ball-mill crushing and tube-mill grinding. The latter was performed in closed circuit with classifiers in cyanide solution. This practice was adopted at other Kirkland Lake cyanide mills which were erected later.

An important addition to gold cyanidation practice in Ontario was made in 1918-19 with the general adoption of the Crowe vacuum process for the mechanical removal of dissolved oxygen from cyanide solutions previous to precipitation. This resulted in a marked reduction in the amount of zinc required for precipitation, and in some instances resulted in a reduction of the free cyanide loss that accompanied zinc precipitation.

Meanwhile, the use of stamps as secondary crushers was gradually disappearing in favour of rolls or ball mills, or both. This resulted generally in lower costs and economy of space. About 1922, rod mills appeared as alternative equipment.

The next important change in the cyanide treatment of gold ores at Ontario plants was due to the introduction of continuous vacuum filters in 1923-24 for the purpose of filtering and washing the tailings previously discarded directly from counter-current decantation, in the effort to reduce the losses of gold and cyanide that were occurring in the tailings.

These continuous filters proved so successful in operation that when the Porcupine Paymaster mill was erected in 1925, two of them were installed in series in place of the usual counter-current decantation equipment with considerable economy of space and no loss in economic results. Since then practically every new mill erected has installed series filtration, and some of the older ones have discarded all or part of their counter-current decantation equipment.

With this new system, it also became general practice to use double agitation by reagitating the pulp from the first filter in cyanide solution before sending it to the second filter. At the same time further economy in space has resulted from the use of tray thickeners instead of the older single type. Flint pebbles, used exclusively in tube mills at first as grinding media, have been gradually replaced by iron or forged-steel balls with a consequent increase in the capacity of the tube mills.

At Kirkland Lake most of the gold was found in intimate association with pyrite, as at Porcupine. In addition, an appreciable amount occurs in association with tellurides. The problem of liberating the gold in association with sulphides or tellurides has been approached in a number of ways in Ontario. At Porcupine the sulphides have been removed either on concentrating tables or in bowl classifiers for regrinding and reagitation, or else disposed of by extremely fine grinding and long circulation double closed circuits with concentrating cones. At Kirkland Lake several other methods have been tried in the attempt to recover the gold in association with tellurides, as the latter have proved difficult to treat by the usual cyanidation process and the loss in the tailings has been quite high as compared with Porcupine losses. The Wright-Hargraves mill in 1926 introduced flotation cells into the ordinary cyanide circuit after the tube mills and classifiers for the purpose of cutting out the tellurides from the pulp as flotation concentrates. These were treated separately with bromo-cyanide and returned to the slime circuit at the agitators. The Teck-Hughes mill added sodium peroxide to the cyanide pulp in the agitators in the attempt to break up the refractory tellurides. Both of these practices proved unsatisfactory and were later abandoned.

Numerous experiments have been made at Kirkland Lake in the past few years to reduce the loss of values in tailings from straight cyanidation by retreating the tailings by flotation methods, but satisfactory results were not obtained until recently.

The first large-scale plant to employ flotation for this purpose was put in operation at the Lake Shore mine in March, 1932. The method used is to treat the cyanide tailings, which are 95 per cent. 200-mesh, in oil-flotation machines from which a concentrate is obtained. The concentrate is then ground in a strong cyanide solution and agitated in a new type of agitator, which also acts as a defrother. After agitation, the pregnant cyanide solution is filtered from the pulp and the latter discarded. The pregnant solution is then sent to the gold precipitation unit.

The new type of agitator, besides acting as a defrothing machine, greatly reduces the time of agitation required for the dissolution of gold in cyanide solutions, which is accomplished by forcing air into the solution to supply oxygen more rapidly for the chemical reaction of the gold with the cyanide solution. It is likely that this new machine will gradually replace the older types of agitators for all cyanidation work.

Meanwhile, prior to 1929, the McIntyre mill at Porcupine had been experimenting with flotation as a primary treatment for their ore. To confirm laboratory results they erected a small flotation plant in 1929, the operation of which proved so successful that in the following year work was started on a new 2,000-ton mill to employ flotation as a primary treatment to precede cyanidation. The mill was completed and put in operation during 1931. After reducing the ore to about 60-mesh it is sent directly to flotation cells, which remove practically all of the sulphides, plus free and attached gold, as a concentrate. The tailings from the flotation cells containing values below the economic limits of cyanidation are immediately discarded. The flotation concentrates, comprising only about 15 per cent. of the original ore by weight, are then finely ground and cyanided.

This process has been made possible by the recent discovery of flotation agents that have a greater selectivity for mineral particles than any previously known. The advantages of this process, for ores that can be economically treated by flotation, include not only the reduction in milling costs due to the elimination of 85 per cent. or so of the mill feed from fine grinding and cyanidation, but also a reduction in plant construction and equipment costs. It is thus possible that the flotation process will play a major part in the future recovery of gold from Ontario ores.

The Natural Gas Industry

Twenty-five years ago the natural gas industry was fifteen years old. It was known that the life of the various fields was limited, but neither experience nor the meagre data then collected were sufficient to form any estimate of their future. Where gas was wasted the life of the field was short, but where care and skill were exercised the inevitable decline in production was postponed. The greatest handicap to the gas industry was the paucity of available technical skill. Fields had been ruined by faulty workmanship. As in all things new and untried, there were more pessimists than optimists, and it required all the energy and persuasion of a few men of vision to keep the industry alive.

The Welland gas field was at its peak of production, and a few wells were still coming in. Gas had been sold to Buffalo since 1891 and netted the producer 5 cents per thousand cubic feet. Development work was proceeding in Haldimand, where gas had been discovered at Cayuga, Caledonia, and Dunnville. The most prolific part of the field at Selkirk had just been opened, although its full extent was still unknown. In the very early days, measuring gas in large volume was a problem, and very crude methods were used. Most domestic gas was not measured but sold at a flat rate. Gas rates in Leamington in 1897 were:—

	Per month
Cook stoves. .	$1 50 to $1 75
House furnace	$2 50
Store furnace	$3 25
	Per M cu. ft
Industries. .	5 cents

Confidence in the future was just beginning to dawn, and a few men were now willing to venture large expenditures. A pipe line was being laid to Hamilton, and drillers were abandoning the old oil fields at Petrolia and Oil Springs to drill gas wells in the new field in Haldimand county. An old well at the village of Vienna that had been drilled in the early sixties to a few hundred feet had been flowing sulphur water and considerable quantities of sulphuretted hydrogen gas. Someone suggested that the gas flow might increase if the well were drilled deeper; eventually at 1,200 feet in the Clinton formation the Bayham gas field was discovered. This field was gradually extended until Tillsonburg was supplied with natural gas.

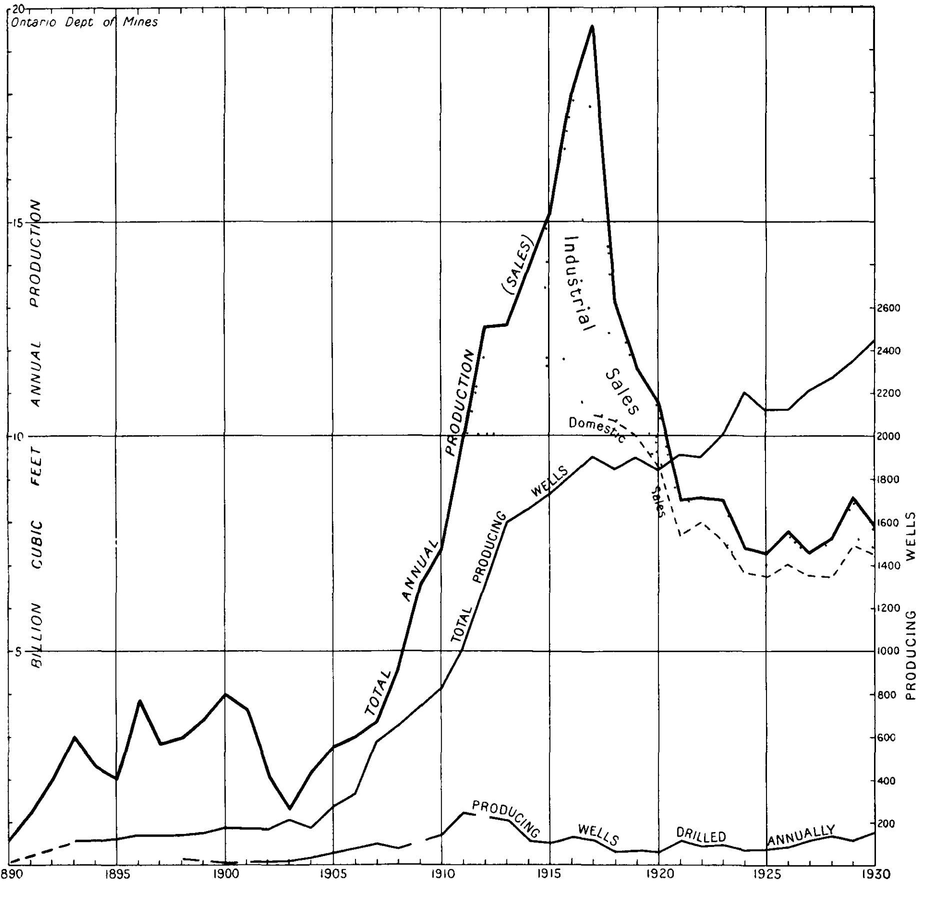
In those days, most of the prospectors for natural gas were handicapped in their exploration work by the absence of surface indications and also by lack of any scientific knowledge of the proper methods of exploring for gas. One procedure that gained in popularity was to drill at the mouth of every stream along Lake Erie. Port Colborne, Port Maitland, Selkirk, Port Dover, Port Rowan, and Port Burwell had rewarded the prospector, but Port Ryerse, Normandale, Port Bruce, Port Stanley, Port Talbot, and all other ports had been failures. However, this method ("creekology" it was called) had produced results for the early prospectors, and our eastern gas fields extended inland from these beginnings.

In the Western Peninsula, the Leamington gas field (which had been discovered in 1889 and from which gas had been supplied to Leamington, Kingsville, and Windsor and the surplus exported to Detroit and Toledo) had suddenly failed or had "gone to water," as a result of the faulty abandonment of some of the wells. Government regulations for plugging abandoned gas wells and the appointment of an inspector to supervise all plugging operations prevented a repetition of this disaster. The oil field a few miles to the east had failed to come up to expectations, and the faith of the operators in that particular section was shaken. Then the old Petrolia and Oil Springs fields, which had at first produced large quantities of gas with the oil, "blew down" in a few months. One of the unsuccessful companies operating in the Leamington oil field had but $1,500 left in its treasury, not enough to drill another well. One director suggested that they give the shareholders a big banquet and "blow it all in"; but another, who "had always believed that there was oil on his father's farm near Tilbury," made so successful an appeal to his associates that they joined him in finding the necessary additional funds and drilled the first producing well in the great Tilbury gas field. These first wells produced a considerable flow of both oil and gas, and the first purely gas wells were allowed to blow into the air, in the hope that the gas would blow off and the oil come into the well. The practice was promptly stopped by the Ontario Government, and this great gas field saved for the benefit of the present consumers. This, then, was the situation in Ontario twenty-five years ago.

The operators in the Tilbury field, forced by the Government to put their gas to some useful purpose, made an agreement with the Chatham Gas Company for the sale of their gas, but their faith in the permanence of the field was not very great. They laid a 3-inch line to Chatham; at the present time, twenty years later, an 8-inch line is required to supply the town. Further exploratory drilling showed conclusively that a gas field and not an oil field lay between the original discovery and Lake Erie. A few years later, pipe lines had been laid from this field to Windsor, Wallaceburg, Leamington, Kingsville, Ridgetown, and Sarnia, with branch lines to outlying towns. In 1912, a magnificent enterprise was begun—the running of a pipe line from the Tilbury field to Hamilton and the exploration of the territory along the way. A 12-inch pipe was laid, and it was proposed to supply gas to St. Thomas, London, Woodstock, Ingersoll, Paris, Galt, Brantford, and Hamilton. All but London and St. Thomas joined in the undertaking; these towns refused to use the gas because of its strong odour of sulphuretted hydrogen. Unfortunately, no more fields materialized, and the supply for this large pipe line was limited to a small part of the Tilbury field.

Ten years' exploratory work in the Haldimand area had extended that field practically to its present limits. As the area was very large and there was little or no competitive drilling, wells are still being drilled within the limits of the old field. Onondaga township in Brant county had been found productive of both oil and gas, also Barton, Glanford, and Binbrook in Wentworth county, Caistor and Gainsboro in Lincoln, and Wainfleet township in Welland. Every township in Haldimand was productive, and all but one (Townsend) in Norfolk. In Houghton township, although no dry holes had been drilled, the wells were comparatively small, and the selling price of gas was not high enough to make worth while the laying of a pipe line to connect the wells to the distribution system. In Elgin county, Malahide had been added to Bayham township as a gas producer.

This great development work was done and the long pipe lines were laid with the intention of supplying gas in large volume to industries at prices ranging from 12½ to 20 cents per thousand cubic feet. The quantity sold to domestic consumers was about 10 per cent. of the total; at the present time the quantity sold to industries is 10 per cent. of the total. Oil refineries, glass factories, sugar refineries, and tile and brick works were among the greatest consumers.



Graph of the Natural Gas Industry for the Past Forty Years

At this time the world war placed enormous demands on industrial plants for the manufacture of munitions; and natural gas reserves, being immediately available, were taxed beyond their capacity. Search for new gas fields went forward with new vigour but without much success. The Dover field in Kent county was the only discovery. In the middle of the cold winter of 1917-18, the natural gas fields, which had been showing a steady increase in output since 1903, reached their peak of production, but still failed to meet the demands for fuel. Practically all residents of Kent, Essex, and Lambton counties had ceased using coal and had turned to gas for heating their homes; consequently, when the gas supply failed and a coal shortage prevailed, there was considerable suffering. In municipalities where distribution plants were not of modern design, there was not sufficient gas for cooking. An immediate and vigorous appeal was made to the Ontario Government to relieve this situation by denying gas to large industries, and the Government replied by appointing a commission to investigate and then the necessary legislation was rushed through the Legislature. Certain industries that had other fuel available were denied natural gas, and all others were then instructed to convert their appliances as soon as possible. The graph and table below will show how the drastic measures taken to preserve our natural gas for domestic consumers resulted in a decrease of sales following the year 1917. The gas companies, suddenly deprived of a large portion of their revenue, demanded that they receive the revenue necessary to allow them to conduct their business at a profit. The municipalities, having agreements at stated prices extending many years into the future, refused to agree to any increase in rates. Seven years of bitterly contested applications for increased gas rates followed, which had the unfortunate effect of disturbing the gas man's faith in the future of his business.

Exploratory work was at a standstill. The legislation of 1917 to 1919 and 1921 appeared to curtail the use of gas to a point where the market was so limited that independent operators and distributing companies saw no profit in "wildcatting." The sudden and enforced curtailment of sales left a considerable surplus of natural gas. With a reduction in sales and no reduction in operating expenses, the gas industry neither desired nor required further reserves of gas until this surplus diminished to some extent. At the same time, the flow from the wells in the Tilbury gas field appeared to be declining rapidly, and the end of its life was forecast; but, by accident, it was discovered that an accumulation of salt on the walls, which prevented the gas from entering the wells, was the cause of this decline. Charges of dynamite, exploded at the bottom of the wells, removed this, and during the following five years the field was revived. The eastern fields were not so severely taxed and continued to supply the demand. Hamilton discontinued using any natural gas in 1924, and this left another small surplus for a year or so. In the mean time the gas companies were slowly succeeding in their battle for equitable rates and were finding it profitable to distribute gas to purely domestic consumers. Following this readjustment distribution plants were enlarged, the design of stoves and water heaters was improved, hydrogen sulphide was eliminated from the "Tilbury" gas, inspection of consumers' appliances was introduced, and consumers were educated in the economical use of gas, all of which resulted in improved service to the consumer. The increase in the number of domestic consumers, shown in the table on next page, clearly demonstrates how the policy adopted by the Ontario Government had the effect of diverting the use of natural gas from industry to the home, and to a greater number of homes annually.

Pessimism regarding the future of the industry has now largely disappeared, the price of natural gas has, to a great extent, been stabilized, and new projects are being proceeded with. Research into the probable reserves has shown that there is possibly much more gas underground than was ever imagined, and it is quite safe to say that there will be a natural gas industry in Ontario twenty-five years from now; it is also quite possible that some natural gas will be used for enriching manufactured gas fifty years from now. The present known fields will, in all probability, still produce one hundred billion cubic feet of gas. It is, of course, unknown what the undeveloped parts of Kent, Essex, and Lambton will produce; but the undrilled portions of Elgin, Norfolk, Haldimand, Brant, and Welland can be estimated, conservatively, at thirty billion cubic feet; and this is, perhaps, the least promising of the undeveloped areas; recent discoveries in Kent county and Lambton county have a much greater potential production.

DOMESTIC CONSUMPTION OF NATURAL GAS, 1921-1931

Year	No. of pay consumers	Total quantity used	Quantity used per consumer
		M cu. ft.	M cu. ft.
1921	58,609	5,937,316	101 3
1922	63,229	6,028,947	95 3
1923	62,352	6,210,459	99 6
1924	61,100	5,933,595	97 1
1925	62,338	5,300,424	85 6
1926	63,695	5,595,521	87 8
1927	66,818	5,210,315	78 0
1928	70,259	5,699,553	71 2
1929	80,991	6,336,873	78 2
1930	84,135	6,332,519	75 2
1931	86,050	5,607,744	65 1

The Mining Act of Ontario

Prior to Confederation regulations with regard to mines and mining lands were made by Order-in-Council, there being no statute law. In 1864, there was a rush of prospectors and miners to the valleys of the St. Francis and Chaudière rivers in Quebec, where alluvial gold had been discovered. Thereupon the Legislature passed the first Act on the subject of mines and mining, known as *The Gold Mining Act*, which provided with much nicety and particularity for the mining of alluvial and quartz gold, the protection of miners' rights, the appointment of inspectors with large powers, for licenses to stake out claims, and for all details of administration in the newly found gold field. The Chaudière diggings proved unremunerative, and they soon ceased to attract attention.

In 1866, a rich deposit of gold was found on the Richardson farm near Madoc, Ont., and another rush ensued. So high did the excitement rise that a company of mounted police was found necessary to keep the prospectors in order. The Act of 1864 was repealed and in the first session of the Ontario Legislature after Confederation, *The Gold and Silver Mining Act* of 1868 was substituted, but the Richardson ore find was not duplicated and the excitement quieted down. Hitherto, gold was the only metal that was envisaged by the law-makers, chiefly as alluvial gold. This was due to the fact that practically all the gold then or previously produced was recovered from sand or gravel. The diggings in California and Australia, then in full operation, typified in the popular mind the occurrence of the precious metal. Now, however, the discovery of silver on the north shore of Lake Superior, led to the inclusion of that metal in the law.

The new features of the 1868 Act related chiefly to the granting of licenses to explore and mine for gold and silver within the limits of a mining division and the levying of royalties. In 1869, *The Gold and Silver Mining Act* was repealed and *The General Mining Act* of that year, which retained many of the features of its predecessor but applied to all metals, took its place.

The finding of gold in the Chaudière valley and again at Madoc brought mining into prominence, and illustrates the important reaction in the mining law, afterwards so noticeable, to the major or supposedly important discoveries of mineral made from time to time. Amendments were framed and new features introduced to meet new conditions as they arose, both for the purpose of protecting the public interest and in an attempt to provide workable regulations under which lands might be taken up and actually used for mining. Take, for example, the discovery of the Sudbury ores in 1883. The true significance of this discovery was not revealed until 1887, when the ore was found to contain nickel in commercial proportions, as well as copper. This greatly enhanced the value of the deposits, since the value of nickel was much greater than that of copper, and the fact was soon established that in the Sudbury area Ontario possessed the greatest source of nickel in the world. *The Mining Act* was amended in such a way as to insist on development as well as to secure a revenue by levying royalties; the price of mining land was more than doubled, and as to title, while a grant in fee simple might be obtained, provision was also made for 10-year leases. In response to a general feeling that nickel should be refined at home, an attempt was made in the Act of 1900 to compel this to be done, heavy "license" fees being placed on nickel ore, to be remitted if the ore was refined in Ontario. These provisions were not to be enforced until proclaimed by the Lieutenant-Governor in Council. No such proclamation followed, and hence the enactment never went into effect. Later, a Government Commission having reported that there was no reason why refining could not be done in Ontario, and commercial conditions being at least as favourable here as elsewhere, a nickel refinery and also a copper refinery were established.

The effect on the law of the discovery in 1903 of the phenomenal silver field of Cobalt was very marked. On accession to power in 1905, and while Cobalt was in the early stage of development, the Whitney Government announced its intention of completely revising the mining law. It arranged for a convention of mining men from the northern districts and elsewhere, which was held in December, 1905. The convention submitted a number of suggestions to the Government for its consideration, some of which met with approval. The mining division and local recording office method of disposing of mining lands was strongly urged. As a matter of fact, this was already a feature of *The Mining Act* and had been applied to the Cobalt silver field almost immediately after the Whitney Government took office, but in no other part of the province. By this time it was found that the law provided three distinct methods of taking up mining lands: (1) by purchase, contingent upon the expenditure of $4 or $5 per acre (according to the area granted) within a limited time after issue of the title, which might be either a grant in fee simple or a 10-year lease; (2) in a mining division, by staking out a claim of 22½ or 40 acres, the expenditure of $150 in work each year for three years on a 22½-acre claim, or for four years on a 40-acre claim, whereupon the land might be purchased or leased; (3) outside of a mining division by staking out a claim of 40 acres and doing work at the rate of $3 per acre for the first year and $7 for the second, after which, on paying the stipulated price per acre, a grant or lease might be had.

The new Act of 1906 swept away these varying methods of acquiring mining lands and substituted one way only, namely, the establishment of mining divisions and the staking out of claims under authority of a miner's license. In the Cobalt division, discovery of mineral in place was rigidly insisted on, inspectors being appointed by the Government to pass upon finds, real or supposed. If the inspector approved of a discovery the claim was allowed;

if not, it was cancelled and thrown open for prospecting by others. This procedure, though discontinued at a later stage, resulted in an intensive prospecting of the Cobalt field. Indeed, it is probable that no mining area in this continent has ever been more closely or more laboriously examined for mineral than was the one at Cobalt, where a crack in the rock an inch wide but filled with solid silver, might spell fortune to the prospector. The whole of the Province, save the agricultural area to the south, was arranged into mining divisions with a local recorder for each. Accordingly, the finding of gold at Porcupine in 1909 and at Kirkland Lake in 1911, epoch-making as these discoveries were, found this decentralized system so firmly established and on the whole working so satisfactorily that it did not necessitate any major change in the law. In fact, *The Mining Act* as regards the taking up of land has remained practically intact from 1906 to the present time, the principal amendmen being the rejection of the "discovery" feature in 1922.

As will have been seen, the development of the mining law of Ontario has been highly empirical. Trial and error and experiment have marked its progress from the beginning. In practically every important feature there has been a complete boxing of the compass. Royalities were early introduced, then abandoned, again imposed, and once more abandoned. Discovery was not required until 1897; it was then introduced, and at Cobalt carried, so to speak, to the breaking point, then done away with in 1922. Until 1891 the minerals were included in a grant for agricultural land. In that year *The Public Lands Act* was amended to declare that they should be reserved, whether or not so expressed in the grant, but in 1908, a change in the law gave the minerals to the surface owner, except where expressly withheld. The size of a mining location prior to Confederation might be as great as 6,400 acres; later it was reduced to 320, 160, 80, or 40 acres. Subsequently, it was standardized at the last-named figure.

Experience during the last twenty-five years or more has shown that the Act in its perfected form is a workable measure, and that it is so recognized is evidenced from the fact that in several of the other provinces, and even in the Dominion itself, it has been taken as a model on which mining regulations have been formed or revised.

The leading features of *The Mining Act* may be summarized as follows:—

Mining Claims.—All Crown lands, with a few minor exceptions, are open for prospecting and may be taken up as mining claims. The province is divided into mining divisions with a resident recorder in each. A miner's license (cost $5.00) is necessary in order to stake or hold a mining claim and may be issued to any person over eighteen years of age. A licensee is limited to three claims for himself in any mining division, but he may stake out also six claims for other licensees, not more than three for each.

In unsurveyed territory a claim consists of a square of 20 chains to a side, or 40 acres, while in a township subdivided into concessions and lots or sections, it must be an aliquot part of a lot or section containing 37½, 50, or 40 acres, according to the method by which the land has been surveyed.

A claim is staked out by planting No. 1 post at the northeast corner, No. 2 at the southeast corner, etc., and by blazing the lines between the posts, the bearings of the boundaries being east and west, and north and south astronomically. Numbered metal tags are supplied by the recorder and must be attached to the posts.

Claims must be registered with the recorder for the mining division in which they are situated within fifteen days from the date of staking, one day additional being allowed for each additional ten miles from the recorder's office. All subsequent transfers, agreements, etc., must be filed with the recorder until issue of title.

If in unsurveyed territory, a claim must be surveyed by an Ontario Land Surveyor before patent and the plan and field notes filed in the recorder's office.

The underground boundaries of a claim, sides as well as ends, are lines vertical to the horizon, consequently there is no "apex" law in Ontario.

There are special provisions for the staking out of claims for petroleum, natural gas, coal, and salt in Northern Ontario, the maximum area of a claim being 640 acres.

Working Conditions.—Thirty days' work of eight hours each day must be done on a claim within three months after recording, and forty days in each of the next four years, plus ten days in any one year, making two hundred days in all in five years, but the work may be completed in any less time. For the first thirty days' work there is an exempted or "close" period from the 16th of November to the 15th of April following, both dates inclusive—the winter season.

Report of work must be filed with the recorder within ten days of the end of the period for which it is done. Before beginning work, the claim-holder must apply to and receive from the Provincial Forester a permit so to do.

Timber.—Pine timber is reserved on all mining claims, and timber of all kinds on claims staked out and recorded on or after the 26th of March, 1918; nevertheless the patentee may cut and use such trees as are necessary for building, fencing, and fuel, or for other purpose essential to the working of the mine. If the timber is under license to cut, disputes between the holder of the timber license and the owner of the land as to value or quantity of timber cut, are settled by the Minister of Lands and Forests.

Title.—On completion of work, filing of survey plan (if required), and payment of purchase money at $2.50 per acre in unsurveyed territory, or $3.00 per acre in surveyed, a patent is issued. In Provincial Forests, title is by way of lease for ten years, renewable, the first year's rental being $1.00 per acre, and for subsequent years 25 cents per acre.

Disputes.—The Mining Recorder is empowered to settle all disputes between licensees, subject to appeal to the Judge of the Mining Court.

The Mining Court of Ontario is a special tribunal established for dealing with matters arising under *The Mining Act*, which come before it on appeal from a mining recorder, or referred to it by him.

The Judge of the Mining Court has authority over patented as well as unpatented mining claims, and may grant easements on adjoining land necessary for the proper working of a mine.

Miscellaneous.—There are no royalties on ores or minerals, but under *The Mining Tax Act*, a tax is levied on the net profits of a mine as noted under the heading "Mine Taxation in Ontario."

A full and complete code of regulations is provided for the operation of mines to ensure the safety and protect the lives of miners and workmen. These are enforced by a Chief Inspector and four assistant inspectors.

Statistical returns of production, etc., are required to be made at stated periods by all operating mines.

Mine Taxation in Ontario

The first mention of mining taxation is found in 1868, when *The Gold and Silver Mining Act of 1868* was passed. This statute provided for a royalty of not less than 2 and not more than 10 per cent. on gold and silver mined. In the following year *The General Mining Act of 1869* repealed all royalties, taxes, or duties. This state of affairs obtained till 1891, when *The General Mining Act* was amended and a royalty was imposed on all ores, silver and nickel ores being liable for a fixed charge of 3 per cent., and iron 2 per cent. Changes were afterwards made from time to time in the royalty rates, and they were lowered for lands patented before a certain time, and raised for lands subsequently granted. But nothing was ever collected under any of these enactments, and in 1900 royalties were definitely abandoned.

In 1907 *The Supplementary Revenue Act* was passed, which imposed a tax on profits, the rate being 3 per cent. on profits in excess of $10,000, profits being determined in the way laid out in section 6 of the Act. On the Revision of the Statutes in 1914, the title of the Act was changed to *The Mining Tax Act.*

No important change was made until 1917, when amendments were passed changing both the basis of valuation for nickel ores and the rate of taxation. At this time the rate of taxation on profits in excess of $1,000,000 was increased from 3 to 5 per cent. In 1924, the changes made in 1917 with regard to nickel were repealed, and all ores were put on the same basis. No important changes have been made since that date.

The Mining Tax Act also levies a tax on the production of natural gas. This is a fixed amount per thousand cubic feet, regardless of whether profits are made or not. Originally the net amount, after making rebate for gas used in Canada, was two-tenths of a cent per thousand cubic feet. In the Session of 1932, this was increased to one cent.