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HISTORY OF COMINCO
BY R.W. DIAMOND

To Dr M. S. Hedley
With my compliments
R. W. Diamond

STORIES OF,
OR
RELATING IN SOME WAY TO THE EARLY DAYS
OF
COMINCO

BY

R. W. DIAMOND

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INTRODUCTION

A few months ago Mr. E. G. Tapp, Executive Director of the Canadian Institute of Mining and Metallurgy asked me, as one who has now retired from the mining scene, to set forth in a paper for publication in the "Bulletin" of the C.I.M.M., some of the highlights of my career in mining and metallurgy. In particular he asked for an account of the development of the treatment, by selective flotation, of the complex ore of the Sullivan mine, and another of the early development of Cominco's fertilizer industry, with both of which developments I was closely associated.

I agreed but soon realized that I wanted to tell a much more comprehensive story than he had asked for, and one that in all probability would be much too long for publication as proposed. I then decided to tell the story I wanted to and from it Mr. Tapp could choose what he wanted for publication. I proceeded on that basis and the following paper is the outcome of that plan.

I first give an outline of the early history of the Company and then tell briefly of my introduction to mining and particularly of my introduction to, and my training in, froth flotation prior to my coming to Trail in 1917. I then give an account of the development of the Sullivan ore flotation treatment particularly between the years 1917 and 1923. That story had never been told until 1961, when I delivered a paper before the A.I.M.E. at their Denver meeting. It was published in the July 1961 issue of the "Quarterly of The Colorado School of Mines". However, because distribution of that publication is limited, and particularly so in Canada, I give herein, what is, in effect, a condensed version of that paper.

I then outline the steps leading up to the establishment of Cominco's fertilizer industry but I do not describe the initial plant because that has already been done in C.I.M.M. publications.

I then outline another major development that took place during those early years because of increased metal production following flotation. While I was in no way associated with it at that time, it is of such importance that it should be mentioned here. I refer to the fuming of lead blast furnace slag.

I do not refer in any way to the major expansion problems, and programs, of the power plants, the Sullivan mine, the smelter (except slag fuming), the zinc plant and the refineries, to make possible the increase in metal production after flotation.

There were of course many other important developments of a special nature between 1919 and 1945, but none of the importance of the three referred to above.

I conclude with observations relating to certain special developments during the years 1939 - 1945, which period includes not only the war years, but the final years of the "Blaylock Era". And I comment upon the men who, throughout the early years, contributed to the Company's progress, and who at all times maintained a happy dynamic atmosphere.

PART I

An Outline of the Early History of The Consolidated Mining and Smelting Company of Canada Limited (now Cominco Ltd.) and of Related Matters

For properly viewing the early history of Cominco one must start with Rossland, with the discovery of the gold-copper ore there and the staking of the Centre Star, War Eagle and LeRoi claims in 1890. It then appeared, and from 1895 it seemed certain that Rossland was to become a great mining camp. For a general account of those early days I shall quote from an article by Prof. John M. Turnbull* which appeared in the March 1963 issue of "The Western Miner and Oil Review" entitled "Rossland, Trail and Early Railroad Competition".

"The historical importance of Rossland can best be understood by setting it against the background of the advance of mineral development in North America from east to west. Advance came in a series of waves, mostly triggered by discoveries of large mineral wealth, coal and oil in Pennsylvania, iron and copper mines around Lake Superior, gold in California and Colorado, and not least, the vast copper deposits of Butte, Montana. All of these had shown their tremendous effects on national life and on the establishment of life lines of communication, roads, railways and telegraphs..

......................By the year 1895 Rossland ore bodies, both large and rich, gave notice to the world that here, at last, the long overdue Eldorado had been discovered. The consequent flood of intense prospecting, excitement, discovery and development, kindled by the success of Rossland spread quickly..

................F. A. Heinze of Butte.................was the first to effectively react to this opportunity. He constructed a smelter at Trail and a rail line from Rossland to Trail in 1896..........................

...................The feature of Heinze's operation which concerns this

*Prof. Turnbull was born in 1877, was office boy in 1890 for Lord Mount Stephen, the first President of The Canadian Pacific Railway. He graduated from McGill in Mining Engineering in 1897 and a few months later was assayer at the North Star Mine directly across the valley from the Sullivan and above the Stemwinder. He joined the C.P.R. under W. H. Aldridge in Trail in 1902 for coal and metal exploration. He continued with them, and later with Cominco until 1915 when he was appointed Head of the Department of Mining Engineering at The University of British Columbia. He is now retired and resides in the City of Vancouver.

history most, was his foresight in obtaining a railway charter for Western extension ....This blocked the C.P.R. objectives in extending its lines in Southern B. C.

"Battles of the railroad giants have been major features in North American history. In Southern B. C. the opponents were The Canadian Pacific and The Great Northern railways...............Around 1895 The Great Northern had a seasoned main line running east and west, roughly parallel to, and about one hundred miles south of the International boundary. In Montana it connected with............the large copper and lead smelters at Anaconda and East Helena (respectively), and on the Pacific end, with the smelter at Tacoma............. In the centre was the city of Spokane.

"The East West main lines of both railroads............climbed over high mountain ranges, but (also) crossed north and south valleys......(which) ....offered natural easy railway grades for branch lines to the (then known) mineral areas..........................(The Great Northern)....... ....connection reached Rossland by a short branch line........from Northport, Wash. in December 1896.(thus providing a convenient outlet for Rossland ores to U.S. smelters)...............The route (of the C.P.R. in 1895)...........was far north of the (then known) mineral resources. ....(To serve them)..........their most obvious move......was ....to build an easier grade railway line through the bituminous coal fields of the Crowsnest Pass further to the south and west across Southern B. C. Prior to this main job (however)..................short lines (to the south from the main line were)..................linked (to the mineral areas) by river steamers on the Arrow, Slocan and Kootenay lakes. (The Crowsnest Pass)...............railway construction reached Cranbrook in September 1898 and Kootenay lake a year later............. In the meantime, Heinze's prior railway charter, plus the growth of Rossland, and the prospect of great ore tonnage in the Boundary country, further west, combined to pose an urgent problem for the C.P.R., to reach and serve....................this..........explosively expanding mining industry...................."

It should be understood that while the C.P.R. had entered into the Crownest Pass agreement with the Federal government in 1897 contemplating a line for their "British Columbia Southern Railway Company" from Lethbridge, Alberta to Nelson, B. C., Heinze's charter contemplated a line from the Trail-Rossland area to Penticton by his "Columbia and Western Railway Company", with branch lines to adjacent mines. Moreover Heinze had already built a line from Trail to Robson as well as his line from Rossland to Trail.

Obviously something had to be done. To help in dealing with Heinze, Sir William Van Horne, the C.P.R.'s second president, was able at that time to secure the services of a capable and experienced young metallurgical engineer who had graduated from The School of Mines of Columbia University in the same class as Heinze. This man was Walter Hull Aldridge. The objective in their negotiations was of course the acquisition of all of Heinze's holdings in B. C. and particularly his railway line and charter.

Aldridge, working under T. G. Shaughnessy (later Lord Shaughnessy and the C.P.R.'s third president) played a most important part in these negotiations and showed himself to be both a clever man and an able strategist. The outcome was that the C.P.R. gained possession of Heinze's "B. C. Smelting and Refining Company" works at Trail, his railway charter and all of his railway holdings. However Heinze retained one half of a certain portion of the provincial land subsidy (approximately 300,000 acres). The total purchase price was approximately $800,000 of which $200,000 was for the Trail plant. Aldridge became Manager of Western Mining Operations 1st March 1898 and the smelting company was renamed "The Canadian Smelting Works".

Not only did this dispose of Heinze as a competitor, but it put the C.P.R. in a much stronger position in its competition with The Great Northern Railway.

Soon after, Aldridge was successful in arranging for a lead bounty from Ottawa to facilitate the smelting of lead ores in Canada. In 1901 he installed a lead furnace in the Trail plant for the smelting of customs lead silver ores. In 1902 he installed the world's first Betts electrolytic lead refinery of about 20 tons daily capacity. In 1904 he installed a gold and silver refinery for the treatment of lead refinery slimes.

As early as 1903, it appears that he had concluded that, to be successful in the smelting business, you had also to be in the mining business in order to insure the continuity of ore supply. To bring this about Edward Beatty of the Legal Department of the C.P.R. (later Sir Edward) and Aldridge opened negotiations for the purchase of the three principal Rossland mines in 1904 and of the St. Eugene, a lead silver mine at Moyie, in the East Kootenay somewhat later. Anticipating success R. H. (Pat) Stewart was engaged to be in charge of the Rossland properties. Mine valuation reports for the C.P.R. were prepared by Dr. R. W. Brock of the Dominion Geological Survey, R. H. Stewart and J. M. Turnbull. Negotiations that followed were successful in the cases of the Centre Star, War Eagle and St. Eugene mines but not of the Le Roi. Consolidation of the three mines acquired, the Trail smelter and The Rossland Power Company then followed. Aldridge was appointed Managing Director of the new company which was called "The Consolidated Mining and Smelting Company of Canada Limited". In this the C.P.R. held a 54.3% interest. Notice of consolidation to the shareholders was dated 26th February 1906. W. D. Matthews of Toronto, President of The Dominion Bank of Canada, was the new company's first president.

The senior staff as recorded by Aldridge in the Company report for the first six months' operations and dated 5th October 1906 was as follows:

R. H. Stewart	-	Manager of Mines
Jules Labarthe	-	Manager, Smelter & Refineries
Wm. Chambers	-	Smelter Superintendent
S. G. Blaylock	-	Metallurgist
J. F. Miller	-	Refinery Superintendent
R. Purcell	-	Superintendent, Centre Star Mines
W. P. White	-	Superintendent, St. Eugene
T. W. Bingay	-	Comptroller
J. M. Turnbull	-	Mining Engineer

The scale of operations of the three mines and of the smelter at that time was very modest from present day viewpoints. The Centre Star and War Eagle together were producing about 500 tons of ore daily, all of which was going direct to the smelter. The output of the St. Eugene was about the same but it was being milled at the mine site. Then there was some customs ore.

The output of the Trail plant in 1905 had been:

Silver	1,360,000 ounces	
Gold (largely in copper matte)	82,644 ounces	
Copper (as matte)	2,286 tons or	6¼ tons per day
Lead (refined)	6,691 tons or	18½ tons per day

The ore reserves of the two Rossland mines were reported as being approximately 150,000 tons and of the St. Eugene about the same. The gross value per ton of Rossland ore was about $10 and of the St. Eugene about $15. The principal assets of The Rossland Power Company were 86 acres of land and certain water rights on Murphy creek. There was no operating power plant.

Rossland operations continued without much change for the next four years. In 1911 the Company acquired the Le Roi mine. During the years 1914-1915 the output of Company mines in Rossland reached a total of about 800 tons daily but the grade was falling off. In the succeeding years the tonnage declined gradually until by 1920 it was down to about 250 tons daily. The mines were then showing signs of depletion and soon they were in a state of clean-up. There were no shipments after 1928.

The total tonnage of ore produced from all Company mines in Rossland (which comprized the great bulk of all tonnages) from commencement in 1894 until shut down in 1928 (which included that prior to Cominco acquisition) was approximately 6,000,000 tons. It was a sad ending to what, just thirty years before, had promised to be one of the great mining areas of the world.*

The St. Eugene outcrop at Moyie lake had been known to the Indians of the St. Eugene Mission, a few miles north of Cranbrook, for many years. About 1893, Father Coccola of the Mission disclosed its location to a good friend, James Cronin, who staked and developed the claims. When the Crowsnest Pass railway was completed through to Kootenay Lake in 1899, it passed right by the mine. With this facility and a gravity mill which was then installed, the operation developed very successfully. As already implied this property was looked upon with great favour at the time of consolidation in 1906.

*A most interesting account of the early days of Rossland and Trail is given in the book entitled "Rossland, the Golden City" published by "The Rossland Miner" in 1949 and written by Lance H. Whittaker, then editor and publisher.

This situation continued and reports for the years ending 30th June 1907 and 1908 were optimistic. However, late in 1908 and throughout 1909 development work proved most disappointing and there was a serious falling off in ore reserves. In the following year no new ore whatever was found and by the middle of 1910 ore reserves were nearing exhaustion. The mine was virtually closed down in 1912.

During its life, the St. Eugene had produced approximately one million tons of ore containing 115,000 tons of lead and 5,365,000 ounces of silver. That too was a sad ending, after but ten years' operation, to what had been a promising mine.

It should now be borne in mind that the St. Eugene had been the principal source of silver lead ore for the Trail smelter for several years and this development at the mine in 1909 was cause for great concern. A new source of lead ore had to be found.

Turnbull's duties at that time included watching ore reserves as insurance for smelter operations and he says in his article "The Kimberley Story" which appeared in the October 1963 issue of The Western Mines and Oil Review:

> "In 1908 it became obvious that the St. Eugene was in trouble. I suggested the Sullivan at that time to Mr. Aldridge as a future possibility..........However none of us then really foresaw the suddenness of the St. Eugene collapse, nor the tough going in the lead business..........in the next few years."

The Sullivan mine is located in the eastern foothills of the Purcell Range of eastern British Columbia about 50 miles north of the 49th parallel and 40 miles by road from Moyie. The discovery was made in 1892. Four claims were staked, of which one was abandoned. The remaining three, the Hamlet, Shylock and Hope, constituted the original Sullivan group. The outcrop was not impressive as the ore body near the surface is relatively thin and contained a high proportion of zinc, which at that time was not considered valuable. Schofield in 1915 recognized the deposit as a bedded replacement in the Aldridge argillaceous quartzite formation of the Pre-Cambrian age.

But little work was done on the property until 1899. In that year with the North Star, the Stemwinder and the Sullivan Mines in sight, the C.P.R. built the Kimberley branch to connect with the Crowsnest main line at Cranbrook, a distance of 19 miles. This afforded an outlet for the Sullivan ore by rail. The first shipments from the Sullivan were made in 1900, and in the three years following about 4,500 tons of 35 - 40% lead ore, containing about 15 ozs. of silver per ton, were shipped to the Hall Mines' smelter at Nelson and the Trail smelter.

By 1903, 300,000 tons of ore, then thought suitable for smelting, had been developed by the owners, The Sullivan Mining Company, and construction of a small smelter at nearby Marysville was commenced. The Federal Mining and Smelting Company, a subsidiary of The American Smelting and Refining Company, had a financial interest in The Sullivan Mining Company. Many metallurgical difficulties were encountered in the smelter, primarily due to the high zinc in the ore, and both mine and smelter were closed down in 1907. Early in 1909 The Sullivan Mining Company encountered serious financial trouble, and to deal with this situation a new company, The Fort Steele Mining and Smelting Company was formed and acquired the property on the 19th July 1909. The total of all stock issued, both common and preferred, was slightly less than one million shares. The Federal Mining and Smelting Company held just under 60% interest. The "Federal" Company then had the property thoroughly considered by a group of eminent mining and metallurgical engineers, all of whom agreed that it would be unwise to spend more money on it because of the high proportion of zinc and the fine grained association of the lead, zinc and iron minerals in the ore, which as of that day, presented insurmountable problems. It was therefore decided to dispose of their interest and an option at 20 cents per share to expire 15th December 1909 was given to Senator George Turner* of Spokane, who represented the minority interests. Turner was unable to arrange financing to exercise his option and then approached Cominco to interest them in it. However, Aldridge was not interested because it did not provide enough time to examine the property thoroughly.

You will recall that it was about this time that Cominco was most concerned about the St. Eugene situation, and that Turnbull had suggested the Sullivan as a possible alternative source of lead ore. It was a fortunate coincidence therefore that it became available, on some terms, at this time. With that in mind, Aldridge went to New York and negotiated directly with Messrs. Newhouse, Eilers and Brush, top officers of The American Smelting and Refining Company. He succeeded in getting an option, subject to Turner's option, but running until 1st June 1911. Coupled with it was a lease, on a 20% royalty basis, with a minimum royalty of 50 cents per ton, which permitted Cominco to remove 30,000 tons of ore. The only firm commitment of Cominco was to spend $10,000 on development.

Selwyn G. Blaylock, who had graduated from McGill in engineering in 1899, had gone directly to Trail, and soon became Chief Chemist. When Cominco was formed in 1906, he was made Metallurgist. Immediately after however, in response to a request from the Bank of Montreal for help in winding up the affairs of The Hall Mines Smelter in Nelson, he was loaned to them by Aldridge, to take over that operation. It appears that he did an outstanding job there but the plant was forced to close down in September 1907. Shortly afterwards he returned to Cominco and was given the job of superintendent of the St. Eugene, his first mining and milling assignment. Again the record shows that he did a splendid job, but within a year, the unfavourable turn of events in regard to development took place.

* Senator Turner had played an important part in early LeRoi mine affairs.

It was then that the Sullivan mine was optioned by Cominco. Because of the close proximity of the St. Eugene and Sullivan properties Blaylock was made superintendent of both.

Late in 1910, development work at the Sullivan having been encouraging, Cominco exercized its option, the Turner option having expired. It thus acquired an approximate 60% interest in The Fort Steel Mining and Smelting Company. The remaining shareholders, both common and preferred, were then approached and most of their shares were acquired at the same price of 20 cents per share. In a few cases, a somewhat higher price was paid. In all, complete ownership of the Sullivan property, which as explained, then comprised but three claims, was acquired for approximately $200,000. Before exercising the option Cominco had staked what appeared to be all of the promising adjoining ground.

In entering into the option agreement, Aldridge had been largely influenced by recommendations of three men in particular, R. H. Stewart, Manager of Mines, S. G. Blaylock, Superintendent of the St. Eugene and J. M. Turnbull, Mining Engineer.

In granting the option on its interest in The Fort Steel Mining and Smelting Company, it appears that The Federal Mining and Smelting Company had concluded that because of the Trail smelter's facilities, its location and the siliceous nature of its furnace charge, it might be able to operate the mine profitably, when neither they, nor anyone else could. Moreover it appears that they were not aware of the situation at the St. Eugene at that time, nor of the threat that this constituted to the lead smelting and refining operations at Trail. In spite of this, one might wonder why the "Federal" Company would enter into such an agreement. It must be remembered, however, that the Sullivan mine had been known of, and not favourably, for almost twenty years. Moreover Cominco had never shown any interest in it, at least as far as the "Federal" Company knew, until Senator Turner had approached them in regard to his option.

Moreover, no one dreamed for one moment at that time that the mine would develop as it did, even in the years immediately ahead, let alone its development of 10 or 20 years hence.

It seems to me that the most reasonable explanation of the failure of The Sullivan Mining Company to make a success of their smelting operation and of the mine is that they did not adopt the highly selective mining and hand sorting methods later adopted by Cominco. Certainly with the Federal Mining and Smelting Company and The American Smelting and Refining Company back of them, the Sullivan Mining Company had plenty of lead smelting "know-how".

The American Smelting and Refining Company's and the "Federal" Company's side of this story is told in the book entitled "Metal Magic" by I. F. Marcosson, published by Farrar, Straus & Co., New York City in 1949.

It is of interest to know that Angus Davis, a well and favourably known B. C. mining engineer of those days, who had worked for both St. Eugene and Cominco, said in his memoirs:

> "And as for the Sullivan, it was a tough looking proposition as far as shipping ore was concerned, and even with a railroad in the vicinity nobody got very excited about it."

He went on to imply that it was because of the developments at the St. Eugene that the Sullivan was optioned.

And Turnbull in his article of October 1963 already referred to says:

"It was developments at the St. Eugene that led to the acquisition of the Sullivan."

And he goes on to say:

"At the start of operations Blaylock was faced with the immediate and insistent demand from the Trail smelter to make up for the St. Eugene shortage. Ore of 1910 shipping quality, even with sorting, only occurred in the Sullivan in local streaks and pods. Systematic development was secondary, and "hunting and gouging" was the compulsory early method of mining.

"However it was a touch and go race most of the time and at one stage the ore reserve figure for the mine was officially reported at 10,000 tons. The deadline in those days for shipments to Trail was 20% lead, not to mention the disadvantage of the high zinc penalty, as compared with the old clean 50% St. Eugene lots."

In spite of this, the mine managed to ship 23,000 tons in 1910.

Earlier herein I referred to The Hall Mines smelter in Nelson and The Great Northern Railway (and U.S. smelters) as competitors of the Trail plant for the customs ores of the district. I shall now explain this situation somewhat more fully.

The Bluebell mine, on the north-east shore of Kootenay lake is the oldest lead mine in the district, having been first reported about 1830 by The Hudson's Bay Company. It then lay dormant for many years but came into prominence again briefly in the mid 1860's, again in the late 1870's and still again in the mid 1890's. Between 1908 and 1931 (when Cominco acquired the property) intermittent operations took place and concentrate was shipped.

About 1883 lead silver claims were staked across the lake from the Bluebell at Ainsworth and in the years following some ore and concentrate were produced from that area.

Late in 1886 a spectacular discovery of copper-silver ore (bornite and grey copper) was made by the Hall brothers of Colville, Wash. on Toad Mountain, about 4½ miles south of what was, because of it, to become the City of Nelson. Four claims were staked, the Silver King, the Kootenai Bonanza, the American Flag, and the Koh-i-noor, only the first two of which were important. In 1893, The Hall MinesCo. (an English company) purchased all four claims for approximately one million dollars. Shipments from the property to the smelter a few years later averaged about 3% copper and 40 ozs. silver per ton.

The "Poorman" property (gold) just west of Nelson was discovered in the late 1880's also and a stamp mill was installed there in 1889.

Many other claims were staked and small mines developed in the surrounding country which includes the Ymir area. Altogether the prospects at that time of the district becoming an important producer were bright.

In the fall of 1891 the Slocan country at the north-west end of Kootenay Lake and west to the Slocan Lake came into great prominence as a producer of high grade lead silver ores, the original discovery being that of the Payne mine. The Town of Kaslo thus came into being. A great many discoveries were made and mines brought into production throughout this area.

In 1895 The Hall Mines Company built a smelter in Nelson primarily for the treatment of its own ores. It was "blown in" in January 1896. In 1897 it installed a lead furnace for smelting of customs ores.

Throughout the 1890's and until about 1910 the Great Northern Railway operated steamers on Kootenay Lake for the purpose, among other things, of capturing customs ores for shipment to U.S. smelters. Initially, they transported the ore up the Kootenay River to rail connection at Bonners Ferry but in 1893 they installed a branch line to Nelson with dock facilities there and another branch line from Bonners Ferry to Kuskanook on the south end of Kootenay Lake.

In 1897, LeRoi mine interests built a smelter in Northport, Washington for the LeRoi ore and for those customs ores from Rossland and elsewhere that they could capture.

It will thus be seen that throughout the early years the Trail plant was faced with keen competition from all sides for customs ores.

It is sad to relate that all of the mining areas above referred to, except the Bluebell had histories somewhat similar to those of Rossland or the St. Eugene. In particular the Nelson mines were short lived. On the other hand the Slocan was active for many years, then declined but remained a producer of sorts into the 1930's, and again somewhat later.

After but a few years' operations, both the Hall Mines and Northport smelters were closed down and dismantled and in due course The Great Northern withdrew its steamers from the lakes.

Aldridge left Cominco at the beginning of 1911 to assemble into a cohesive unit the numerous Thompson mining properties in the U.S. Then in 1918 he was appointed President of The Texas Gulf Sulphur Company. After a distinguished career he died at his home in New York City in August 1959 at the age of 91.

His departure from Cominco constituted the end of an era. He had played a most important role in the acquisition of the Trail smelter by the C.P.R. in 1898. He had been largely responsible for the formation of the Company in 1906 and he had been largely responsible for the acquisition by the Company of the Sullivan mine in 1910. Certainly Cominco had many problems ahead, but Aldridge had laid a broad and firm foundation for a great structure and pointed out the path to follow. Moreover, throughout his twelve years in the Kootenays, he had proven to be not only an able engineer and administrator but to have commanded the regard and admiration of all of his associates and inspired the complete loyalty of his staff.

Following Aldridge's departure, Stewart was made General Manager and Blaylock Assistant General Manager. C. H. MacDougall followed Blaylock as Superintendent of the St. Eugene and Sullivan properties.

For the next few years efforts at the Sullivan were aimed at discovering ore sufficiently high in lead and silver and low enough in zinc to be smelted with the equipment available at Trail. A considerable measure of success was achieved. The annual output increased from 23,000 tons in 1910 to 44,650 tons in 1915. During this time development work had proven most rewarding and it became certain that the Sullivan contained a large tonnage of refractory ore. During the same period a great deal of adjoining ground was staked. I shall not give an account of subsequent developments that established the Sullivan as one of the really great mines of the world. I shall instead consider the treatment of the ore and certain related developments.

Soon after the option on the Sullivan was exercised an aggressive program of test work was commenced, aimed at successful milling of the ore or its metallurgical treatment, by other than blast furnace smelting. The milling and pyrometallurgical work was most disappointing, but some encouragement was encountered from roasting and leaching tests.

About this time, the electrolytic zinc process patented by A. G. French, and controlled by "French's Complex Ore Reduction Co. of Canada Ltd." was being widely discussed, and an option was taken on it 31st May 1912. This process was thoroughly investigated but it was found to offer no advantages over other similar methods and the option was terminated 26th January 1915. As Cominco's interest in the French process lessened, its interest in electrolytic zinc in general had increased. Studies were therefore continued, concentrating on the use of sulphuric acid alone as a leaching agent. F. W. (Bill) Guernsey had been, and continued for a short time in charge of this experimental electrolytic zinc work.

In 1914, a one ton test plant was built and from it a few carloads of high grade zinc were produced and marketed in 1915. This work was of course spurred on by the outbreak of war and by the shortage of zinc that then developed in Britain for munitions purposes.

Early in 1915, a contract was entered into between the Company and the Imperial Munitions Board for the output of a proposed 35 ton per day plant. Construction was commenced in the late summer of 1915 and completed a year later. As was to be expected from a new complex chemical-metallurgical process such as this, working on a refractory ore, many "birth pangs" and "growing pains" were experienced but 1,500 tons of high grade zinc were produced before September 1916 and about 10,000 in the following 12 months. Many of the troubles experienced were directly attributable to the fact that the Company was forced to operate on crude ore with a very high iron content and a zinc content of no more than 24%.

I shall resume consideration of the Trail zinc plant and its problems in PartIII of this paper.

The Anaconda Copper Mining Company had first considered development of a process for the reduction of zinc ore by the electrolytic zinc process in December 1914. Their early testing was at Anaconda and on crude ore but soon they swung to flotation concentrate, which, compared with Sullivan ore, was very low in iron and high in zinc. A few months later they built a one ton plant which operated satisfactorily and on 10th June 1915 they decided to build a ten ton per day plant. Commercial production commenced November of that year. Very soon after this plant was enlarged to 25 tons. Meanwhile a 100 ton plant was being built by them at Great Falls, Montana.

It will thus be seen that while Cominco had commenced electrolytic zinc studies in 1912, had produced some zinc in 1914 and commenced commercial production in the summer of 1916, the Anaconda Company hadn't started until late 1914 but were in commercial production in late 1915. It should be borne in mind however that the Anaconda Company's problem was relatively simple compared with that of Cominco because of the nature of the feed to their respective plants.

In retrospect it is interesting to realize that these two developments were carried on relatively simultaneously but quite independently until about 1917 or 1918 when close collaboration was established between the two companies. Moreover it should be understood that the Cominco and Anaconda plants were the first two commercial electrolytic zinc plants in the world.

The present day electrolytic zinc process is very similar to that patented by Léon Létrange in Paris, France in 1881 and 1883. He proposed roasting zinc blende to make the zinc soluble in water, or sulphuric acid, thus obtaining a sulphate solution. This he electrolyzed for the precipitation of zinc using anodes of lead or carbon, and zinc, copper or brass cathodes. Nothing of a major nature was done towards the development of his process for several years. However in the mid-1890's E. A. Ashcroft carried on similar experiments on Broken Hill products in Australia and in 1898 built a zinc plant rated at 10 tons per day at Cockle Creek, New South Wales. While he made some zinc he encountered many serious difficulties and the plant was soon closed down. Cowper-Coles similarly tried to apply the process in a pilot plant in England about the same time but failed. For several years before the turn of the century the Siemens-Halske Company in Germany had tried to develop the Letrange process without success and their efforts were continued into the early years of this century.

U. C. Tainton, C. A. Hansen and others conducted studies and took out patents. A complete bibliography of all early work was prepared and published by H. L. Wheeler of The MissouriSchool of Mines in 1919.

I have already given the approximate production figures of the Trail plant at the time of consolidation in 1906. By 1910 these had reached their peak to that time with full operation in Rossland, normal tonnage of concentrate still coming from the St. Eugene, additional tonnage from the Sullivan and an appreciable tonnage of customs ores. The output of the Trail plant in that year was as follows:

Silver	2,162,406 ounces
Gold (largely in copper matte)	137,614 ounces
Copper (as matte)	2,987 tons or 9.2 tons/day
Lead (refined)	21,184 " " 58 " "

Note that the lead refinery had been increased in capacity in 1906.

In 1911 and 1912 smelter production fell off seriously in both lead and copper to about 55 - 60% of the 1910 figures. It then crept up slowly toward the 1910 figures.

Altogether the years 1911 through 1918 were difficult ones. The collapse of the St. Eugene, the continuing struggle at the Sullivan for lead ore of smelting grade, the falling off in grade of Rossland ore, the starting up troubles of the zinc plant and war time conditions generally, all had contributed to this situation. Stewart had taken charge early in 1911 as General Manager but in the middle of 1915 J. J. Warren had been appointed Managing Director. He moved to Trail and immediately assumed active control. Stewart resigned early in 1917 and opened a consulting office in Vancouver.

The West Kootenay Power and Light Company was incorporated on 8th May 1897 primarily to supply power to the Rossland mines and the Trail smelter. Sir

Charles Ross was the Company's first President and L. A. Campbell was its first General Manager (and later President). Construction of the first power plant at Lower Bonnington Falls on the Kootenay River, of a capacity of 4,000 H.P., was completed in 1898. In order to keep pace with the demand, No. 2 plant at Upper Bonnington with a capacity of 34,000 H.P. was completed in 1907. The next expansion was in 1923. However, it is not my purpose to record the power developments at this time. I do however want to record that all of the common stock of the West Kootenay Power and Light Company was purchased by Cominco in 1916 and subsequent to that time and up to the present, while title to most of the power plants has been held by Cominco, operation and power distribution have been the responsibility of the West Kootenay Power and Light Company under a management contract.

The average annual net profit of Cominco from 1906 through 1912 was approximately $300,000. From 1913 through 1915 it was about $750,000 and from 1916 through 1919 it averaged close to $1,000,000 with but moderate variations from these averages throughout. However, in 1920 it fell off to $40,326 and in 1921 it was $338,447. It then began to increase rapidly.

During this same overall period relevant metal prices were as follows:

	High Grade Zinc N. Y. ¢/lb.	N. Y. Lead ¢/lb.	Elec. Copper N. Y. ¢/lb.	Silver N. Y. ¢/oz.
Average 1908-1914 incl.	-	-	13.9*	-
" 1906-1915 "	-	4.6*	-	56.8*
1915	-	-	17.5	-
1916	22.2	6.8	28.5	65.6
1917	14.5	8.7	29.2	81.4
1918	11.75	7.5	24.7	96.8
1919	8.1	5.8	18.9	111.1
1920	9.0	8.1	17.5	100.8
1921	6.8	4.5	12.6	62.7
1922	6.7	5.7	13.7	67.6
1923	8.6	7.2	14.6	64.9
1924	8.3	8.1	13.2	66.8

(Source: Amm-Metal Statistics 1925)

* With only moderate annual variations therefrom.

Early in 1919, Mr. Matthews, President of the Company, died and was succeeded by Mr. Warren, who then moved to Toronto. Mr. Blaylock was made General Manager and senior officer in the West. It was then that the "Blaylock Era" began. The senior staff members under him at that time as they appear in the annual report for 1918 were:

T. W. Bingay	Comptroller
W. M. Archibald	Manager of Mines
E. G. Montgomery	Superintendent, Sullivan Mine
James Buchanan	Smelter Superintendent
G. E. Murray	Assistant Smelter Superintendent
B. A. Stimmel	Zinc Plant Superintendent
F. E. Beasley	Refinery Superintendent
R. W. Diamond	Superintendent of Concentration and Testing
G. F. Chapman	Construction Engineer
E. M. Stiles	Chief Draftsman

All of these men (except Beasley who died shortly after) contributed in important ways to the progress of the Company in the years following.

This concludes my account of the early history of Cominco and of related matters.

PART II

An Account of my Introduction to Mining and Particularly to Flotation, which in Due Course Led up to my Long Service with Cominco

My introduction to mining was certainly a strange one. After graduation from high school in the little town of Campbellford, Ontario, in 1908, I decided to work for a year before entering college. By chance I got a job as office boy and "handy man" around a small gold and silver refinery in a broken down factory building, on a back street, in downtown Toronto. We dealt in precious metals through many channels. We made gold and silver in all forms and grades for manufacturing jewellers; gold foil, gold cylinders and silver alloy for dentists, and gold leaf for sign writers. We bought manufacturing jewellers' and dentists' "scraps" and "sweeps"; old jewellery from pawn brokers, and precious metal buttons from divers sources. It is the only place I have ever seen gold beaters at work. One of my jobs was to weigh in certain "parcels" or "lots" of ore brought in personally by one or more individuals. These lots weighed anywhere from a few pounds up to perhaps 100 pounds. They all had a high native silver content, and some pieces of ore were almost massive silver. Occasionally there was a lot of "leaf" silver. I was of course intrigued by this ore, and the men who brought it in, but, being just a seventeen year old naïve youngster, knowing nothing whatever about mining, I believed what I was told by the men themselves, and what was accepted as the situation by others there - that these men were prospectors from around Cobalt, and that this was their own ore. In dealing with them, everything appeared to be done quite openly. One morning I came to work and found that the police had moved in, that my employer was in custody and that the rounding up of the men, whom we then learned were "high-graders", was under way. In due course the courts released my employer with a warning but the high-graders were sent to Kingston Penitentiary.

I had found all of my work at the refinery so interesting that I decided to embark on a career in mining and metallurgy. I entered the University of Toronto in the fall of 1909. Dean Galbraith was "Head" of the Faculty of Engineering then, H.E.T. Haultain was "Head" of the Mining Department and George Guess was to start the Metallurgical Department about two years later.

The following summer I was with a prospecting party on the East Branch of the Montreal River in Northern Ontario.

After my second year at college I worked on the converter floor at the Copper Cliff smelter, part of the time "punching" tuyeres. They were still using "ganister" or "acid" lining in small converter shells, but on one stand they had a large experimental basic lined Pierce Smith converter. Basic lining of course, became general practise at Copper Cliff, and in copper smelters around the world, soon after. A.P. Turner was President of The Canadian Copper Company then (the predecessor of The International Nickel Company), John L. Agnew was General Manager and Donald McAskill was Smelter Superintendent. I recall that the labour rate was 16.5¢ per hour, 11 hour day shifts, 13 hour night shifts, 17 and 19 hour change shifts, and seven days a week.

After my third year at college, in the spring of 1912, having just been impressed with the fact that the State of Montana was a very large copper producer, I decided to go there for the summer. At Anaconda I rustled at the smelter gate for a few weeks, getting the odd shift's

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work in the plant, before getting an engineering job on the water supply system. While rustling, I worked a number of shifts in the mill. I mention this because it was one of the old style gravity mills, and a large one. It was equipped with hand fed jaw crushers, two stage low speed rolls, trommels of all sizes, Hartz jigs, Wilfley tables, Chilean mills and Frue vanners for the slimes. Bucket elevators were used throughout and practically every piece of equipment was belt driven from long line shafts. As I recall there were no conveyor belts whatever. I went back to college that fall with the promise of a job at Anaconda the following spring.

I was married right after graduation in the spring of 1913 and my wife and I went straight to Anaconda where I started in the Testing Department at $90.00 per month, working with about 40 other young engineers. On that job you might be working anywhere in the plant on furnace work, gas work, mill work, whatnot, or you might be working in the laboratories. All work however was of an experimental nature.

Late in May 1914, Frederick Laist, then Manager at Anaconda (and later to become Vice President of Anaconda in New York in charge of all metallurgical operations), and Albert Wiggin, Superintendent of Concentration called me to the office and told me I was to be in charge of experimental work they proposed undertaking, using a new ore concentration process. This was froth flotation. There were very few mills anywhere in the world using it at that time, and most of them were in the Broken Hill area in Australia where the process had been developed. However one of those in the Americas was the Butte and Superior Mill in Butte, using the "Hyde" process. Mr. Laist had made arrangements for me to spend two or three weeks there to learn something about laboratory flotation testing. On the 1st June 1914

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I accompanied him and Mr. Wiggin on a trip through the plant and my experience there in the days that immediately followed was a memorable one.

I then worked with Geo. Chapman (a pioneer in flotation in Australia) of The Minerals Separation North American Corporation, who was stationed in Anaconda for a few weeks. E.H. Nutter was Chief Engineer, and Head of the Minerals Separation Corporation in San Francisco at that time.

I next worked with J.M. Callow in his Salt Lake City General Engineering Company laboratories and again with him at the Inspiration Test Mill in Miami, Arizona, for a few weeks on the experimental Callow pneumatic flotation cell installation there. Marcy, Hardinge, Greniger, of the Minerals Separation Corporation, the Deister brothers, and others with their then modern pieces of equipment were there also. I was with Mr. Callow in Miami in August 1914 when the First World War was declared.

It was not long before Anaconda decided in favour of, and entered into a license agreement with the Minerals Separation N.A. Corporation. Flotation proved most successful and developments of a major nature took place at a rapid pace. A large slime flotation plant was first built, then the eight sections of the copper mill were progressively remodeled, bringing the total capacity to 16,000 tons daily. A new 2,000 tons per day zinc mill was rushed to completion to supply concentrate to the new zinc plants then under construction.

It is of interest to recall that the large tonnages of fine copper concentrate from flotation spurred pyrometallurgical developments

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on a broad front. In fact, altogether the scope of milling, pyrometallurgical and hydro- and hydro-electro-metallurgical developments that took place under Mr. Laist's management from 1913 through 1916, and that I was privileged, either to take part in, or to closely observe, was most impressive.

On the 25th January 1917 E. H. Hamilton, Metallurgical Manager at Trail, wired and wrote me, offering me a position as Shift Superintendent of their then new electrolytic zinc plant. My name had been given to him by E. P. Mathewson who had been Manager at Anaconda in 1912 when I first went there. I declined that position but explained that because of my interest in flotation I might consider a position with them of that nature if they had a challenging problem. In his reply of 31st January he said that they had no flotation problem at that time.

I had continued in charge of flotation research and plant testing at Anaconda but the major problems there of that nature had by that time been resolved, and in general, overall milling and metallurgical plant revision and expansion had been completed for the time being. Because of this I then felt that, in my own interests, I should look farther afield.

Early in February 1917 I went to Utah on leave of absence from Anaconda to develop a flotation treatment for the partially oxidized copper ore of The Ohio Copper Co. of Utah, at Lark, near Bingham. On the 8th March 1917 I heard from Mr. Hamilton again asking me to come to Trail to meet him and the Managing Director (Mr. Warren) and explaining that they did have a flotation problem after all. It was not convenient for me to go to Trail at that time and shortly after I received a letter dated 21st March from S. G. Blaylock, Assistant General Manager, referring to my correspondence with Mr. Hamilton, reopening negotiations, and explaining the nature of the Sullivan ore problem.

After a further exchange of communications, very preliminary tests on a sample of the ore sent to me in Utah, a visit to Trail, and bearing in mind certain special knowledge I had acquired that might have a bearing on the problem, (to which I shall refer later) I accepted an offer to head up milling for them and in particular to carry on flotation and concentration tests on Sullivan ore. I moved to Trail 1st June 1917.

PART III

The Development of the Treatment, by Flotation, of the Ore of the Sullivan Mine

The Sullivan ore of 1917 was a fine grained massive sulphide, very high in iron with a specific gravity of about 4.35, a sulphur content of about 32% and an insoluble content of about 5%*. It was essentially a mixture of galena, zinc blende and pyrrhotite (with small amounts of pyrite). The blende was a marmatite represented by the formula FeS-5ZnS (about 10% Fe).

Gaudin, who became familiar with Sullivan ore and its treatment in the late 1920's, said on page 234 of his text book "Flotation" published in 1932:

> "The sulphides occur in an extremely fine state of division resembling a matte.
>
> "As compared with ores of the Coeur d'Alene, Butte and Salt Lake regions, the Sullivan ore is characterized by its much higher iron content."

I might add that the iron sulphide content of the ore of the Broken Hill region in Australia is much lower than in those of the Coeur d'Alene, Butte and Salt Lake regions and incomparably lower than that in the Sullivan ore.

Froth flotation as known in America in 1917 consisted of separating all sulphide minerals from all nonsulphide gangue minerals. This was usually accomplished in an acid circuit. The problem presented by the Sullivan ore was not one of ordinary froth flotation as then known, but one of selective flotation. Specifically, the problem was to separate this complex ore into three sulphide products: (a) a lead concentrate, (b) a zinc concentrate, (c) an iron concentrate - with each of these three products containing as high

*Present day ore contains more "insoluble" because of dilution from mining of pillars, and from mining of some banded ore in the lower levels. This insoluble is now separated as waste by a "sink-float" operation prior to grinding for flotation.

a percentage of the respective lead, zinc and iron minerals in the original ore as possible. There was no such separation being made anywhere in the world at that time. If it were not possible to achieve such a separation by selective flotation alone, then some supplemental process was to be found and employed. While there was appreciable silver in the ore, it could be overlooked in the concentration studies because it invariably followed the lead.

For the background of selective flotation as then known, we must go to Australia. That is, of course, largely true for "bulk oil" flotation, "film" flotation and simple "froth" flotation also.

Undoubtedly major contributions were made to "bulk oil" and/or "film" flotation by Haynes in 1860, Everson in 1885, Robson, Crowder, Elmore, DeBavay, Cattermole and others in the late 1890's and the first four or five years of this century. However, it was not until the work of Potter and Delprat in Australia, 1902-1904, and of Froment in Italy about the same time, that gas as a buoyant medium in flotation was recognized. And it was not until the work of Sulman, Picard and Ballot, supplemented by that of G. A. Chapman, 1904-1906 (with whom I was associated in Anaconda in 1914) that froth flotation as we know it today, had its beginning. The Minerals Separation Company, London, controlled the patents of Sulman, Picard and Ballot, and those of Chapman, so it can be said that The M.S. Company played a leading part in froth flotation from its inception.

As I have stated, selective flotation came along somewhat later. In 1910 Horwood patented a process in which a lead-zinc ore was subjected to a collective float, the mixed concentrate from which was roasted at 400 - 500°C. The lead was thus dimmed and the zinc could then be floated off.

Lyster first observed a selective lead float in 1912 and The Zinc Corporation Mill in Broken Hill began a successful operation in September of that year.

In addition to those of Horwood and Lyster, many other processes were patented during the ensuing three or four years.

It is likely that all up-to-date information in regard to selective flotation then known by The M. S. Company in San Francisco, was in the possession of E. W. Wilkinson of their staff when he came to Anaconda in the summer of 1916 to conduct selective flotation tests on Butte zinc ore. I worked with him throughout those tests. He had had some success in San Francisco with tests on Butte ore in a small bronze sub-aeration laboratory machine with a conical top. Many similar tests were made by him in Anaconda. In most of them he was unable to produce even a lead concentrate. However some tests were encouraging. Copper sulphate was not used by him, nor even considered as far as I know. Attempts by him to duplicate the results of the better laboratory tests in a small continuous redwood spitzkasten type of machine were a complete failure. After many such tests, his efforts were abandoned and the selective flotation work terminated for the time being. One could only conclude that, as of that day, selective flotation of even a comparatively simple ore by a highly skilled operator was not easy, and was far from being an established art.

The Trail zinc plant commenced operations in the summer of 1916. Several difficulties of a serious nature were immediately encountered. The Sullivan zinc ore, which was the feed to the plant, was first crushed to one inch and then ground in dry, single pass, high speed tube mills using small steel balls. Unfortunately the product from this open circuit grinding contained a high percentage of oversize. The ground ore was then fed directly to Wedge roasters, and the calcine delivered to acid pachucas for leaching. Dorr classifiers removed the oversize from the acid pachuca discharge slurry before it went on to thickeners. The tonnage of this oversize was very much greater than anticipated, and after leaching still contained a high percentage of zinc because of the poor roast effected on the coarse sizes. This oversize was removed from the plant and accumulated in a stock pile. In addition to the difficulty experienced with the oversize, the ore fed to the plant had a high free iron content, and as I have already explained, the zinc mineral itself contained about 10% Fe. Because of this high iron in the roaster feed, there resulted a very high percentage of insoluble zinc ferrate in the calcine. To make matters still worse, the grade of the zinc ore fed to the plant, even though low to begin with at 25%, fell off progressively as the months passed, and by 1918 was down to around 20%.

The final effect of these three major, and other less serious troubles, was a low overall zinc recovery and a high cost for the finished zinc.

I am explaining this situation in the zinc plant because the troubles referred to made its position untenable except with very high zinc prices. With falling prices in prospect, the only way to save the situation was by the rapid development and use of milling methods which would improve the zinc plant feed in both grade and physical condition. The decline in zinc prices had already started in 1917 and continued downward for the next few years to very low levels.

You can well understand, therefore, the great urgency back of the mill test work. In fact from the commencement of our work in 1917, considerations in regard to it had to be merged with zinc plant considerations, and altogether, for the next four or five years, we were in a race against time.

Because of my familiarity with modern milling equipment and practise and because of my familiarity in a general way with the electrolytic zinc process, from observations and associations at Anaconda, and because of the interlocking considerations of the Trail zinc plant and the milling test work, I was given a loose zinc plant assignment in addition to my milling responsibilities, to ensure proper collaboration between the two problems.

Our milling plans as of the early summer of 1917 included:

(1) The building of a test mill with daily capacity of from 150 - 300 tons, depending upon the service for which it was used;

(2) Plant scale Horwood tests on Sullivan zinc ore as soon as the test mill was completed;

(3) Setting up of an ore testing laboratory for facilitating studies of selective flotation, and of other milling processes that offered any promise in the treatment of Sullivan ore.

The test mill was proceeded with immediately. It included wet grinding equipment, a 16 cell 24 inch "standard" M.S. machine, gravity tables, thickeners, etc.

For the Horwood tests ground ore from the zinc plant was to be transported to the smelter, and roasted there under Horwood conditions in an old one-hearth "Godfrey" furnace. The hot calcine from the "Godfrey" was to be transported to the test mill one-half mile distant, in open, narrow-gauge "V" cars, and it was hoped that sufficient natural cooling would take place in transportation, and in mill bins, for subsequent handling.

Horwood tests were started in late 1917 following completion of the test mill. It was found that because of the high fuel value of the ground ore, due to its pyrrhotite and pyrite content, the roasting temperature could not be controlled within the Horwood limits. Moreover, the transportation of the hot calcine presented serious difficulties. It flowed like water, would not cool in reasonable time, and was very dusty. The Godfrey furnace was quickly abandoned and attempts were then made to achieve suitable roasting conditions in a zinc plant Wedge furnace. The calcine was removed at a suitable stage from an intermediate hearth. This furnace produced better results, but in all tests, a substantial amount of water soluble zinc sulphate was formed, and the problems of dust and handling remained. These Horwood tests had taken several weeks, and it was obvious that the time required to overcome the problems we faced, even to a reasonable extent, could not be spared. In view of the urgency of the zinc plant problems, some immediate relief had to be found.

As we surveyed the situation generally, we recognized a similiarity in the normal zinc plant calcine as then produced, to the Horwood calcine. There existed in both a substantial part of the zinc, still in sulphide form. Following through our reasoning, it seemed that flotation should have some application in the treatment of zinc plant calcine. That application became immediately apparent. We were already separating most of the sulphides as acid classifier sands, and slight consideration convinced me that they would react favourably to ordinary acid circuit flotation. Simple tests proved this to be the case. There resulted a good grade of zinc concentrate containing about two thirds of the zinc, and a lead iron residue suitable for direct smelting containing about 80% of the lead and 85% of the iron. Moreover, this separation could be introduced immediately. The test mill was ideally designed for it. The result was that early in 1918 the test mill became an operating plant treating all of the current acid classifier sands, and provision was being made for recovery and treatment of the sands from the stockpile.

The following table illustrates the separation achieved:

		Assays			% of Total		
	% Wt.	% Pb	% Zn	% Fe	Pb	Zn	Fe
Feed	100.	11.8	16.2	31.6	100.	100.	100.
Soluble loss	6.9	-	-	-	-	8.8	4.0
Zn conc't.	24.6	10.0	42.4	14.7	20.2	64.2	11.4
Pb conc't.	68.5	14.1	6.4	41.2	79.8	27.0	84.6

This operation proved to be a real life saver for the zinc plant for many months in the face of falling metal prices. Its introduction added substantially to the zinc plant recovery and to the reduction of zinc costs. It was continued until a flotation machine was installed in the zinc leaching plant late in 1918 and discontinued there only after Sullivan milling commenced at Kimberley.

In retrospect it is interesting to see how the early Horwood test work, while itself unsuccessful, had opened the door to the first major improvement in zinc plant conditions.

While these zinc plant and test mill developments were under way, work in the ore testing laboratory had been going forward. Nothing of interest had resulted from selective flotation tests except some promise for a reasonably successful lead separation. It appeared then that the high iron in the ore, and its separation from the zinc, presented the principal flotation difficulty.

A careful review of all concentration test work prior to the summer of 1917 was then made. This test work had been carried on in commercial, government and Cominco laboratories and included those of The General Engineering Company of Salt Lake City (where various processes were employed). The Mines Branch in Ottawa, The Sterns-Rogers Company, The Dings Magnetic Machine Company and The Magnetic Manufacturing Company for magnetic tests, and finally The Minerals Separation North American Corporation in San Francisco. and the Mineral Separation Company of Australia for flotation tests. The Company's own work embraced only gravity and magnetic tests. The results from all laboratories were poor throughout, and seemed to offer but little if any promise.

However, from our 1918 review of these results we were impressed by the statement in the summary report of the work in Cominco laboratories which follows:

> "It was found that a very slight roast, in fact only heating the ore to below the point where SO_2 begins to be evolved, made a marked difference in its susceptibility to magnetic treatment."

We decided to reopen the study of magnetic separation on Sullivan ore and to concentrate on the heating phenomena, and on wet separation. Dry separation seemed to offer little promise at the fine sizes at which we had to work.

This decision was influenced also by the fact that up to that time we had met with no success in the zinc iron separation by selective flotation, and we thought that if it were possible to eliminate even a reasonable proportion of the iron by magnetic separation in a product low in lead and zinc, a flotation separation of the non-magnetic portion into a lead concentrate and a zinc concentrate would then be possible.

Our decision to proceed with magnetic studies was influenced in an overall way also by most urgent zinc plant considerations. Flotation of acid classifier sands had helped a great deal and continued to help, but zinc prices had continued to fall in an alarming way. We couldn't afford to pass up any milling possibilities whatever.

In planning our study of the heating phenomena we decided to work first on ore samples through a range of sizes, with ore crushed to about one inch at the coarse end of the range. It was at this time that we realized that the preheating in all of the early tests had been on relatively fine sizes. From our very first tests on coarse ore, we were amazed to find after fine grinding, that the wet separation gave much better results than in any former tests. Further tests proved that, to secure best magnetic results, the ore should be heated in what might be called "lump" form, although some of the lumps might be as small as 1/4 inch. No upper limit in lump size was determined. It was found also that control of most favourable heat conditions was simple. It consisted of heating the ore in coarse crushed form, preferably with fines removed, to 750-800^{o}F. just long enough for full heat penetration, and then allowing it to cool slowly. Grinding and wet separation could then be proceeded with at leisure.

So good, and so simple, was this separation that it was decided to rush the installation of a 150 ton per day plant. This was during October, 1918. The crushed ore with fines removed after being heated in a slowly revolving kiln, with practically no sulphur elimination, was to be cooled by passing through a rotating inclined cylinder sprayed externally with water. It was then to be ground wet in a ball mill in closed circuit with a Dorr classifier. The ground ore was to be treated on wet magnetic machines of a modified cross belt, Wetherill or Rowand type, and the magnetic portion cleaned and recleaned before discard. The non-magnetic portion was to be treated on tables for lead recovery pending development of the lead zinc separation by flotation.

This plant went into operation on the 1st March, 1919. It was an immediate success, and became the second major milling contribution to the improvement of zinc plant conditions. Not only were the quality of the feed, the recovery and the costs bettered, but a substantial reduction in the dry grinding operation, which had always been a troublesome one, was affected.

The separation on high grade zinc ore was about as follows:

		Assays			% of Total		
	% Wt.	% Pb	% Zn	% Fe	Pb	Zn	Fe
Feed	100.	10.1	22.3	29.6	100.	100.	100.
Non-Magnetic	60.6	14.7	35.2	13.4	88.	95.	28.
Magnetic	39.4	3.0	2.8	55.0	12.	5.	72.

As soon as the success of this plant was assured, it was decided to rush its expansion to 600 tons daily. This would help the recovery and costs in the zinc plant still more. It would permit the use of lower grade ore, and thus simplify and reduce the cost of mining and hand sorting at Kimberley. It would permit shutting down the dry grinding plant completely, and it would facilitate a greater refined zinc output. This expansion to 600 tons was completed, and the plant put into operation late in 1919.

After the success of the 150 ton magnetic plant, and because we were of the opinion then that the final process for Sullivan ore would be magnetic separation followed by selective flotation of the non-magnetic portion it became imperative that we determine without delay the most favourable conditions for the flotation separation of the non-magnetic portion into a lead concentrate, and a zinc concentrate.

In our review of methods we considered all knowledge than available to us, but the amount of this was limited. We concluded that because The M. S. Company had access to most of such knowledge, it would probably be borne in mind in test work that they might do for us. We had taken out a license with them in 1917 but they had contributed nothing towards the solution of our problem up to that time. In the spring of 1919 we again sent them samples of Sullivan ore and of the non-magnetic portion from the mill. Their results were again very poor on both samples. In spite of this we were convinced that, because of their background, their knowledge of selective flotation must be more extensive than that of anyone else, and that if they could not help us, there was not much use looking elsewhere. We therefore proceeded in our studies, and with our recognition of their specialized knowledge in mind, we kept coming back in our considerations to the reagents and the laboratory methods used by Wilkinson of The M. S. Company in his pre-Anaconda, and his Anaconda selective flotation test work of 1916. We thought that surely his practise at that time must have embraced the best from a screening of all M.S. selective flotation knowledge as of that day. We concluded that we would be on firm ground therefore if we placed particular value on his work, and used it more or less as a guide. This was in spite of the fact that his efforts at that time, and the later work of The M. S. Company on our samples had both been unsuccessful. This reasoning proved to be generally sound.

We met with our first success in May, 1919 working on the non-magnetic portion from the treatment of high grade zinc ore. A small bronze sub-aeration machine was used with soda ash, and the minimum amount of coal tar creosote. Neither wood oil nor copper sulphate was used. After more testing we concluded that with proper cleaning operations, an overall separation of Sullivan ore about as follows might be possible from a combination of magnetic and flotation processes:

	% Pb	% Zn	% Fe
Feed	12.0	20.0	30
Pb conc't.	66.0	9.0	5
Zn conc't.	5.0	40.0	14
Tailing	3.5	2.5	55

Our principal criticism of such a separation was the high lead and the high zinc content of the tailing. We therefore attacked the problem of direct treatment of the ore by selective flotation in a more determined way than ever. In due course we found that by most careful manipulation in a bronze sub-aeration laboratory machine, and with very sensitive reagent control, we could effect a fairly good separation, but with a non-commercial froth. The following approximates the results from a number of tests made at that time:

	% Pb	% Zn	% Fe
Feed	12.0	20.0	30.0
Pb conc't.	62.0	10.0	8.5
Zn conc't.	6.0	37.0	20.0
Fe conc't. (or tailing)	0.5	2.0	47.0

The lead concentrate was fairly high in zinc, and the zinc concentrate was too high in iron, but the tailing was quite good.

The expansion of our magnetic plant to 600 tons was then under way (August 1919). The results shown above were, on the whole, comparable to those thought possible from magnetic separation followed by flotation. This made us question the wisdom of proceeding with the magnetic plant expansion. However we realized that our flotation separation on the ore had been possible only by delicate manipulation in a laboratory machine, of which we had no commercial counterpart in Trail at that time. We decided that we should not interrupt our magnetic expansion plans, but should try to develop the flotation separation to a point where it appeared to have more promise of commercial success. With this in mind, we decided to build a single cell, sub-aeration type, redwood test machine of about 60 lb. batch capacity for larger scale tests. Moreover we decided to determine the best results possible from the bronze laboratory spitzkasten machine. Difficulties were immediately encountered in the large batch machine in our attempts to duplicate in it the results obtained from the small sub-aeration bronze test machine. Some lead selection was achieved, but the zinc work was very poor.

While we were faced with this puzzling problem, there appeared in the December 27, 1919 issue of the Engineering and Mining Journal an article referring to the work of C. C. Freeman of Broken Hill on the differential flotation of lead and zinc sulphides. According to this article, Freeman effected differential flotation of lead sulphide by first carrying on the operation in an iron or wooden machine using sodium carbonate as a frothing agent. Most of the lead sulphide was floated and most of the zinc sulphide remained in the residue. The residue was then subjected to flotation using a machine made of copper, or after the addition of copper salts, thereby floating the zinc sulphide. Nothing was said of a zinc iron separation. This information was of course most interesting and we found from tests we then made, that, as he claimed, copper sulphate in a wooden machine gave results comparable to those from a bronze machine without copper sulphate. Freeman disclosed, but did not claim, in his Canadian patent No. 169,601, the idea of separating mixed sulphides by floating galena in the absence of copper and copper salts in dilute sodium carbonate solution, followed by floating zinc blende in the presence of copper or copper salts. His claims were limited to a process for separating galena from mixed sulphides by flotation in dilute sodium carbonate solution in the absence of copper and copper salts. He did not claim the flotation of zinc blende in the presence of copper or copper salts. I knew in 1914 that copper sulphate had been used extensively in Australia and at the Butte and Superior in acid circuits as a means of reducing sulphuric acid consumption but I had not known until this time of its ever having been used in an alkaline circuit for making a wooden machine adaptable to selective flotation.

Management's view of the overall Company situation at that time was one of grave concern. Lead and zinc prices had fallen drastically.

Average Price - Cents per Pound

Year	Prime Western St. Louis	High Grade Zinc New York	Lead New York
1916	13.57	22.125	6.83
1917	8.93	14.5	8.71
1918	8.04	11.75	7.46
1919	7.04	8.125	5.81

(Source: AMM Metal Statistics 1925.)

Costs had been reduced substantially throughout the Company's operations, and especially in the zinc plant, but not fast enough to offset the decline in selling prices. The financial position of the Company was seriously threatened.

The situation generally in regard to milling was that zinc plant sand flotation was continuing and playing its part. The 600 ton magnetic plant had gone into operation in December, 1919 and was contributing substantially to the improvement of zinc plant conditions. There was nothing more we could do except by flotation of the lead-zinc concentrate from the magnetic plant, or by selective flotation of the Sullivan ore itself. All of our test work had indicated that for both of these separations a commercial sub-aeration machine would be required. We had only a "Standard" or spitz type of machine installed in the test mill. We hesitated to recommend the installation of a commercial sub-aeration machine at that time both because of the expense, and because of the delay. Moreover any plan considered for the treatment of the lead-zinc concentrate from the magnetic plant, even in a sub-aeration machine seemed to ignore the success we had had in recent months in the laboratory in the selective flotation of the ore itself. Hence we concluded that adoption of any such plan for the mixed concentrate implied a lack of courage on our part.

On the 2nd of March 1920, in spite of the financial risk involved and the flotation difficulties anticipated, I recommended to Mr. Blaylock that we put the test mill to work on Sullivan ore at once without a sub-aeration machine. We had accumulated a lot of flotation knowledge and while it was unfortunate that we couldn't patch together an ideal procedure, it seemed reasonable that we could do something worth-while in the test mill as a basis from which to go forward. Mr. Blaylock approved immediately and we turned in the feed 7th March 1920.

We started flotation with lime, soft wood creosote, and coal tar creosote. Circuit temperature was about 15°C. Flotation feed density was about 40%. Tonnage rate was about 400. Results were very poor for the first few days until we established that copper sulphate was imperative. Even then the results were barely good enough to justify continued operation. Three weeks later we substituted caustic soda for lime, with some improvement. A mixed lead-zinc concentrate only was being produced. By May, 1920, lead and zinc recoveries were about 80 and 85% respectively in a concentrate containing about 12.5% Pb and 27.3% Zn from feed of 9% Pb and 18.4% Zn. In early June we stopped use of soft wood creosote completely. Results had improved sufficiently later that month to permit shutting down the magnetic plant.

In the months following, or until the new Sullivan mill in Kimberley began operations in August, 1923, we made innumerable changes in equipment and control with progressive improvement in overall results. It is impossible to record all of these changes so I shall just skim over that period and explain a few of the highlights, I shall also show certain mill results as measures of progress.

In early August, 1920, we substituted soda ash at the rate of 6 to 8 lbs./ton for caustic soda. We then moved the point of addition of copper sulphate down the flotation machine and commenced making a lead float. From the 13th August, 1920, commercial separation by selective flotation of Sullivan ore into a lead concentrate, a zinc concentrate and an iron concentrate, was a reality. Results were by no means consistently good in the months that followed. We had many ups and downs but on the whole we kept moving forward and at a fairly fast rate. We had started our operation in March at a 400 ton rate. By September we were up to 700 tons.

With the progress made, and the momentum thus established, and the skies clearing in regard to our process, we proceeded in the fall of 1920 with test mill expansion - more grinding equipment, more flotation machines, both sub-aeration and standard, more milling facilities generally. The results for the average good day during the last four months of 1920 were about as follows:

	% Pb	% Zn	% Fe
Feed	10.3	18.7	29.8
Pb Conc't.	46.3	15.3	11.7
Zn Conc't.	5.1	35.4	23.0
Tailing	1.1	3.8	42.2

From a management viewpoint this milling development was of course most encouraging, but the cheerful aspects of it were submerged to some extent, at least, by troubles the Company had experienced during 1920. This is explained by Mr. Blaylock in his annual report for the year 1920 to the President. He said:

"During the year the Company has passed through the most drastic period of deflation ever known. During the last quarter the selling prices of metals produced dropped very suddenly to below pre-war levels."

The price changes he referred to are the following:

	Price - Cents per Pound	
Period	Prime Western Zinc St. Louis	Lead New York
September, 1920	7.77	8.52
October, 1920	7.25	7.47
November, 1920	6.37	6.61
December, 1920	5.84	4.94

More cheerful notes were struck by him, however, in the following quotations from the same report:

"The metallurgical processes have made great strides during the year, both in cost reduction and recoveries, mainly in the concentration of the Sullivan ores, into more suitable lead and zinc concentrates, these concentrates in turn making much better work possible in both the lead and zinc plants."

"The cost of producing zinc has been lowered 40% during the year in spite of the heavy increases in the cost of ... etc."

"This plant (the concentrator) has been very much enlarged and improved until it is now capable of handling 900 tons of Sullivan ore per day with results very much ahead of anything thought possible last year and with the certainty of still further improvement."

In January, 1921 water gas tar was substituted in large part for coal tar creosote, with marked improvement..

In February, 1921 we started adding all oil for lead flotation to the ball mill feed.

In July, 1921 the grind, while better than in earlier months, was still too coarse at 69.6% -200 mesh.

Commencing in October, 1921 the feed to lead flotation was increased from about 40% density to 50%, with improved results.

In November, 1921 the benefit of higher temperatures for zinc flotation was determined. Approximate temperatures adopted were 20°C for lead and 30°C for zinc.

A substantial improvement in grinding was effected in May and June, 1922 to about 2% +100 and 80 to 85% -200 mesh.

In January, 1923 we began using a small amount of cresylic acid, a reagent that was later to become a standard with us for many years.

In February, 1923 we started using cyanide under license from Sheridan and Griswold, in fact we were their first licensee. Its use has continued ever since. Its merit, of course, is in lowering the zinc content of the lead concentrate.

The overall results for March, 1923 were as follows:

Tons Treated - 33,450

		Assays			% of Total		
	% Wt.	% Pb	% Zn	% Fe	Pb	Zn	Fe
Feed	100.	11.8	13.4	31.0	100.	100.	100.
Pb conc't.	15.4	59.8	7.8	9.3	77.6	8.9	4.6
Zn conc't.	27.9	5.8	38.8	19.5	13.8	81.1	17.5
Tailing	56.7	1.8	2.3	42.3	8.6	10.0	77.9

Temperatures: Lead circuit 19°C; Zinc circuit 27.5°C.
Grind flotation feed: 80.4% -200 mesh.
Reagents: Cyanide 0.1 lb./ton, Copper sulphate 1.2 lb./ton
Soda ash 6.9 lb./ton, Coal tar creosote 0.2 lb./ton,
Water gas tar 0.4 lb./ton.

The new mill in Kimberley commenced operation in August, 1923 and I shall now show results for certain years after 1923 as a measure of progress there. Those for the year 1925 follow. In this case I show the silver behaviour also.

Tons Treated in 1925 - 1,093,198

		Assays				% of Total			
	% Wt.	% Pb	% Zn	% Fe	Ozs. Ag/Ton	Pb	Zn	Fe	Ag
Feed	100.	10.6	8.4	38.6	3.4	100.	100.	100.	100.
Pb conc't.	14.2	64.0	6.2	8.2	20.3	85.9	10.6	3.0	83.9
Zn conc't.	13.8	3.9	44.7	16.9	1.8	5.1	74.1	5.7	7.1
Tailing	72.0	1.3	1.8	48.9	0.4	9.0	15.3	91.3	9.0

The results for 1932 follow. These, together with those of 1933, are the best ever achieved. Perhaps I should remind you that the pure zinc mineral in Sullivan ore contains only 54-55% zinc, and about 10% Fe, so you will realize that a concentrate of 49.8% zinc is extremely high grade.

Tons Treated in 1932 - 1,440,520

	Assays				% of Total		
	% Wt.	% Pb	% Zn	% Fe	Pb	Zn	Fe
Feed	100.	9.3	8.1	36.1	100.	100.	100.
Pb conc't.	11.6	71.2	4.6	5.2	88.8	6.5	1.7
Zn conc't.	13.9	3.5	49.8	12.6	5.2	85.5	4.8
Tailing	74.5	0.8	0.9	44.4	6.0	8.0	93.5

The following quotation from recent personal notes by Hugh Brock of the Sullivan Concentrator staff is of particular interest at this time:

> "Xanthate was not yet developed when the Sullivan separation was worked out 1917-1923, and even as late as 1933 water gas tar, coal tar creosote and cresylic acid in soda ash circuit were still the important promoters and frothers in the Sullivan concentrator. Xanthate was first introduced in March, 1925 as an auxiliary zinc promoter, but did not become an essential one until 1933, when a major change from soda ash to lime alkalinity regulators was made."

The test mill in Trail had been built in the summer of 1917 to facilitate development of a milling process for the ore of the Sullivan mine. There was little of a tangible nature upon which its design could be based. The mill was simply a step forward in the right direction. No one could have foreseen the developments there of the ensuing years. In retrospect, it is interesting to observe that, overall, it served its purpose well. I shall not attempt to summarize activities there during the six years between the summers of 1917 and 1923. Suffice it to say that not only did it serve well as an operating plant, but that from it, as a test plant, all of the information necessary for the design of the Sullivan mill in Kimberley was collected.

Construction of the Sullivan mill commenced in the spring of 1922 on an ideal site about three miles from the mine portal. It was completed and operation commenced in August, 1923. The plant was an immediate success in every way, and has always been a source of pride to the Company, and to everyone directly connected with the mill in particular. The design and construction were carried out by Cominco men throughout. There are numerous descriptions of it in the technical press.

I should now like to speak of the men, who, with me, constituted the team directly responsible for the development of the Sullivan ore milling process. I refer particularly to those men who were actively engaged in that development in a responsible technical capacity for at least a substantial part of the critical years between the summers of 1917 and 1921.

I think of the remaining two years of the test mill operation, between the summers of 1921 and 1923, as being of great importance in the process development of course, but not as being "critical" years. The success of the process had, by the middle of 1921, been assured.

There were five of us on the team to which I have referred. Two of us served throughout the critical period, the other three for but parts of it. Everyone on the team played an important role, and everyone made major contributions. However, it would be impossible, and it would be unfair of me to attempt to allocate credit for this, or for that. It is proper that the outcome be looked upon as the achievement of the team as a whole. I was simply the captain of that team.

First there was W. H. (Bill) Hannay who had carried on most of the gravity and magnetic test work on Sullivan ore prior to my arrival and who learned flotation under me. He played an important part throughout the test period and in mill operation until 1925. For many years after that he served as one of the senior men in the Research Department of the Company.

Clarence Thom, a chemical engineer from Colorado, our first assayer who graduated into test work and was identified particularly with the magnetic work but later with flotation testing. He left the Company in 1922 and for many years was in charge of research for The Denver Equipment Company.

Carle P. Lewis, an agricultural graduate whom I had recruited from the labor gang in Anaconda and trained in laboratory flotation testing there. After discharge from the U.S. Navy about the end of 1918 he was with me in Trail for about ten months and carried on important lab flotation testing. Later he was with The M. S. Company in San Francisco where he was associated with C. H. Keller in the discovery of Xanthate. He died at an early age.

And finally there was C. T. (Cliff) Oughtred who started with me in 1919 and was particularly identified with test mill operation. Later he was superintendent of the Sullivan mill and succeeded me as Superintendent of Concentration in 1929. In his untimely death in 1941 the Company lost one of its very able men.

Then there were other men who came along in the early years following who made major contributions to Sullivan milling.

H. W. (Bill) Poole, one of our most skilled men in the flotation of Sullivan ore, who in due course became mill superintendent.

S. (Stan) Gray, who played an important part in early operation.

H. R. (Bert) Banks, who from 1924 on played an important part, and who later as mill superintendent made many major contributions.

It is proper that I should at this time acknowledge the indirect help of The Minerals Separation North American Corporation. Cominco had taken out an M.S. license in 1917. This was more or less imperative despite the high royalty rates if we were to be sure of avoiding litigation, because they controlled most of the important patents. However, there were also other reasons why it was wise. Undoubtedly a great deal of the general flotation knowledge that prevailed among mill men in those early days stemmed from the M. S. reservoir of knowledge. I myself had in large part been trained by George A. Chapman of The M. S. Company, and had become familiar with their laboratory methods, reagents and equipment as a result of their instruction and facilities. In fact my flotation background, when I came to Trail, had been largely shaped by M. S. influences in one way or another. Then I had had the opportunity of working with E. W. Wilkinson of their staff whose selective flotation work at Anaconda, while unsuccessful at that time, had played an important part in our laboratory procedure on Sullivan ore. To the extent implied by the information I have given above, The M. S. Company made its contribution to the solution of the Sullivan ore problem and I think this should be rated as a major one in spite of the fact that the results of their test work on Sullivan ore itself had been negative throughout, and in spite of the fact that they had never had anyone stationed in Trail in the early days and assigned to our problem even for a few days.

In this regard the following information given to me in 1961 by Carl Williams, one of their very early engineers, is of particular interest.

In 1917 the mining world, had only recently learned of the tremendous possibilities of flotation and wanted to find out all they could about it.

The M. S. Company had /a laboratory in San Francisco but trained men were at a premium, and at that time, and for the next few years, they were simply deluged with ore samples for testing, requests for information, and help in the field. Most of the ores submitted were simple and reacted favourably. Some of those ores represented great reserves, potential large operations and large royalty producers. With many, major construction was soon under way. There were plenty of simple ores to fully occupy their time. The Sullivan was a complex ore and did not react favourably. Moreover The M. S. Company knew little at that time of the potential of the Sullivan ore body and, Cominco, as a Company, did not then occupy a very prominent place in the mining world. Consequently our problem was not given the consideration it deserved by The M. S. Company.

In regard to copper sulphate, he explained that in those early years they were not impressed with its possibilities and he quite understood why Wilkinson had not used it in 1916. He indicated that, with them also, it was around 1920 before they became properly aware of its possibilities. In this regard we must again remember that the Sullivan ore was a very special problem and that copper sulphate meant more to us than was the case with perhaps 99 out of 100 ores.

He then reminded me of another situation which had a bearing on our problem. Throughout the flotation field at that time a great deal of bitter patent litigation had come about, and continued for many years, with the result that every mining company, every licensing company or process company, and every individual in flotation, became very secretive, and information was hard to come by.

Finally I want to acknowledge the great help I received in those early days from two of the senior officers of Cominco. I refer to James J. Warren, Managing Director in 1917, residing in Trail, and in 1919 to become President, and S. G. Blaylock, Assistant General Manager in 1917 and in 1919 to become General Manager. The success of our efforts was of course based upon their keen interest, their understanding, encouragement and confidence, and finally upon their courage in taking financial risks.

I should like to acknowledge also the splendid cooperation I received from B. A. Stimmel. He became Superintendent of the zinc plant in 1918. Throughout our long and close association, he was always prepared, in the most pleasant manner possible, to do everything that offered any chance of forwarding our common cause.

This concludes my account of the development of the treatment by flotation of the Sullivan ore.

It is now many years since I have been directly associated with flotation and so I have lost touch. However, as I look over technical articles of recent years, I am most impressed, and humbled by the scientific approach to present day flotation problems. Our approach in my generation was largely, if not altogether empirical. For this favourable trend over the years a large part of the credit must go to Prof. A.M. Gaudin of M.I.T. and men like him - and so in conclusion I salute him and his co-workers in the scientific flotation field, and I salute also the operators, who, down through the years, have applied the scientific findings and brought froth flotation to its present high technological level.

PART IV

An Outline of the Early Development of Cominco's Fertilizer Industry

Because of the success of flotation, and the consequent increase in output of the Sullivan mine, lead production from the Trail plant rapidly increased from an average of about 55 tons daily for 1918 and 1919, to 415 tons daily in 1930, and 604 tons in 1940. Similarly zinc production increased from about 38 tons daily in 1918 and 1919 to 327 tons in 1930 and 400 tons in 1940. All increases in metal production until about 1931 were paralleled by similar increases in sulphur gas released to the Trail atmosphere from the roasting operations for the two metals. Soon the sulphur smoke became a serious nuisance, not only in the adjacent British Columbia countryside, but also across the "Border" in Stephens County in the northern part of the State of Washington. Major damage claims were made by farmers, and others, on both sides of the "Border". Many of them were unreasonable. However, because of this overall situation, an "International Tribunal" was established during the 1920's by Ottawa and Washington to investigate the situation, to fix damages, and to specify corrective measures to be taken by the offending party. I shall not detail this development. Suffice it to say that the problem was finally resolved by the implementation of the Company's fertilizer program.

It had of course been realized by the Company that the smoke condition, as it became worse, had to be corrected, and it was hoped that in doing so the sulphur would prove to be an asset.

Conversion of the sulphur gas into sulphuric acid was the most obvious course to follow, but disposal of the very large quantity of acid that would have to be made to control the smoke presented a major problem, particularly in an area like Trail where there was but a small market for sulphuric acid as such. However, that situation had to be faced and to use the acid, production of chemical fertilizers on a large scale was decided upon. The Anaconda Company had already faced a similar problem and had built a large "chamber" acid plant and a triple-superphosphate plant. However, they had experienced difficulty in disposing of all of their "triple-super". Foreseeable marketing problems in our case made a program such as Anaconda's unattractive. A greater variety of fertilizer products was desirable.

At that time the building of synthetic ammonia plants had become widespread in Europe and several of them employed electrolysis of water as a source of hydrogen. Cominco had potential low cost power available on the Kootenay river and ammonia production in that manner seemed logical. Ammonia along with sulphuric acid and phosphate rock would make possible a sufficiently wide range of fertilizer products for our purposes.

In 1927 Company exploration engineers had discovered phosphate rock in the Crowsnest Pass area of south eastern British Columbia but this rock was too low grade for our purposes and we had to turn to Montana as a source of suitable rock.

The general plan for the production of both nitrogen and phosphate fertilizer on a large scale was formally approved by the Board of Directors in the spring of 1929 and at the same time I was placed in charge of production. It was a major plan contemplating the expenditure of about 10 million dollars. E. M. (Ed) Stiles, Chief Engineer, and I, as a team, were responsible to Mr. Blaylock for the development of plans and facilities.For most of our needs we had to go to Europe, but for the phosphoric acid plant design, we called on The Dorr Company.

Our original plans contemplated the production of ammonium sulphate, mono-ammonium-phosphate (11-48-0), ammonium phosphate-sulphate (16-20-0) and triple-superphosphate. Production of "triple-super" proved to be impracticable and was dropped.

It was realized from the beginning that all foreign markets would have to be studied and utilized, and the Company's Sales Department acted accordingly. Similarly it was realized that the Canadian prairie offered a tremendous potential market which would have to be opened up. Until that time no chemical fertilizer had been used on the prairie. In 1927 it was decided to produce 180 tons of "triple-super" in a make-shift plant for the commencement of prairie tests. Dr. R. E. Neidig, a highly trained agriculturist, was engaged and placed charge of them. During the first three years, commencing with 1928, an extensive research program was carried on in cooperation with the Dominion and Provincial governments. The results were most encouraging, and favourable reports were issued by government officials. In due course the prairie universities were enrolled in the program. Company engineers had designed and developed a fertilizer drill attachment for grain drills which greatly facilitated the field tests and these were made available to farmers at low cost. Great progress was made from the beginning. The program was broadened, became very extensive, and was continued for many years. It was of course hampered somewhat during the drought and depression years of the 1930's. I shall not describe subsequent developments in this prairie work except to repeat that these tests marked the beginning of the use of chemical fertilizers on the Canadian prairie, a practice which today is recognized as almost imperative. Over the years the increase in demand has therefore become phenominal.

Construction of the fertilizer plant at Trail commenced early in 1930 and production commenced in 1931. Output grew from 61,141 tons in 1932 to 170,108 in 1938 and 327,232 in 1944.

About 1940 the Federal Government decided to build ammonia and ammonium nitrate plants in Canada for munitions. Calgary was chosen as the site of one of these plants because of the availability of natural gas for ammonia production. The "Imperial Chemical Industries" of England was chosen to supply the process "know-how" and special equipment design. However, because of the aggressive approach to the Government by Mr. Blaylock, Cominco engineers were loaned to the Crown corporation that was formed, the Alberta Nitrogen Co., and they teamed up with the I.C.I. engineers for general plant design and construction. On October 4, 1941 the operating company, the Alberta Nitrogen Products Ltd. took over the plant and production commenced immediately. Cominco managed the plant on a "no fee" basis.

Shortly after the Calgary plant was commenced, the Government in collaboration with Cominco built another ammonia and ammonium nitrate plant, this time in Trail, and using the "Coke-Ammonia Process". In due course it was completed and the operating control was merged with that of the Cominco fertilizer plant.

Both of these Government operations proved successful for the purposes intended. After the war, they were offered for sale and both were purchased by Cominco in 1946.

During the seven years 1929-1936 when I was in charge of fertilizer production it was a privilege and pleasure to work closely with a splendid group of men on my staff. It was they who became skilled in the science and technology of the processes, and who, by their control and cooperation made the development such an outstanding success.

This concludes my account of the early development of Cominco's fertilizer industry.

PART V

An Outline of the Development of the Fuming Process for Lead Blast Furnace Slag

From the time shipments of crude lead ore from the Sullivan were commenced in 1910, and shipments from the St. Eugene began falling off in 1911, the lead smelter was forced to operate with as high a zinc content in its blast furnace slag as possible. Moreover, after flotation of the Sullivan ore commenced, and shipments of crude lead ore from the mine were discontinued, the smelter had the problem of treating as much of the residue from the zinc plant as possible. It contained all of the lead, silver and iron in the original zinc plant feed, and it also still contained a relatively high percentage of zinc. The high zinc slag had therefore to be continued and it couldn't be discarded because of its metal values which ran as high as 18% zinc and 2% lead. A process had to be found or developed for the recovery of these values. In the meantime the slag was stocked. Similarly the zinc plant residue that couldn't be smelted had to be stocked and this consisted of the great bulk of it.

During the 1920's a great deal of consideration was given to the slag treatment problem, and in due course, a fairly successful method of fuming off the lead and zinc was developed on an experimental basis by blowing powdered coal for the reduction of the lead and zinc, into a molten bath of slag in an electric furnace. The metal thus recovered burned in the air to oxides and, after cooling, was collected in a baghouse.

About the same time the Anaconda Copper Mining Company, in its Tooele plant in Utah, was developing a somewhat similar process, but they used a furnace in which powdered coal was used, not only for the reduction of lead and zinc in the slag, but also as a source of heat for keeping the slag molten. It appeared that both of these processes could have been developed into commercial ones, but for certain reasons Cominco adopted the Tooele method, developed it further and adapted it to Trail conditions. At the same time the Anaconda Company developed and applied their process commercially.

As I have already stated I was in no way associated with this development at the time, but because it was one of the three major new developments of the Blaylock Era, it should be referred to herein. James Buchanan, as Smelter Superintendent, was of course generally responsible for the development, but it was the immediate responsibility of G. E. (George) Murray, assisted by R. R. (Ron) McNaughton.

The story of the development of the fuming operation at Trail is given in the paper entitled: "The Recovery of Lead and Zinc from Blast Furnace Slag at Trail, B. C." by G. E. Murray, C.I.M.M. Bulletin, April 1933, and also in the paper entitled "Slag Treatment for the Recovery of Lead and Zinc at Trail, B. C." by R. R. McNaughton, Transactions of the A.I.M.E., 1936.

This operation has continued as a most important one up to the present day, and it was only a few years ago that all of the stocked slag and zinc plant residue from former operations was finally cleaned up.

<u>CONCLUSION</u>

Mr. Warren died on the 28th January 1939. Mr. Blaylock then became President, but he continued to live in Trail, and to carry on as senior officer in the West much as before. R. E. Stavert became Vice-President at Montreal where the Head Office of the Company was located. W. M. Archibald, Vice-President, Mines retired. James Buchanan became General Manager at Trail and I became Assistant General Manager and deputy head of the Mines and Exploration Department under Mr. Blaylock who acted as Manager.

During the war years, maximum metal production was a constant requirement and this presented many problems. The challenge was met and a most creditable record was achieved.

Mr. Blaylock, whose health had been failing badly, retired in April 1945 and died in November of that year at the age of 66. Mr. Stavert became President and continued to live in Montreal. James Buchanan retired, and I became a Director, and Vice-President and General Manager, and as such, senior officer in the West. W. S. Kirkpatrick became Assistant General Manager.

I should like at this stage to give the names and positions of all of the senior staff in the West at the end of 1945, and to record the commendation that each deserves. In fact, if it were appropriate for me to so act in retirement, I should like to record commendation for all supervisory personnel and workmen who served so faithfully and contributed so much to the success of the Company throughout the early years. However such action on my part, even if it were appropriate, is impracticable.

I shall, however, name a few men in the West of particular prominence in the very early years.

I shall say nothing of the careers and achievements of my close friends and long-time associates who are still "in harness": W. S. (Bill) Kirkpatrick, R. (Bob) Hendricks, R. D. (Ralph) Perry, D. D. (Pat) Morris and other men in the upper echelons of the Company today. Nor shall I speak of R. E. (Ewart) Stavert who was my close friend and associate from 1937, and from 1945, my Chief as well, until my retirement in 1956.

The men I have marked for special mention are:

R. H. (Pat) Stewart who was Manager of Mines from 1906 until he became General Manager in 1911. He played important parts in both the acquisition of the Sullivan Mine and the adoption of the electrolytic zinc process. He resigned early in 1917 but again served Cominco well as Consulting Engineer at the Sullivan Mine from 1940 until his death in 1952.

T. W. (Tom) Bingay, Comptroller for many years and later Vice-President in Charge of Finances, who served the Company and its predecessor well from the late 1890's until his retirement in 1934. He had been recognized by Aldridge, Stewart, Warren, Blaylock and all senior members of the staff as one of the "key" men of the Company throughout his working life.

James Buchanan who was Smelter Superintendent from 1911 until 1936, General Superintendent of the Trail plant until 1939 and General Manager at Trail until the end of 1944. He was responsible for much of the splendid growth of the smelter throughout those years.

L. A. (Lorne) Campbell, first General Manager and later President of the West Kootenay Power and Light Company, Limited, the Power Czar for 49 years. He it was who foresaw the great power potential of the Kootenay River between Kootenay Lake and the Columbia River and brought about its total development step by step down through the years, paralleling this with an expanding distribution system which served not only all Cominco plants but satisfied the public utility load throughout the West Kootenay, Boundary and South Okanagan Districts.

G. E. (George) Murray who as Assistant Smelter Superintendent and later Metallurgist for the Trail plant, established for himself an outstanding record of achievement between the years 1911 and the time of his tragic death in 1936. In his passing the Company lost a brilliant man with a promising future.

R. C. (Rolly) Crowe who as Solicitor from 1920 and later Vice-President and General Counsel was responsible for all legal matters for the Company and who also died while still a young man in 1940.

W. M. Archibald who as Manager of Mines from 1916, and later Vice-President in Charge of Mines until he retired in 1939, had built for himself a reputation throughout Canada as one of her outstanding mine finders.

E. M. (Ed) Stiles who from 1917 until his retirement in 1952 served the Company, first as Chief Draftsman and later for many years as Chief Engineer, in a most capable and commendable manner in all fields in any way relating to civil, mechanical and structural engineering.

Finally, I want to speak of Mr. Blaylock - or "Blay" as he was known to his host of friends. His retirement in 1945 constituted the end of "The Blaylock Era". For 26 years he had been, beyond question, the dominating personality in Cominco affairs, and for 46 years he had served the Company and its predecessor wonderfully well.

After 1919 he had, in a major way, determined the fortunes of the Company. Specifically he had in 1909 and 1910, while Superintendent of the St. Eugene, played a part in the acquisition of the Sullivan Mine. In 1912-1915 he had, as Assistant General Manager, played some part in the adoption of the electrolytic zinc program. In 1917 he had initiated the intensive concentration study on Sullivan ore. In 1925 he had initiated a comprehensive and continuing geological study of the Sullivan orebody first under the direction of Dr. J. A. Bancroft of McGill and later of Dr. W. J. Mead of the University of Wisconsin and still later of Dr. C. O. Swanson of U.B.C. In the 1920's he had initiated the fertilizer and slag fuming programs. And after Sullivan milling commenced in 1920 and 1923 he had guided, and provided the momentum for the major expansions in plant facilities and operations called for at the Sullivan Mine, the smelter, the zinc plant, the refineries and the power plants.

Nor should I let this opportunity pass without saying something of his absorbing interest in employee relations and in employee security. Certainly his advanced thinking in that regard made him a pioneer in that field, particularly in the mining industry. His efforts resulted in the adoption, in the early years, of splendid medical and hospital protection for Company employees, in Company loans for house construction, and in group insurance and non-contributory pension plans. There is no doubt but that the overall result of these and related developments contributed in a major way down through the years to good labour relations.

Now I want to reflect upon him as a man, and as an executive, I think I knew him as well as anyone in the Company because I was closely associated with, and directly responsible to him for 28 years. It is of course, hard to describe any man in a few words, but it is particularly hard to do so in the case of such a remarkable man as he was. In attempting to do this I concluded that I could do no better than to repeat what I said at a retirement party for him in Montreal in 1945.

> "To but few men is given the ability such as his, of cutting corners to the correct answers to problems in so direct a line and in so short a time, and but few men, seeing an objective, put their full weight behind the effort with such unflagging interest as he has done.
>
> "He is a man with great imagination, initiative, courage and determination. He is a man with a big heart, fine judgment and broad vision - a man who inspires confidence and loyalty in all with whom he associates."

Many honours were showered upon him by universities and engineering societies. He was justly proud of the Honourary Doctor of Laws degree from his Alma Mater, McGill, of The James Douglas Medal from the A.I.M.E. and of the Gold Medal of The Institution of Mining and Metallurgy in London, and many others.

And now, with Blay still in mind, and having told the Cominco story to the end of "The Blaylock Era", as best I could, it is proper that I should come to a close, and that I do.