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COBALT:

CANADA'S MINING AND MILLING LABORATORY, 1903-1918*

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INTRODUCTION

Within a year of its establishment in 1891, the Ontario Bureau of Mines complained that the province had been so 'disappointingly slow in developing its mines' that much of the mining was being done by Americans and Europeans, and predicted that no meaningful advances were likely to occur until Ontario ceased shipping its ores to other countries and built its own refineries.[1] Fifty years later, E.S. Moore observed that Canadian mines were still controlled by American-based companies which imported their capital equipment, and conducted research and development in the United States.[2] Subsequent studies, in the 1970s, conluding with J.J. Brown's influential *Ideas in Exile*, reached similar conclusions.[3] 'The story of Canadian invention and technology,' Brown pronounced, 'can be seen as a melancholy procession of golden opportunities which we have let slip through our fingers.'[4] In the last decade, a small group of researchers interested in Canada's technological growth began to question the validity of the earlier studies. Philip Enros, for example, identified the period immediately following the First World War as an era of technological innovation in Canada, and Christian De Bresson collected data on Canadian innovations between 1947 and 1976 which disproved many of J.J. Brown's assertions.[5] No one, however, has studied the impact on Canadian mining technology that was sparked by the discovery of rich silver deposits in Northern Ontario in the first two decades of the twentieth century. *Ideas in Exile*, for example, dismisses this period in two sentences.[6] This study explores the growth of mining and milling expertise developed in Cobalt and concludes that in this area Canada has a rich heritage of technological innovation that is comparable, if not superior to, kindred developments in other parts of the globe.

DISCOVERY AND EXTRACTION

The boom which the discovery of silver touched off was one of the most colourful and exciting ever seen in Canada. Prospectors, writers, stock brokers and mining engineers from New York,

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London, Brisbane, San Francisco and Johannesburg all journeyed to Cobalt. The aspiring prospector boarded a Pullman car at Toronto in the evening, and awoke the next morning in the town of Cobalt. The art of prospecting, however, proved more difficult than the novice expected. Because the newly arrived miners often lacked experience, they were easily deceived into purchasing divining rods, or conjuring devices such as the Daft-Williams Electric Ore Finder, which purported to emit electrical 'earth waves' that could locate and trace valuable silver veins below the surface.[7]

The prospectors discovered the first silver veins where the bare rock was exposed to the air. By the end of 1904, after all the surface exposures had been examined, prospectors turned to digging trenches through the overburden in search of valuable ore veins. Narrow trenches were dug, washed clean and carefully examined for signs of silver-bearing fissures.

During the next four years the terrain around Cobalt Lake was systematically criss-crossed by miles of trenches, dug at intervals of approximately one hundred feet, with intermediate ditches added as circumstances warranted. The Nipissing Mine alone dug over sixty miles of ditches and located one hundred and thirty-one veins. By the end of 1909, however, it had trenched only half of its property. The Company's general manager informed the stockholders that:

> This method of prospecting covers a large area at small expense and is far ahead of underground exploration as a means of finding new veins. At the present rate, however, it would take many years to completely trench the property and then many veins would probably be missed. The only sure way to find all out-crops is to entirely remove all the overburden on the rock surface, and preparations are now under way with this in view.[8]

Nipissing had experimented with different prospecting methods as early as 1906. In that year it purchased a single-stage centrifugal pump with a 650 horse-power motor to rinse the surface soil off the bedrock with a pressurized stream of water. Working 120 hours per week, men removed the soil at the rate of six acres per month. The bedrock was thereupon washed clean and inspected for surface veins.[9] Because this procedure produced a great deal of mud, the method was confined to hillsides. At the bottom of a steep hill a section of ground was washed bare and thoroughly examined. The next area further up the hill was similarly cleared, and the covering material washed down the hill. This method bared the whole surface of the Nipissing Hill on the east side of Cobalt Lake. Although Nipissing discovered few important veins, the Company was satisfied that nothing had been missed. Meanwhile, Nipissing Hill had been scoured to bare rock.

Cobalt was the ideal poor man's lode camp: the ore was rich and close to the surface, cheap rail transportation was available, there was ample wood for fuel and timbering and law and

order were well preserved. All the requisites for speedy development thus existed. The prospectors' one consuming passion was to discover a valuable ore deposit, sell it for a profit and return home to live in comfort.

Because of the richness of many of the veins, and as most of the early companies were short of working capital, the first shipments consisted almost entirely of ore taken from surface excavations. The first carload of ore from the Trethewey property brought its owners $34,000 net profit, and the original shipment from the Right-of-Way allowed the company to repay the entire purchase price of the property.[10]

Ore extraction by means of open-cuts and underhand stoping was the universal practice in the early camps, and with two or three exceptions, not a single shaft exceeded one hundred feet in depth.[11] By the close of 1906, the total value of the mining machinery at Cobalt probably did not exceed $100,000. For example, the hoist at the Foster Mine employed horsepower, but the other mines used ordinary hand-windlasses.[12] The miners' tools consisted of a wheelbarrow, a pick, a shovel, a piece of drill steel and a hammer. Miners jokingly described the Right-of-Way Mine as seven men, three planks and a wheelbarrow, to which had been added a couple of candles for the night shift.

Limited to hand drilling and an occasional blast of dynamite, the miners tore great vertical adits in the face of the cliffs and gouged tremendous pits, or glory holes, in the surface. Down to a certain depth such open cutting proved the cheapest method of extraction; the richness of the surface ore tempted the miners to open every mine by open cuts, regardless of the loss of silver ore.

As profits mounted, the mining companies purchased machinery for a more systematic development of the property. Despite the prevailing fear that the camp was only a surface proposition, modern mining methods were adopted as the veins were followed to greater depths.[13] This growth was further stimulated by the provincial Bureau of Mines which published geological reports on the area, examined the paragenesis of the Cobalt ores and delved into the metallurgical peculiarities of the ore bodies. Prior to 1900, there had been only two reports (William Logan in 1845-6, and Alfred Barlow in 1897) on the geology of Cobalt. The next twenty years saw the complex structure of the rocks gradually unravelled. In December 1903, Willet G. Miller published his first report on Cobalt in the *Engineering and Mining Journal* (10 December) and the *Canadian Mining Review* (31 December). The following year William Parks wrote an article for the Geological Survey of Canada describing the veins and rocks in the Cobalt vicinity. In 1905 Miller published his first full report for the Ontario Bureau of Mines ('The Cobalt-Nickel Arsenides and Silver Deposits of Temiskaming'). At the same time, J.E. Hardman and Robert Bell of the Canadian Geological Survey Branch described the new mineral area. The next year, Miller published the second edition of his *Report*, and Cyril Knight and W. Campbell worked on the paragenesis of the Cobalt ores. During the next four years

Canadian mining journals carried numerous articles on rock formations in the Cobalt area until the topic was exhausted.

By 1906 the mining companies began to dig shafts, install drilling plants and erect steam hoists. Open quarrying gave way to shaft mining, and the number of men employed underground rose rapidly from 186 at the beginning of 1906 to 586 near the end of September.[14] The Toronto *Globe* reported in the fall:

> Several of the producing mines in the camp are getting down to the two hundred foot level, and with increase of depth come all the signs of increase of confidence, namely marked increase of output, the ordering of better machinery, the erection of handsomer and more permanent structures of all kinds, a larger number of women ... and all the other indubitable signs that the wise man trusts to more than words.[15]

Most of the mining companies in the Cobalt camp imported machinery from the United States, which had a longer period of mining experimentation, and adapted the equipment to local conditions.[16] The major problem, however, was providing enough power to meet the rapidly growing demand.

ADVANCES IN HYDRO-ELECTRICITY

At the commencement of mining operations in Cobalt the exceptionally rich outcrops of silver ore enabled the mines to keep their returns above expenses, even when costs were unreasonably high. With deeper mining, and higher tonnages of low grade material, costs began to rise. Energy was needed to run the mills, hoist large quantities of ore from greater depths and run the drills. The first steam plants used the trees cleared from the land as their source of fuel. However, the soft-wood forest was soon exhausted;[17] the obvious next step was to turn to coal. The mining companies imported bituminous coal from the United States at an exhorbitant price. The freight charges exceeded the original cost of the coal and power generation was thus very costly. Some mines paid up to $250 monthly per drill. Despite the excessive rates, the demand for coal increased as the mines sank deeper shafts, and as low-grade milling became a feature of the camp. Coal shipments rose from 55,800 tons in 1908 to 105,400 tons the following year.[18] In 1907 a small generating plant was built in nearby Latchford, and the following year a gas burning plant was erected at Cobalt. However, they only provided a fraction of the camp's needs.

Cheaper power was a prerequisite for continued profitable operations. Lack of power, for example, prevented the Buffalo Mine from sinking shafts below the two hundred-foot level, and both the McKinley-Darragh and the Buffalo mill were forced to operate below capacity. The Badger Mines' owners borrowed power from the Rochester Mining Company, but when the Rochester needed power, the Badger Mine had to stop drilling until the other company finished mining operations for the day.[19]

This demand for more and cheaper power resulted in the completion of three large power projects, the and the installation of a revolutionary new technique in water power. In 1909, the Cobalt Power Company erected a hydro-electric plant at Hound Chute on the Montreal River -- seven miles from the town of Cobalt. The Mines Power Limited, situated on the Matabitchewan River, twenty-four miles from Cobalt, served the newer mining areas in South Lorraine, and constructed substations at Brady and Cobalt Lakes to provide power for the Cobalt camp.

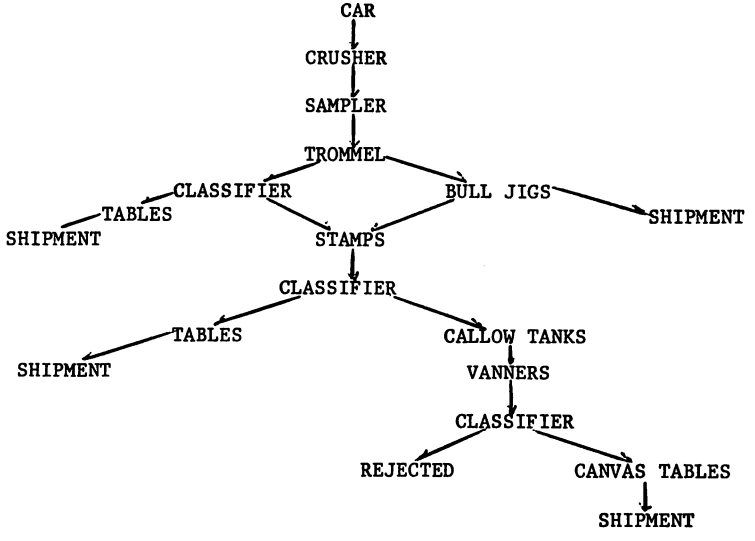
The Cobalt Hydraulic Power Company, located at Ragged Chutes on the Montreal River nine miles from Cobalt, provided compressed air to the entire camp. The principle of compressed air had been known for centuries, but not until C.H. Taylor of Montreal improved the concept had the principle become a reality. Taylor revealed that the power derived from freeing trapped bubbles from fast-flowing water could be determined by the diameter of the down-flow pipe, as well as by the height of the falls; the pressure depended solely upon the depth of the shaft.[20] Using Taylor's observations, the company chose a point on the river where the water tumbled over a thousand feet of short rapids in a total fall of fifty-four feet. To harness the river, it built a 660-foot long concrete dam to divert the water into a large basin. Just below the surface of the basin two sixteen-foot diameter intake heads sucked the water into a 350-foot vertical shaft. As the water rushed into these pipes, it entrained air bubbles. The pressure and water velocity was increased by contracting the diameter of the intake pipes, thus forcing the water to hold more oxygen. Forty feet from the foot of the shaft the diameter was expanded to lessen the water compression, which liberated the air. When the water reached the bottom of the shaft it struck two steel-sheathed concrete cones which further diminished the flow speed and liberated more air. The water was then diverted into a horizontal tunnel, where it lost its momentum and yielded the remainder of the air. The compressed air gathered in the tunnel dome and was piped to a valve house at the surface.[21]

From the valve house the compressed air was transmitted in twenty-inch steel pipes to Cobalt. Feeder pipes encircled Cobalt and conducted the compressed air to Kerr and Giroux Lakes -- a combined total of twenty-one miles of pipes. The utility sold the air by meter to the larger mines, and at a graduated scale based on the number of operating drills to the smaller customers.[22]

In 1911, the Hydraulic Power Company and the Cobalt Power Company merged with the Cobalt Light, Heat and Power Company to form the Northern Ontario Light and Power Company. A year later the conglomerate absorbed the Mines Power Company and the power plants in the Porcupine region; and several years later added the Charlton and Englehart power companies. Electricity, like mining, was becoming big business in northern Ontario.

The introduction of a cheap and dependable supply of power worked wonders. The savings were immense. The McKinley-Darragh

NORTHERN CUSTOMS CONCENTRATOR--FLOW SHEET



Mining Company reduced its mining costs from $3.09 per ton of milled ore to $1.31.[23] The average power rate in Cobalt shrank from $150 per hoursepower year to only $50. The *Canadian Mining Journal* declared in 1909 that in conjunction with the growth of concentrating mills, the development of hydro-electricity in Cobalt was the 'most significant feature in the industrial growth of silver mining in Northern Ontario.'[24] Faced with the prospects of declining profits, the Canadian technological and engineering community had acted quickly to alleviate the immediate problem. The road was now cleared to tackle the difficulties encountered in the milling processes.

ADVANCES IN HIGH GRADE MILLING

The discovery of silver at Cobalt presented the world's mining and metallurgical engineers with several unique and puzzling problems. The complex nature of the ore, and its high arsenic content, made it difficult to treat by ordinary refining methods. Soon, all attention became focussed on the problem of refining Cobalt silver ore. Arthur Cole, the mining engineer for the Temiskaming and Northern Ontario Railway, reported in 1907 that 'nearly every mining school and testing laboratory

on the continent has run small mill tests on the ore.'[25] Between 1906 and 1914 the pages of the *Canadian Mining Institute Transactions*, the *Transactions* of the American Institute of Engineers, the *Canadian Mining Journal*, the *English Mining Journal*, the *Mining and Scientific Press* (San Francisco) and the *Engineering and Mining Journal* (New York) teemed with discussions and reports on the problems of refining and milling the silver at Cobalt.[26] One hundred and sixty members of the American Mining Institute toured the area in 1907, and the next year the Canadian Mining Institute boarded the Temiskaming and Northern Ontario Railway for a Cobalt inspection tour.

Initially, the companies sent only the high-grade ore to the refineries located in New Jersey, Colorado and Pennsylvania. The Canadian Copper Company erected a refinery in 1905, but it sent the rich cobalt-nickel-silver speiss to New Jersey for final separation. The general practice in these refineries was to smelt the ore in a blast furnace and recover the silver as base bullion. The resulting speiss was roasted and treated for the recovery of the remainder of the silver, together with the cobalt and nickel. The arsenic was recovered in bag-houses. Because of the complex nature of the ore, the process was slow, the refining plants were very expensive and American refineries dictated prices. Smelting facilities were vital to mining prosperity. The *Canadian Annual Review* was particularly worried that the Cobalt ores would become subservient to American demands and considerations.[27] In 1906 the mining companies, which were more concerned with expenses than issues of nationality, refused to sell their ore to the Jersey City smelters which were charging inflated prices and offered no compensation for arsenic and cobalt by-products. During the summer, the larger mines stored their output and waited for the completion of several Ontario smelters. The mine closures also served to thwart union organizers in the camp.

The Deloro plant, built for the O'Brien Mining Company, successfully implemented the ideas of Dr S.F. Kirkpatrick, of Queen's University Mining School, for extracting silver from arsenical ore.[28] At Thorold, the Coniagas Mine utilized cheap hydraulic power and built its own reduction plant. Other major Ontario refineries emerged at Orillia, Welland and Copper Cliff. These refineries benefited from the Ontario Metal Refining Bounty Act of 1907, which offered a bounty of six cents for every pound of refined cobalt oxide. By 1910, nine refineries were competing for the Cobalt silver ores. Table I illustrates the transfer from American to Canadian smelters.

TABLE I

SILVER ORE REFINED IN CANADIAN AND AMERICAN SMELTERS

Year	%Canadian	%American
1904	0	100
1905	0	100
1906	0	100
1907	17	81
1908	29	69
1909	34	65
1910	52	48
1911	66	34
1912	60	40
1913	-	-
1914	83	17
1915	84	16
1916	87	13
1917	75	25

(Source: Ontario Bureau of Mines *Annual Reports;* A.A. Cole, 'Mining Industry Reports,' 1907-1917.)

The bulk of the Canadian ore was high grade; its value was thus much greater than the low-grade ore which was still shipped out of the country. To compensate for smelter schedules and freight rates, the ore had to run at forty-five ounces per ton; all inferior ores were concentrated before shipping.[29] To avoid these difficulties, the Nipissing Mining Company investigated the possibility of treating its ore locally without incurring the expense of building the usual smelter. Ideally, it wanted an efficient and inexpensive process which would produce easily marketable fine silver bullion. To this end, the company examined numerous processes and built a small experimental plant. Finally, Charles Butters and his assistant, G.H. Clevenger, Nipissing's American consulting engineers, devised an acceptable method and the company began operations in February 1911.[30]

The Nipissing high-grade mill employed a unique combination of amalgamation and cyanidation. The ore was mixed with mercury and ground in a tube mill. The critical step in the process was running crushed ore into a tube mill along with mercury and a five percent cyanide solution. The mercury amalgamated with about 97% of the silver, and the residue from this amalgam was removed and cyanided to recover the remaining three percent. The product was melted and refined to a fine bullion in an oil-fired reverberatory furnace. Nipissing shipped the bullion direct to London, avoiding additional freight and refining charges.[31]

During the following decade this process underwent several alterations as a result of the changing character of the ore, technological advances and the availability of precipitants. Early in 1915, the Nipissing high-grade mill modified the metallurgical treatment to accommodate the less complex silver ores that were beginning to be milled, to take into account the high cost of aluminum and to benefit from the increasing value of the cobalt and arsenic by-products which had previously been discarded. As a result, sodium sulphide replaced aluminum as a precipitant, and calcium hypochlorite was later adopted to avoid the high cost of mercury.[32] Advances in high-grade milling thus kept pace with the changing ore bodies and the price dislocations caused by the First World War.

MILLING LOW-GRADE ORE

In mining the rich, but narrow veins it was often necessary to remove over a foot of country rock for every inch of high-grade ore extracted. Initially, the high-grade rock was separated from the wall rock in the ore house and the rest was discarded. This rejected rock, however, contained a small percentage of valuable silver. In 1908, for example, tests at the La Rose Mine showed that their dumps contained 55,000 tons of milling rock which, after deducting the cost of concentrating and smelting, would net a profit of $330,000. In addition, the La Rose was producing approximately one hundred tons of concentrating rock and screenings daily, which meant an additional annual saving of about $200,000.[33] Since the future of the Cobalt camp depended on the success of low-grade milling techniques, the mills had to adopt foreign techniques, or develop new ones.

Unfortunately, the unique nature of the Cobalt ore prevented comparison with other mining camps. Ore samples were sent to chemists in Toronto, New York, Montreal and London. Manufacturers of mining machinery vied with each other to become the first to solve the problem and establish a patent. The larger mines hired teams of chemists to work on the problem. 'The three mills now in operation,' the *Canadian Journal of Mining* reported in 1908:

> are tentative in design -- experiments on a large and practical scale. Standard designs will be the result of experience and can only be arrived at after patient investigation. But it is recognized that the whole future of the camp depends upon the successful solution of the milling problem.[34]

In 1907, the McKinley-Darragh Mining Company and the Buffalo Mine erected the first low-grade mills at Cobalt. By the end of the year, these mills had proven so successful that the number of concentrators mushroomed from five in 1908 to fourteen mills in 1910. Even mines without mills adopted a partial mechanical concentration process using jigs or tables.[35] The following table illustrates the growth of low-grade milling in Cobalt.

TABLE II

MILLING IN COBALT, 1908-1914

Year	Concentrates Shipped (Tons)	Ore Milled in Gravity Concentrators (Tons)	Ore Milled in Cyanide Plants (Tons)
1908	1,100	49,000	0
1909	3,200	122,700	3,700
1910	7,100	269,000	36,500
1911	9,600	329,500	52,400
1912	10,500	390,500	65,000
1913	11,300	531,500	133,300
1914	12,700	591,400	152,100

(Source: Ontario Bureau of Mines, *Annual Reports*, 1904-1915.)

Between 1904 and 1911 the production of silver at Cobalt rose steadily. Thereafter, production gradually declined. Table II also illustrates the importance of milling to the camp. Although total production fell after 1911, the tonnage of ore milled in Cobalt continued to rise until 1915. As early as 1911, A.A. Cole stated that half the shipping mines would be closed down if they had to depend upon high-grade ore for profit.[36] Two years later, the Ontario Bureau of Mines reported that, although the high-grade ore was by no means exhausted, the future of the camp depended largely upon the lower grades.

The general practice at Cobalt was to separate the high-grade ore at the mine, cobb the mixed pieces and send the rest of the rock to the concentrator. Here, the rock was sprayed with water to help the pickers who were on either side of the inclined bumping table, to recognize the rich ore. The high-grade ore was removed before the concentrating process because it tended to slime, with a consequent loss of some of its value. The remaining ore was reduced in gyratory crushers and concentrated on jigs and tables. The residue was passed through a series of crushers, sifted over screens and reground until it passed through a very fine mesh screen. Water was added and the pulp passed over a series of jigging tables which separated the heavier from the lighter material. The coarse rock was concentrated on Wilfley, Deister or James sand tables, and the fines were separated on Frue vanners, or on James and Deister slime tables.[37] The resulting concentrate was dried and dropped into shipping bins. Depending on the nature of the ore, the mill crushed the rock in stamps, ball mills or rolls. In the stamp mill a battery of cast-iron stamps weighing approximately 1,300 pounds each, were lifted seven inches and dropped onto a heavy cast-iron die. The crushed rock was fed into the stamps, pulverized and washed away by water. The resulting sludge was sent to the classifiers which sorted and separated the material into sand and slime, the former

passing to the Wilfley or James tables, and the latter to the Deister. It was on the Wilfley tables that the bulk of the silver was recovered. At some mills the final crushing was performed by rolls or ball mills. The extremely hard Cobalt rock, however, broke crusher swing-jaws and corrugated roll shells. By 1913, over eighty per cent of the mills reduced their ore, at least in part, by stamps.[38]

The same principle was adopted by all the mills. The only difference consisted in the details. The flow sheet of the Northern Customs Concentrator illustrates the general method adopted in the mills of the camp.[39] (See illustration)

Although the mines obtained good results from the gravity concentrators, a few managers believed that the slime tailings contained sufficient silver to merit cyanidation. In 1908, this process was first attempted at the Buffalo mill as an accessory treatment to concentration. The ore, however, was so complex and refractory that this early experiment proved unsuccessful. In addition, because the working solution quickly became foul and lost its dissolving efficiency, the consumption of cyanide was very heavy, and therefore expensive.

The research conducted on these problems led to some important developments in the treatment of complex silver ores. The O'Brien Mining Company developed the first successful cyanide treatment in 1909. After the usual preliminary treatment of hand-sorting and jigging, the ore was concentrated and given a cyanidation treatment below the stamps. In preparation for this last process, the ore was crushed into slime by tube or high speed Chilean mills, until the tiny silver particles were liberated from the enveloping rock. The resulting sludge was treated with sodium cyanide in huge mixing tanks termed agitators. As the silver in the sludge became exposed, it was gradually attacked and dissolved by the cyanide solution. Aluminum dust (a discovery of the O'Brien matallurgists) was added to the resulting silver cyanide solution and the silver was precipitated. It was then melted in a furnace and poured into bars.[40]

Since this process recovered up to 97% of silver values and avoided smelter and freight charges, cyanidation was competitive with the older gravity concentration process, and by 1911 four mining companies (Nipissing, O'Brien, Buffalo, Nova Scotia Dominion Reduction Company) adopted the cyanidation process in their mills. At the Nipissing mill, tests showed that the profits from cyaniding at a 90% extraction rate were $12.09 per ton, whereas the profits from concentration at 80% recovery were only $10.50.[41] Cyanide ore went straight to the bullion brokers in London without having to be shipped to the smelters. The Cobalt *Nugget* commented that it 'can easily be conceived what an immense sum could have been saved if all the low-grade ore sent all across the continent to Denver had been treated right in the camp by a plant such as the Nova Scotia now have.'[42]

The increasing tendency towards final treatment of the ore in Cobalt reduced the gross shipments from 34,300 tons in 1910 to

26,700 tons in 1911. Table III illustrates the corresponding increase in bullion shipments and the growing importance of cyanidation.

TABLE III

SHIPMENTS OF BULLION FROM COBALT, 1910-1915

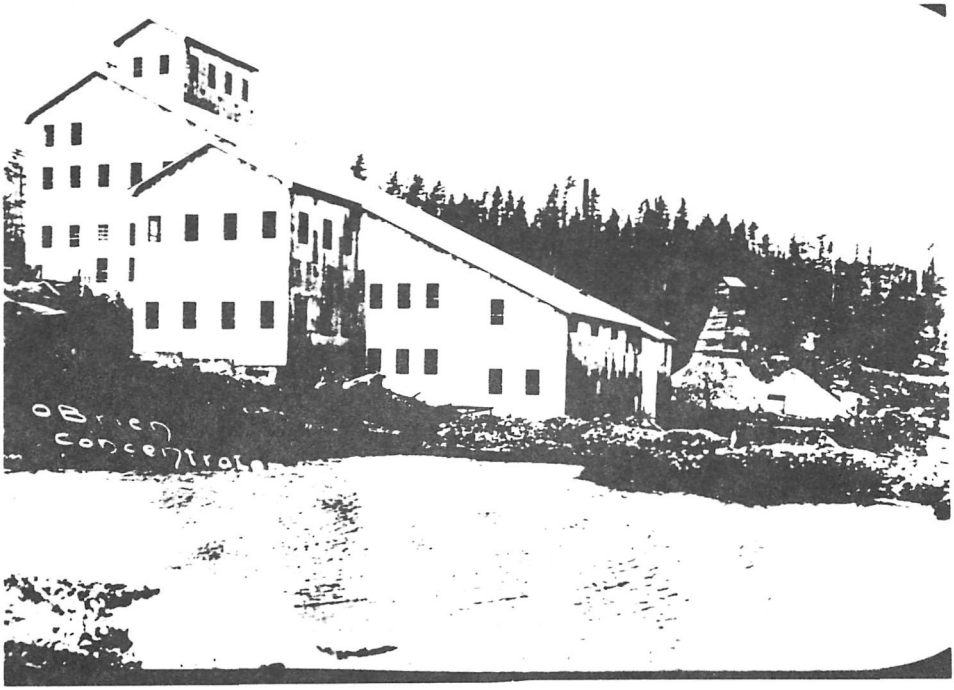
Year	Total Bullion Shipments (oz.)	Bullion from Cyanide Mills (oz.)
1910	946,000	-
1911	3,773,000	960,000
1912	5,450,000	764,000
1913	9,874,000	2,463,000
1914	9,625,000	3,848,000
1915	9,110,000	4,140,000

(Source: A.A. Cole, 'Mining Industry Report,' 1910-1916.)

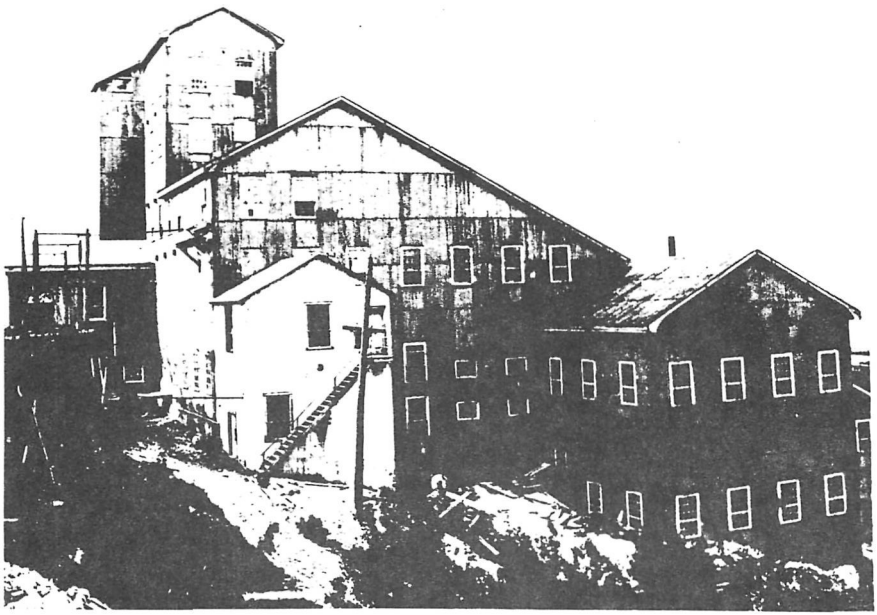
Early in 1915, changes in the character of the ore at Cobalt, and economic disturbances resulting from World War I, made changes in metallurgical treatment essential. Germany and Belgium had been the chief suppliers of cyanide and zinc dust. When the war forced a shift insupply lines to Scotland and the United States, the price of these ingredients increased by 25% and 80% respectively. To reduce costs, desulphurization was discontinued, sodium sulphide was substituted for aluminum dust, the all-cyanidation practice was cut back and several experimental flotation machines were installed.[43]

Ore flotation, like cyanidation, originated in Europe in the nineteenth century, but was not perfected until the first decade of the twentieth century. Partly due to patent problems, Cobalt mines were slower to adopt flotation methods than had been the case with cyanidation. The process was relatively simple. The ore was finely ground and mixed with different oils and chemicals in flotation cells. Compressed air was forced into the tanks from below, and as it bubbled to the surface, the metal particles which clung to the oil were brought to the top as a bubbly froth. This layer was skimmed off and separated from the watery residue. Because different metallic compounds have an affinity for specific oils, the cobalt and arsenic could also be separated. This was particularly important during the war when these minerals were in demand.

At Cobalt, the flotation process used a mixture of 15% pine oil, 75% coal tar creosote and 10% coal tar. The rapid growth of flotation soon increased the demand and thus the price of pine oil -- which was imported from the southern United States. The problem was considered of such importance that the Dominion Government suggested that the Dominion Mines and Forestry Branches pool their resources to produce pine oil in Canada, or find a suitable substitute. The federal Department of Mines



The O'Brien Concentrating Mill; old shaft house in the background. (Courtesy Noranda Mines)



First cyanide mill at O'Brien Mine, Cobalt, ca. 1916 (Courtesy Ontario Archives)

had been created in 1907 at the request of the Canadian Institute of Mining and Metallurgy, and was responsible for studying all technical and scientific problems arising from the development and treatment of Canadian minerals. Experimentation revealed that, although the production of pine oil in Canada was very expensive, several hardwood distillation products made good frothing agents.[44]

The first serious adaptation of the flotation process to Cobalt ores was initiated in the fall of 1915 by the Buffalo Mines. The following year, both the Buffalo and the McKinley-Darragh Mine erected flotation plants to treat the slime tailings from their concentration mills. The first tailings from these experimental plants contained approximately 1.5 ounces of silver per ton. As thousands of pounds of mill tailings at Cobalt had four to eight ounces of silver per ton, flotation soon became popular. The process proved so adaptable that the Coniagas mill had only to eliminate the canvas tables and send the tailings from the slime tables directly to the flotation machines. By the end of 1917, nine flotation plants were in operation at Cobalt. In that year the Bureau of Mines reported:

> Doubtless the process of flotation for the concentration of low-grade ores is one of the most important developments of modern metallurgy. It has been found adapted to the treatment of the heaps of tailings which have accumulated round the mines of Cobalt, as well as to the leaner wall and mine rock, and its effect in prolonging the life of the silver mining industry there will undoubtedly be considerable.[45]

The major problem with flotation was that its concentrates were too fine for efficient smelting at Cobalt. 'At the present time,' stated the Nipissing Mine Manager in March 1917, 'there is only one smelting concern in Canada or the United States known to the writer which will buy this product. Such a situation is disquieting, to say the least.'[46] Threatened litigation by the patent-holding Minerals Separation Company of Germany also seriously hampered the free-flow of metallurgical knowledge concerning the flotation process. Its demand for a two-and-a-half per cent royalty of the gross value of the concentrates recovered was bitterly resented, because the success of the flotation process in Cobalt was due to local enterprise.

CONCLUSION

In 1903, when silver deposits were discovered in Northern Ontario, the province, indeed the nation, lacked the hardrock expertise needed to extract the precious metal from the earth, and the metallurgical skills required to separate silver particles from the surrounding rock. In the ensuing two decades, American and European mining technology was imported to Cobalt and adapted to suit local peculiarities.[47] When American methods proved unsatisfactory, Canadians (and Americans) pioneered new extractive and milling technologies.

Before the ore had petered out in the 1920s, the camp had been the world's fourth largest silver producer. While the actual silver production was tremendous, Cobalt's greatest contribution lay in the impetus it gave to the Canadian mining industry, and the resulting development of the vast mineral resources of the Precambrian Shield. Silver was discovered at Elk Lake and Gowganda, gold was found at Porcupine, Kirkland Lake and Timmins. The financial resources and organizational talents acquired at Cobalt enabled Canadians to develop these areas. For the next half century, nearly every major discovery in Canada -- from Noranda to Eldorado to Elliott Lake -- owed its life to the skills and financial resources acquired at Cobalt. The search for the most efficient and profitable mining and milling techniques created a well-trained corps of Canadian geologists, mining engineers and metallurgists ready to tackle not only the resources throughout the northern half of the continent, but to venture to Australia, South Africa and South American mining camps.

NOTES

1. Quoted in Wallace Clement, *Hardrock Mining: Industrial Relations and Technological Changes at Inco* (Toronto, 1981), 38-9.

2. E.S. Moore, *American Influence in Canadian Mining* (Toronto, 1941), 90.

3. For example, *Canadian Mining Journal* [*CMJ*] (1974), 15; P.R. Richards *et al.*, *The Role of Innovation in the Mining Supply Industries* (Ottawa, 1976).

4. J.J. Brown, *Ideas in Exile* (Toronto, 1967), 339.

5. Philip C. Enros, 'Towards a History of Research and Development in Canada: Industrial Research in Ontario, 1900-1930.' Paper read at the CSHPS, Ottawa, 1982; Christian De Bresson, 'Have Canadians Failed to Innovate? The Brown Thesis Revisited,' *HSTC Bulletin* 6:1 (January, 1982), 10-23.

6. Brown, *op. cit.*, 173.

7. *Cobalt Nugget*, 15 March 1909.

8. Roy Longo and George Lon, *Historical Highlights of Canadian Mining* (Toronto, 1973), 73.

9. *The Engineering and Mining Journal* (24 November 1906), 968; A.A. Cole, 'Mining Practice in the Cobalt Area,' Haileybury School of Mining, 1926.

10. H.P. Davis, *The Davis Handbook of the Cobalt Silver District* (1910), 36.

11. Toronto *Globe*, 3 October 1908.

12. Frank C. Loring, 'Mining at Cobalt,' *Journal of Canadian Mining Institute* [*JCMI*] (1908), 335-6; Reginald Meeks, *The Engineering and Mining Journal* [*EMJ*] (26 January 1907), 274-5.

13 For a detailed discussion of the extractive mining techniques implemented at Cobalt see Douglas Owen Baldwin, 'Birth of Canadian Mining Expertise,' *The Northern Miner* 14 April 1977.

14. Harold A. Innis, *Settlement and the Mining Frontier* (Toronto, 1936), 329.

15. Toronto *Globe*, 3 October 1908.

16. *CMJ* (1908), 173.

17. E.T. Corkill, 'Water Powers for Working Mines,' Ontario Bureau of Mines *Annual Report* (1910), 131.

18. Temiskaming and Northern Ontario Railway, *Reports* (1905-1909); *Cobalt Nugget*, September, 1910; R.S. Sommerville, 'The Mining Industry in Relation to Development in Northern Ontario, 1911-1918,' (BA Thesis, University of Toronto, 1933).

19. *Cobalt Nugget*, September 1910; 'The Badger Mine,' pamphlet in possession of Mrs Helen Dixon, Toronto.

20. Although the idea was Taylor's, the plant was built by American engineers, and the pipes were manufactured in Germany. C.H. Taylor, 'Cobalt Hydraulic Air Compressor,' *Mines and Minerals* [Scranton, Pennsylvania] (April 1910), 532-4; 'Hydraulic Air Compression,' *ibid.* (October 1910), 129-31.

21. 'The Plant and the Equipment of the Cobalt Hydraulic Company,' *CMJ* (15 October 1909), 611-17; *Cobalt Nugget*, September, 1910; *Temiskaming Speaker*, 1 August 1963.

22. H.A. Innis, *op.cit.*, 333.

23. *Cobalt Nugget*, September, 1910.

24. *CMJ* (15 October, 1909), 611; *Cobalt Nugget*, Spetmeber, 1910.

25. A.A. Cole, *Mining Industry Report* (T. & N.O. Railway Commission, 1907), 12.

26. For a discussion of this literature see: Cyril Knight, 'Literature on Geology,' Ontario Bureau of Mines *Annual Report* (1922), Chapter V.

27. *Canadian Annual Review* (1907), 207.

28. S. and A. Young, *O'Brien* (Toronto, 1967), 110-11.

29. A.A. Cole, *Mining Industry Report* (1908), 12.

30. Butters gained his experience in the South African mines which were then the seedbed of the cyanide process. James Otto Petersen, 'The Origins of Canadian Gold Mining: The Part Played by Labour,' (PhD Dissertation, University of Toronto, 1978), 200.

31. *English Mining Journal* (7 December 1912), 1077-80; R.H. Hutchison, 'Mining and Metallurgical Practice in Treatment of Silver Ores at Cobalt,' Ontario Bureau of Mines, *Annual Report* (1922), part II, 305.

32. Ontario Department of Mines, *Twenty-Five Years of Ontario's Mining History*, Bulletin No. 83 (1933), 41-2.

33. H.P. Davis, *op. cit.*, 37.

34. *CMJ* (15 May 1908), 200.

35. *Canadian Annual Review* (1909), XXXIX.

36. A.A. Cole, *Mining Industry Report* (1911), 16.

37. Frue Vanners were developed at Silver Islet in the 1870s to meet the problems of concentrating low-grade ores by mechanized processes. See Petersen, *op. cit.*, 167.

38. D.M. Le Bourdais, *Metals and Men: The Story of Canadian Mining* (Toronto, 1957), 143-4; F.D. Reid, 'Milling Practice in Cobalt,' *JCMI* (1914), 50-8; Hutchison, 'Mining and Metallurgical Practice,' Ontario Bureau of Mines, *Annual Report* (1922), part II, 264; E.T. Corkill, 'Milling and Concentrating Methods at Cobalt,' *ibid.* (1913), Appendix IV; *Cobalt Nugget*, 10 September 1910.

39. H.P. Davis, *op. cit.*, 21.

40. Aluminum regenerated the cyanide without much loss. Hutchison, *op. cit.*, 277; Herbert A. Megraw, *Details of Cyanide Practice* (New York, 1914), 2-6.

41. James Johnston, 'The Mill and Metallurgical Practice of the Nipissing Mining Company, Cobalt, Ontario *JCMI* (1914), 64-5.

42. *Cobalt Nugget*, 10 September 1910.

43. Harold A. Innis, *op. cit.*, 337; A.A. Cole, *Mining Industry Report* (1916), 23; Department of Mines, *Twenty-five Years of Ontario's Mining History*, pp. 40-42.

44. Ontario Bureau of Mines, *Annual Report* (1917), 128.

45. Hutchison, *op. cit.*, 272; A.A. Cole, 'Concentration of Cobalt Silver Ores By Oil Flotation,' *CMJ* (15 June 1916), 301; Ontario Bureau of Mines, *Annual Report* (1917), 94.

46. R.B. Watson, 'Notes on Metallurgy at Cobalt During 1916,' *CMJ* (1 March 1917), 102.

47. John Davis, *Mining and Mineral Processing in Canada*, Royal Commission on Canada's Economic Prospects, 1957, 341-2.