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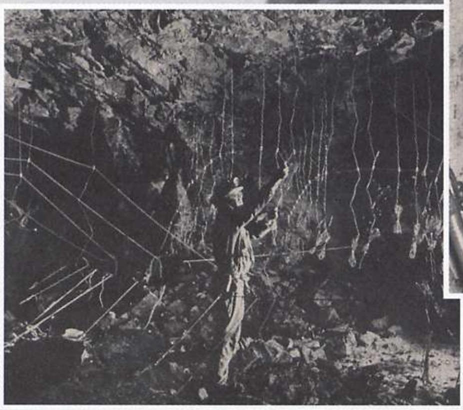

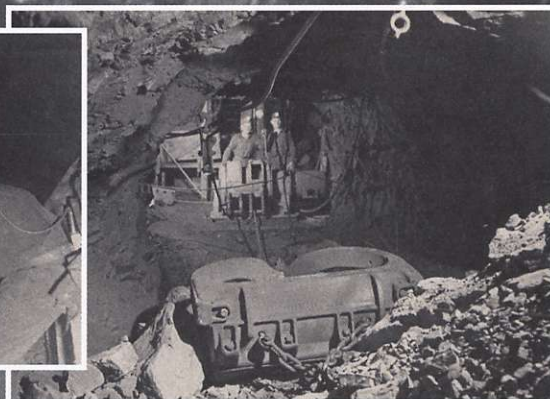

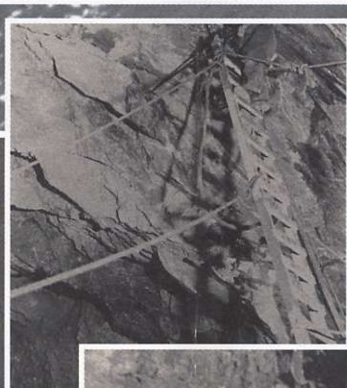

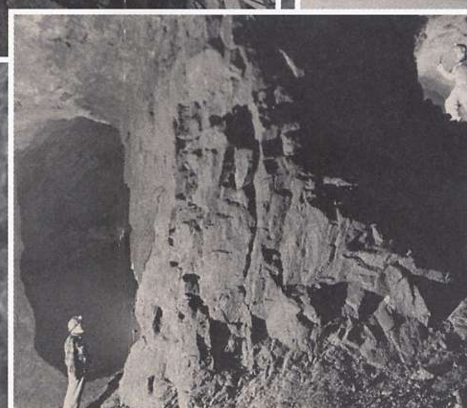

Sullivan: End of an Era

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Salute to Sullivan

By Bruce McKnight
Executive Director,
BC & Yukon
Chamber of Mines

No other mine, and no other corporation arguably has had a larger influence on BC's development than Sullivan and Cominco.

Forget about corporate strategy, scientific investing, or whatever. Think about luck coupled with perseverance. Many of the largest mining companies in the world grew up by having the good fortune to stumble over one huge mineral deposit, *plus* having the skill to recognize it and the financial resources to exploit it. This was largely the case with the Sullivan Mine and Cominco predecessor, Consolidated Mining and Smelting Company (CM&S).

These company-making deposits are so rare and important that they are known as "world class" mines; the Sullivan is clearly one of them. They even spawn their own nomenclature such as "*Sullivan-type*" environment or geology, or looking for *"another Sullivan.*" Conferences are held to discuss them, their technical attributes, including geological features, and, in particular, how to find more. And for very good reason, because deposits like Sullivan are fantastic economic prizes for all the participants in their development – the company, employees, suppliers, customers, communities and governments. In many ways this one mine is tied to not only the history of Cominco, but also the history of mining in BC and the history of BC itself. No other mine, and no other corporation arguably has had a larger influence on BC's development than Sullivan and Cominco. The entire pattern of southeastern BC's development – towns, railways, highways and ports as well as numerous offices, warehouses, processing and research facilities – was strongly influenced by this one mine and the developments that it spawned.

Although the Sullivan mineral showings, outcropping on North Star Mountain, were known as early as 1892, the deposit had only limited (mainly lead and silver) production until it came under the control of CM&S, in 1909. Even then commercial success was highly dependent on transportation access to a smelter combined with risky technological breakthroughs. CM&S already owned the Trail smelter and was fortuitously controlled by the CPR; a combination that allowed CM&S, using Sullivan ore, to become the largest lead producer in the British Empire during WW1. Zinc production, however, awaited CM&S research into differential froth flotation (to separate sphalerite from galena), which was finally perfected by 1920 and a 2,500 ton per day concentrator built at Sullivan by 1924.

And the rest, as they say, is history.

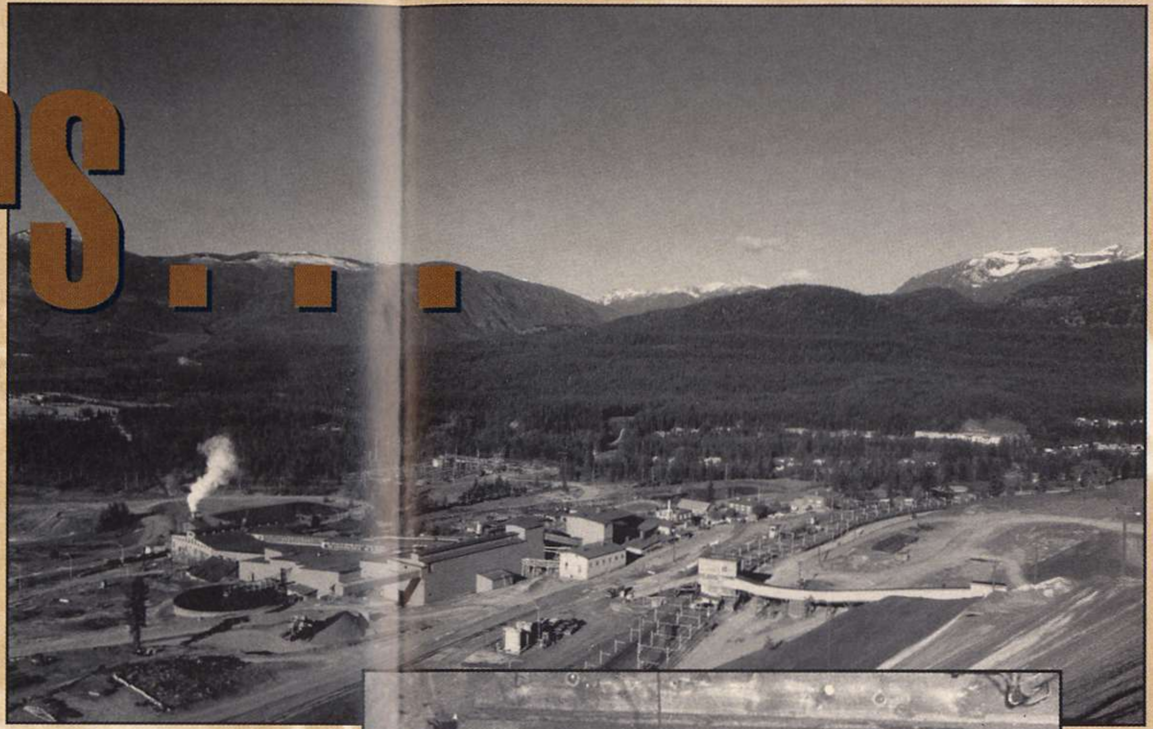
...Sullivan operations began deep in the horse and buggy era and continued well into the space age, touching three centuries and using the technology of all three. It also continued well into the age of "Sustainable Development" and over the past 30 years the mine has made major investments into the environmental and socio-economic sustainability of Kimberly...

And a colourful and varied history it has been, all largely fuelled by millions of dollars of Sullivan profits and staffed by thousands of Sullivan graduates. Along the way at Sullivan, the milling rate was increased to 8,500 tons per day in 1934, a tin circuit added in 1945, and numerous technological, safety and environmental improvements were made. These advances should come as no surprise, for Sullivan operations began deep in the horse and buggy era and continued well into the space age – touching three centuries and using the technology of all three. It also continued well into the age of "Sustainable Development" and over the past 30 years the mine has made major investments into the environmental and socio-economic sustainability of Kimberly, the mine's host town and the community where four generations of Sullivan employees have lived.

So we at the Chamber of Mines say "so long Sullivan," we salute you for your enterprise, your technological innovation and your contributions to our community. We only wish there were more "Sullivans" now ready in BC to replace you, because we know there is potential for more. We just have to overcome those same technological and transportation barriers which you overcame a century ago. ■

Over a Hundred Years...

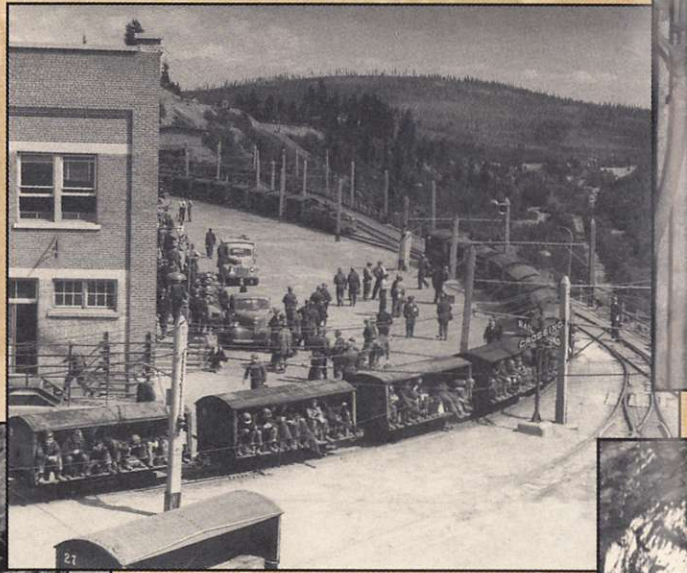
The History of the Sullivan Mine



(above) The Sullivan Mine – 1999

(right) Ore dumping – 1930

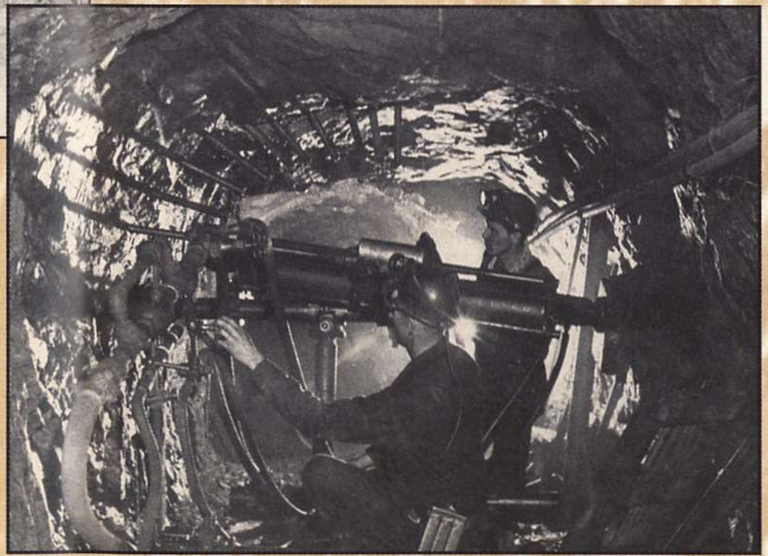
(right) Crew cutting first station, 3932 Raise – 1925



(left) S.G. Blaylock delivering speech at the Sullivan Mine for the War Effort – 1942

(above) Crew going on afternoon shift – 1948

(right) Drilling a ring in a sub-level – 1950



The Sullivan mine is Canada's longest-lived continuous metalliferous mining operation. Sullivan was discovered in 1892 by prospectors Pat Sullivan, Ed Smith, John Cleaver, and Walter Burchett, who were attracted to the area by the lead-silver discoveries on North Star Hill. It was first mined for lead and silver in 1900 after the building of the C.P.R. Cranbrook- Kimberley branch line, and up to 1903, 3,000 tons of lead ore was sent to the Nelson and Trail smelters. During the period 1903-7, 75,000 tons of lead ore were smelted at nearby Marysville. The Consolidated Mining and Smelting Company of Canada (now Cominco) optioned the property in 1909, and started mining in 1910, sending the hand-cobbed galena to the company's smelter at Trail, B.C. During the First World War, Sullivan was the largest single source of lead, critical for munitions, in the British Empire.

By 1914, the immense size of the Sullivan deposit and the importance of its zinc content had been realized. After experimenting with various separation processes to treat the complex lead-zinc ores, the differential sulphide flotation process was invented, which in 1920 produced the first lead concentrate on a commercial scale. By 1924, a concentrator had been built near the mine site to handle 2,500 tons or ore per day to produce both lead and zinc concentrates, and by 1934, its capacity had been increased to 8,500 tons per day. A tin circuit was added in 1942. By 1945, about 30,000,000 tons had been treated, and, to 1999, about 130,000,000 tonnes have been mined from an initial resource estimated at 162,000,000 tonnes containing 6.0% Pb, 5.9% Zn, 67 gm/T Ag and 26% Fe (Ransom, 2000). After a long and productive history, the Sullivan mine is scheduled to close in 2001. ■

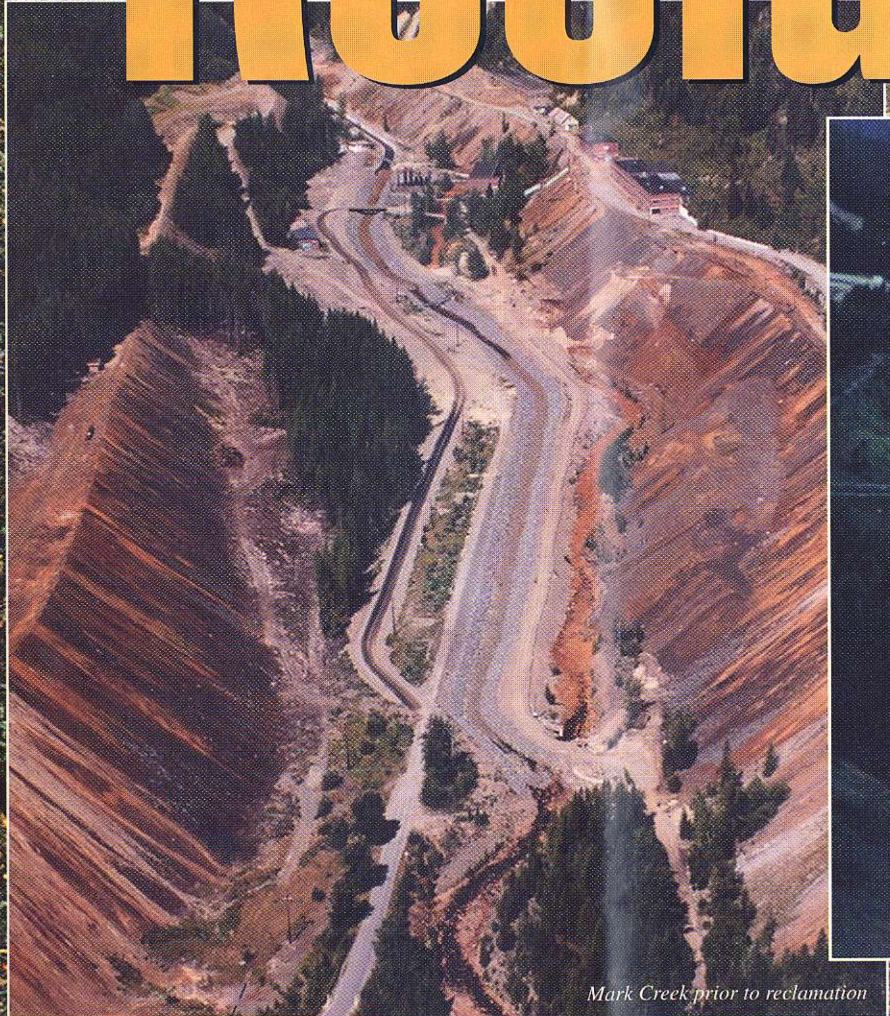
(above) Open pit operation – 1954

(left) Wiring for a blast – 1954

(below) The Kimberley Townsite Rink in 1923

Barring loose rock in a stope – 1935

Sullivan Mine Reclamation



Mark Creek prior to reclamation

Mark Creek after reclamation

Acid Rock Drainage? Metal contaminants? When Sullivan commenced operations in 1909 these terms meant about as much to humanity as "Penicillin" or "Continental Drift."

Programs to address environmental concerns at Kimberley Operations were initiated in the late 1960s with the focus at the time being on reduction of waste discharge directly to watercourses and the reclamation of waste disposal areas on land. A research program was initiated in 1972 to develop revegetation technology for returning waste disposal sites and disturbed land to productive forest and rangeland.

Upgrading of tailings disposal facilities and development and design of a drainage and effluent collection and treatment system was initiated in the mid-1970s. These activities were culminated in October 1979 with the commissioning of the Drainage Water Treatment Plant at a cost of $10 million. With the commissioning of this system, contaminated mine drainage and tailings effluent, which to that point in time discharged to Mark and James Creeks, were now collected and treated before discharge to St. Mary River.

As the exhaustion of the orebody became apparent, a comprehensive decommissioning and closure plan was developed and submitted to the BC Ministry of Energy, Mines, and Petroleum Resources in May 1991, and addressed the principal closure concerns of acid rock drainage abatement, protection of watercourses, reclamation of land and protection of the public from potential safety hazards. In response to public concerns, the Sullivan Public Liaison Committee was established to involve generate input from the public towards the closure plan. This committee was composed of Kimberley City Council, the Bavarian Society, the East Kootenay Environmental Society, the Ktunaxa-Kinbasket Tribal Council, local labour unions, and federal and provincial regulatory agencies. Their response to the closure plan in 1992 identified portions which required further development including groundwater impacts and soil cover systems for tailings and phosphogypsum ponds. Further hydrogeological investigations, soil cover system tests and other studies were also initiated.

Surface Reclamation

Even though mine production is primarily from underground, more than 1,050 hectares of forest and native rangeland have been disturbed by surface activity. These lands are being reclaimed to productive forest and range. Reclamation plans have been developed for each type of land disturbance and are based on research and on-site field investigations conducted over the past 25 years. Appropriate site preparation measures, including recontouring, placement of soil covers and scarification, were applied to enhance vegetation establishment on sites planted with legume, grass and tree species. Soil covers have been placed on waste dumps and tailings and gypsum ponds to reduce precipitation infiltration into the underlying waste.

To December, 1999, 42% of land disturbed by mining and associated activity have been revegetated either by planting or natural regeneration. The indigenous woody plant species used in the revegetation program are propagated from seed and cuttings collected either on the mine site or within the region. 66,066 stems have been planted with 15,600 stems growing in the nursery for planting in 2001. A seed supply equivalent to 337,000 potential trees is in storage.

Watercourse Protection

Prior to 1991, Mark Creek water quality was adversely impacted by seepage and groundwater contaminated by ARD from waste dumps. Seepage discharge was substantially reduced in 1991 with construction of the Mark Creek Diversion. The creek was diverted through a concrete flume and a new riprapped channel along the centre of the valley isolating the creek from seepage flows from waste dumps. Water quality was also affected by discharge of groundwater from aquifers contaminated by waste dump seepage. Geophysical surveys were conducted and monitoring wells were installed to locate the contaminated groundwater stream and provide information needed to develop an effective interception and collection system. Two aquifer dewatering well and pump systems were installed in 1994 and are effectively removing the contaminated groundwater that previously entered Mark Creek.

During the early years of concentrator operation, tailings decant was discharged to Cow Creek. In 1948, a large volume of tailings was released to Cow Creek as result of a dyke failure, inundating the creek channel almost to the St. Mary River. In 1996, a substantial improvement in water quality was achieved with the removal of 318,000 tonnes of tailings and contaminated soil, replacement of 84,000 tonnes of clean sand and gravel to reconstruct the creek channel and revegetation of 12 hectares of bordering land.

Reclamation of the former Gypsum Release Pond was completed in the spring of 1992. The St. Mary Riverbank was reprofiled and covered with riprap, the pond area was leveled and covered with soil material ranging up to one metre thick and the site has been vegetated with grass, legume and native woody species.

A survey of 110 domestic drinking water wells in the Kimberley-Cranbrook region was conducted in 1992. No evidence was found that would indicate that mining and associated operations have impacted groundwater quality on a regional basis.

Acid Rock Drainage

Acid generation will continue in underground workings and possibly waste dumps and tailings after mining ceases. Under these circumstances ARD will be controlled by measures that reduce migration of contaminants from ARD sources to the receiving environment. ARD abatement following mine closure will involve continued operation of the drainage, seepage and groundwater collection systems and the drainage water treatment plant. Measures which reduce acid generation and contamination flushing, including backfilling the open pit with waste rock, placing low permeability covers on waste dumps and tailings ponds and diverting uncontaminated surface drainage, will be in place by 2005. All systems will be maintained, as required, to ensure satisfactory operation. In accordance with reclamation permit requirements, Cominco is in the processor establishing a security bond of $13 million to ensure that sufficient funds are available into the future.

Through the course of the past century, the people of Sullivan witnessed and adapted to great leaps in the understanding of earth processes. They can look back with pride upon their strong positive addition to the legacy of mining. ■

teckcominco

The Sullivan Mine & Sustainable Development

By Doug Horswill,
Vice President, Environment & Corporate Affairs, Cominco Ltd.

Sustainable development in the mining industry means the creation of lasting benefits after an orebody is exhausted. Environmental protection and the avoidance of environmental harm go hand in hand with the responsible operations which sustainable development implies. People often ask how the exploitation of a non-renewable natural resource can be compatible with the concept of sustainable development. The Sullivan mine in Kimberley, British Columbia holds the answer to that question.

The mine began production in 1909 after discovery in 1892. The real key to the mine's economic success, however, came with the development, by Cominco, of the processes necessary to separate lead and zinc minerals in the treatment process. This occurred in 1916. Since that time, the mine has produced ore containing more than 17 million tonnes of zinc and lead metal and more than 285 million ounces of silver for a total value to the British Columbia economy of more than $20 billion dollars in today's prices.

Over the past 91 years of mine operation, the average number of employees has exceeded 1,000 people. With salary plus benefits estimated to average $68,000 per employee, the total contribution from the mine to employees has exceeded $6 billion. Taxes, payments to suppliers and the purchase of local and provincial services, along with smelting and refining of concentrates in Trail, have helped to make up a good part of the mine's $20 billion direct contribution to the local and provincial economies. Beyond the direct contribution, economists often refer to the indirect effects of a major resource industry. These include the economic contribution in the local retail industry, purchases of services, housing, education, etc., through the region. This would amount to three times the direct contribution, or another $60 billion in total gross provincial product added to the B.C. economy from the Sullivan mine over its long and illustrious life.

Typical of the Sullivan situation is the fact that numerous people in Kimberley are fourth generation employees at the Sullivan mine. The number of children who have grown up, earned an education and gone on to other occupations either within the region or outside of it are too numerous to mention. Many individuals who got their start in Kimberley have achieved wide recognition, including some through the arts, others through athletics and many as business professionals.

(left) Mine office and staff quarters – 1912

(above) Schoolchildren learn about reclamation – 1995

The Sullivan mine began when society's consciousness respecting environmental issues was far different than it is today. No one was aware that tailings and waste rock could make run-off water acidic and polluting. However, as this understanding grew, Cominco pioneered the development of high-density sludge water treatment and installed one of the first operating plants in the world in Kimberley in 1979 to treat acidic drainage water.

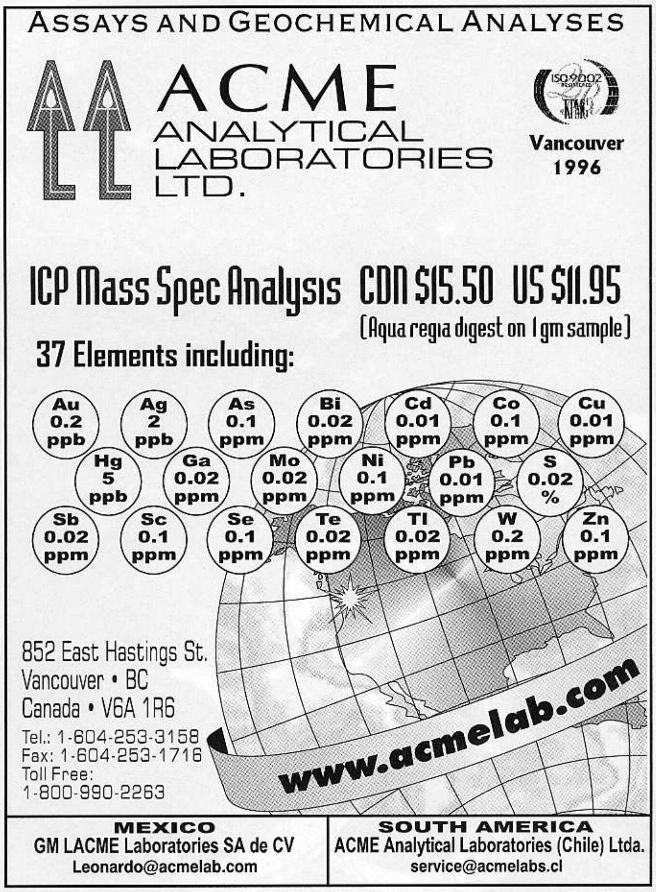
In order to leave a positive environmental legacy behind, Cominco has faced up to the task of reclaiming all of the tailings deposits and waste dumps in the area in order to bring them back to a level of productivity that will sustain wildlife and natural use for the long-term future. This has been based on research with special soil and rock covers that began 22 years ago.

In today's world, Cominco designs its new mines for ultimate closure in order to minimize the environmental consequences and the cost of reclamation. This was not the case in the early part of this century. However, the company recognizes its responsibility to bring the Sullivan mine to an environmentally safe and protected status and will spend in the order of $70 million to accomplish our goal.

One of the keys to sustainability is to ensure that current practices do not hamper the opportunity of future generations to pursue what is in their best interests. Far from hampering that opportunity, the Sullivan mine has vastly enhanced it. The social capital created by the mine's operations – which includes the community of educated and able people, and infrastructure in the form of schools and hospitals, roads and other services, has given the City of Kimberley the foundation upon which it can build its future. Cominco and the City of Kimberley teamed up in the early 1990s to transform the City into a tourist and retirement destination. They have also investigated numerous industrial opportunities, none of which to this point have actually taken root but many of which may take hold in the future.

Land that Cominco has held over the years has been turned over to the City to enable it to develop recreational facilities. The company helped develop the Kimberley ski hill many years ago and it is now being successfully operated as a private undertaking. A new 27-hole golf course is being constructed in Kimberley which will bring the City to the peak of prominence as a golf destination in the East Kootenay area of British Columbia, with the original Kimberley and much newer Trickle Creek courses also within the City's boundaries.

The company's legacy to the community will also include the means to understand the history of mining in British Columbia. A mining museum will be built which will chronicle mining in the region and, of course, it is this industry which founded the entire Kootenay region of British Columbia and of the north western United States. The local Bavarian railroad, the reclamation work and the remaining structures from the mine will all come together to give tourists, students and the public at large an ongoing understanding of the importance of mining and, in particular the Sullivan mine, to British Columbia's past, its present and its future. ■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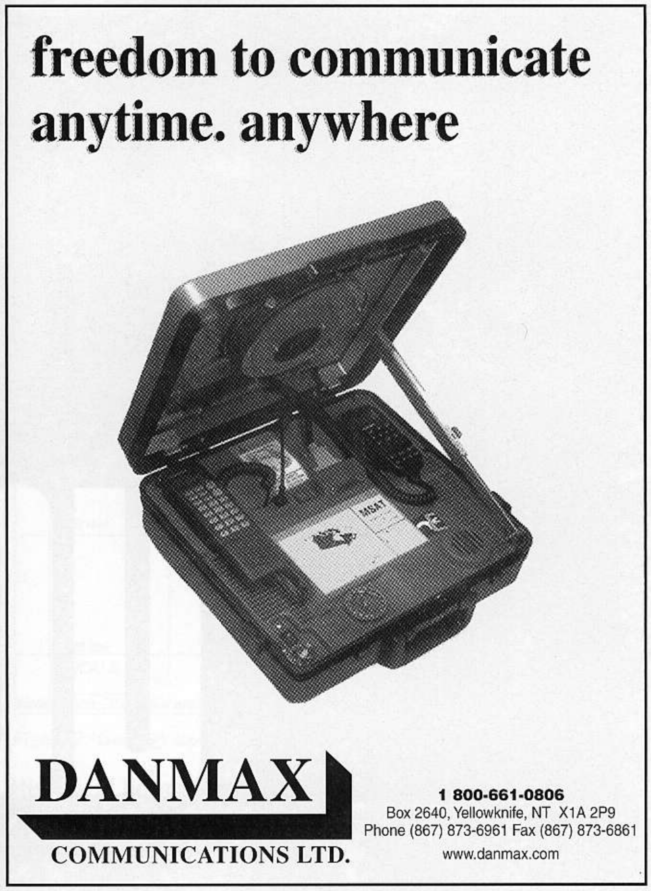
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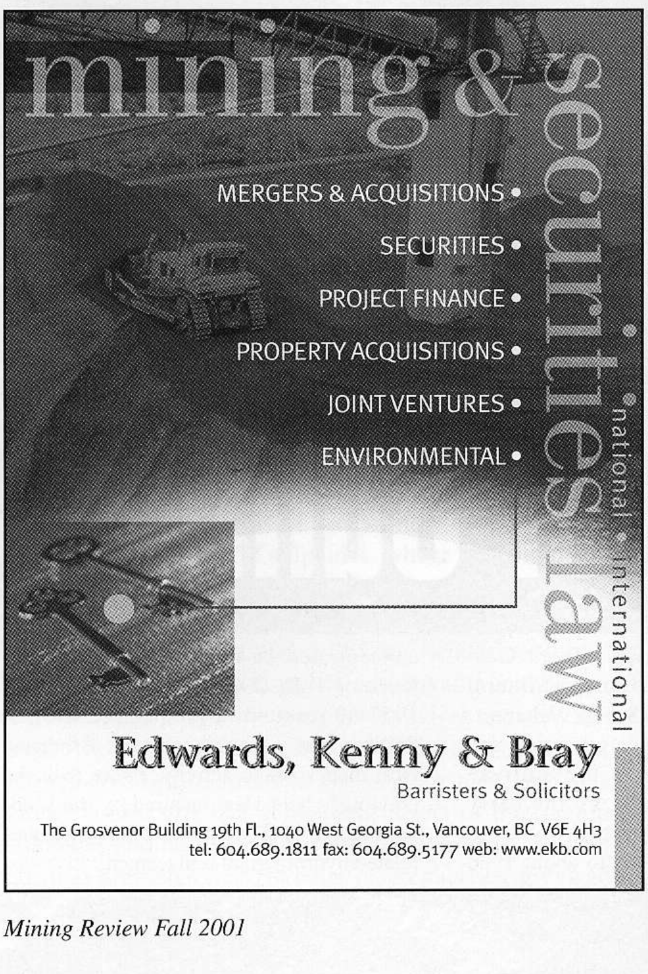
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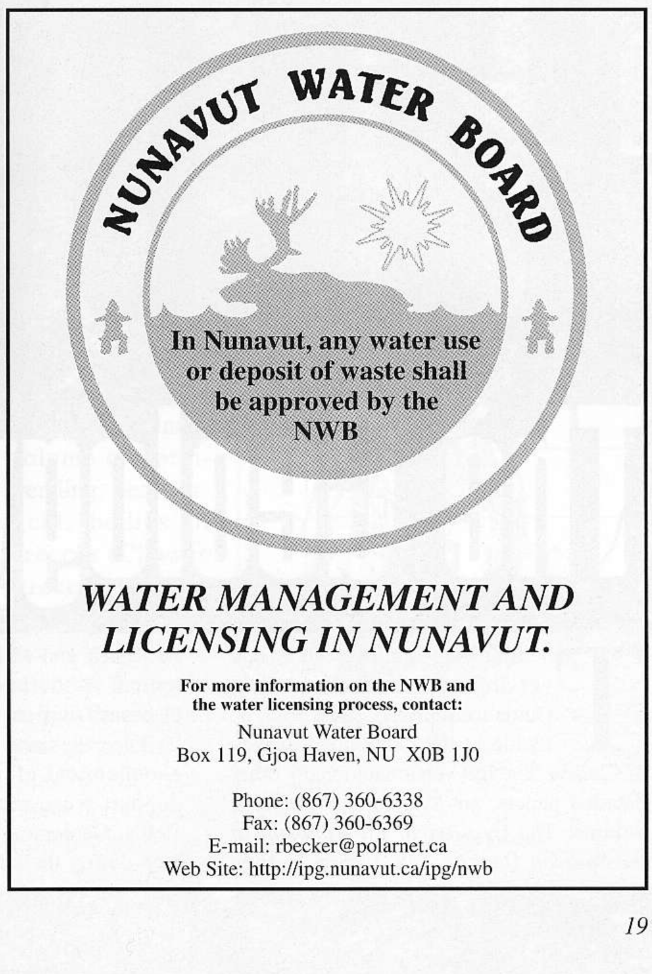
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The Geology of Sullivan

The following is a much shortened version of "GAC Field Trip Guide to Sullivan" 2000, by J.W. Lydon at the Geological Survey of Canada. The full version and many other detailed papers, are available in the large volume: *The Geological Environment of the Sullivan Deposit*, J.W. Lydon, T. Hoy, J.F. Slack and M.E. Knapp, editors, Geological Association of Canada Mineral Deposits Division, MDD Special Volume 1.

The extent and the main geological and geochemical elements of the Sullivan deposit were recognized by the early 1940s. Geological investigations by Cominco during the later 1940s to about 1960 concentrated on regional mapping. The work of O.E. Owens during the period 1957-60 resulted in the perspective that Sullivan was a sea floor deposit associated with mud volcano activity, rather than the previously held view inspired by the Lindgren school of thought that it was a granite-related hydrothermal replacement.

Geological Setting

The Mesoproterozoic Belt-Purcell Supergroup represents the infill and burial of an intracontinental rift. The Aldridge Formation, which hosts the Sullivan deposit, forms the basal part of the Supergroup and consists of a sediment-sill complex that occupies the axial and deepest part of the rift basin. The sediments are mainly turbidites and the sills (Moyie Sills) are of tholeiitic composition. The Sullivan deposit occurs at the top of the Lower Aldridge within a stratigraphic interval that throughout most of the Purcell mountains is commonly marked by a 20 m thick, dark grey, laminated, carbonaceous, argillaceous siltite or arenite (the CWL horizon). The CWL horizon is regarded as a "quiet time," between the argillaceous distal fan turbidites of the Lower Aldridge and the sudden influx of arenaceous turbidites that characterize the Middle Aldridge. In the Sullivan Sub-basin of the Kimberley area, where it is intercalated with mud volcano and hydrothermal rock types, the CWL extends over a stratigraphic interval of up to 200 metres.

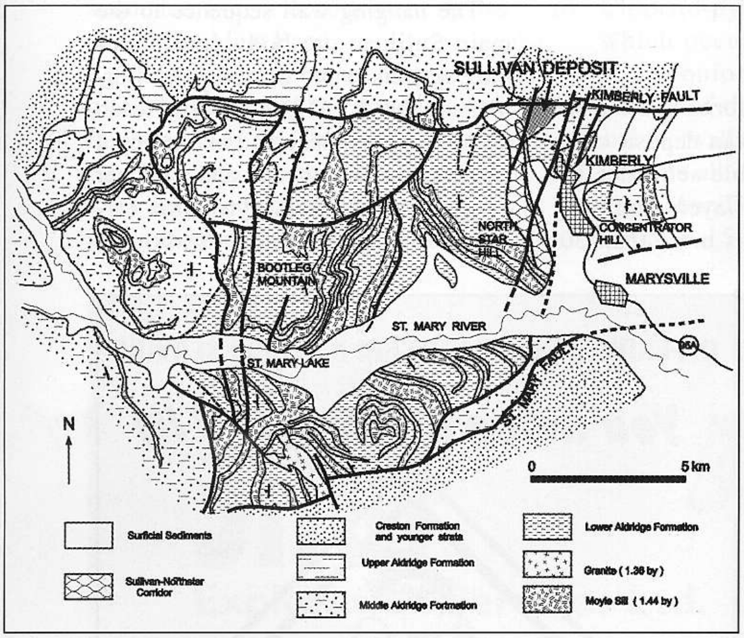

Figure 1: Regional Geology

Deposit Geology

The Sullivan deposit is a classic example of the sedex type of sulphide deposit, which are formed in submarine hydrothermal vent fields of sedimentary basins. It consists of a concordant body of sulphides, whose economic portion is about 2,000 m by 1,600 m in area, and up to 100 m thick (figure 2). The ore body can be divided into a thicker, more massive, western part and a thinner, bedded eastern part, the two being divided along the structurally complex Transition Zone. The western part overlies a sub-vertical hydrothermal upflow zone and alteration pipe, and is termed the Vent Complex. The eastern part, or "Bedded Ores," consists of five concordant layers of interlaminated sulphides and argillite, termed the "Ore Bands" by Cominco, that are separated by beds of arenaceous greywackes termed the "Waste Bands". The ore horizon has been traced about 7 kilometres east and 12 km south of Sullivan.

The main sulphide minerals are pyrrhotite, pyrite, sphalerite, galena and minor boulangerite, with associated magnetite, cassiterite and manganiferous carbonate and garnet. Sulphides accumulated in the crater or on the flanks of a mud volcano.

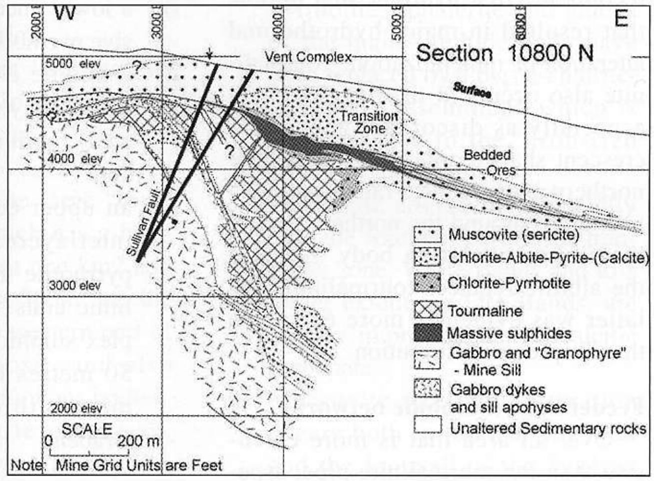

Figure 2: Geology and Alteration Section View

History of Formation

The geology of the deposit can perhaps best be understood in terms of the history of this mud volcano, and contemporaneous or later hydrothermal and tectonic events.

Footwall

The northern two thirds of the deposit is underlain by a pebble conglomerate – the Footwall Conglomerate. It is thickest (80 metres or more) under the vent complex, thins rapidly to the south, and more gradually to the east and to the north.

The Footwall Conglomerate is overlain by a sequence of thin to medium bedded quartz wackes interbedded with pyrrhotite laminated argilllites (Footwall Bedded Sequence) that infilled irregularities on the surface of the former.

Under the Vent Complex, a large volume of north-trending, near vertical, bodies of breccia (Chaotic Breccias) up to 120 m wide and 900 m long formed after the Footwall conglomerate and extend up to the base of the sulphide body (figure 3). The shape and deformation of

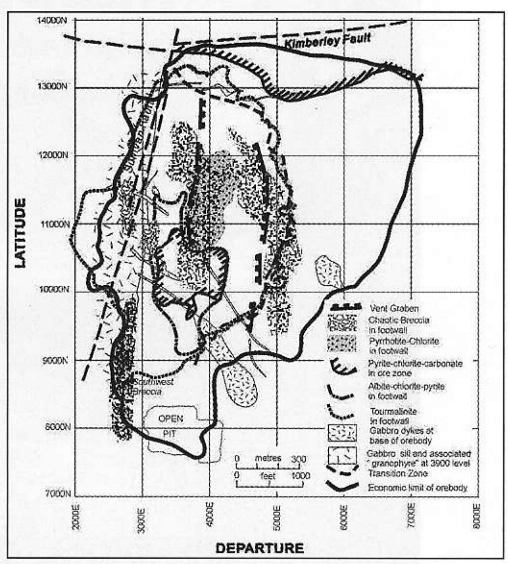

Figure 3: Geology and Alteration Plan View

individual blocks of detached sediments indicate that the wall rocks were in a relatively soft state at the time of brecciation.

Tourmalinite pipe

The pre-ore tourmalinite pipe records the first hydrothermal upflow that resulted in major hydrothermal alteration or mineralization. Tourmalinite also occurs in the hanging wall, especially as discordant zones in a crescent shaped area that follows the northern part of the Transition Zone and wraps around the northern part of the albitite alteration body. Because the albitite replaces tourmalinite, the latter was evidently more extensive than its present distribution.

Feeder zone (Sulphide network)

Over an area that is more extensive than the tourmalinite pipe, especially in a N-S direction, footwall rocks are cut by a variety of discordant sulphide-bearing veins and zones of replacement. The sulphide is predominantly pyrrhotite, with minor sphalerite, and most commonly occurs as veinlets or interstitial disseminations.

Vent Complex Ores

The main sulphide body of the Vent Complex is grossly layered and consists of:

i) a lower uneconomic zone of massive pyrrhotite-rich sulphide;

ii) a middle economic ore zone of crudely layered (tectonically foliated) pyrrhotite-galena-sphalerite; and

iii) an upper economic ore zone of interlayered galena-sphalerite-pyrrhotite massive sulphides and lithic units. The main Vent Complex sulphide body is commonly 50 metres thick, and up to 100 metres thick within the Vent Graben.

Bedded Ores

The Bedded Ores forming the eastern part of the Sullivan deposit consists of a conformable sequence of alternating sulphide layers and siliclastic sediment. It is more than 30 metres thick near the transition zone and gradually tapers to <10 metres at the economic limit of the orebody. A very consistent stratigraphy can be recognised throughout the bedded ores. From base to top, the principal sulphide layers have been termed the "Main," "A," "B," "C" and "D" Ore Bands, and the intervening siliclastic layers the "A," "B," "C," and "D" Waste Bands. Thicknesses of individual Bands, and to some extent the grades of the sulphide layers, change only very gradually laterally.

Contacts between Waste and Ore Bands are commonly sharp and marked by a chloritic displacement surface that may be slickensided.

Hanging Wall Sequence and Ores

The hanging wall sequence to the main Sullivan ore body consists of three sequences of "graded beds" (turbidites), the "I," "H," and "HU," each up to 10 metres thick and marked by a basal, quartz rich arenite and an upper interval of laminated, pyrrhotitic carbonaceous argillite up to about 3 metres thick. Especially in areas above the Transition zone, the laminated pyrrhotitic argillite may contain base metal sulphides that are ore-grade, and form the Hanging Wall ore-bodies. An uppermost carbonaceous silty argillite marks the top of the Lower Aldridge formation.

Transition Zone

The Transition Zone is characterized by spectacular convolute folding of the Bedded Ores and a structural complexity in which stratigraphic correlation between the Bedded Ores and the Vent Complex is lost. The fundamental structure seems to be a zone of reverse faulting or underthrusting, developed during the westwards movement of the Bedded Ores sequence over a decollement at the base of the Main Band.

This structural complexity is but one expression of the fundamental importance of the Transition Zone to the Sullivan Deposit. The Transition Zone marks one of the most important zones of cross-stratal weakness in the Sullivan. It also coincides with the eastern extent of the tourmalinite pipe, and is a locus for chlorite-pyrrhotite alteration and highest Pb:Zn ratios in the Vent Complex, suggesting that it was a main conduit for upflowing ore solutions.

Hydrothermal Alteration

There at least five "stages" of hydrothermal alteration associated with the Sullivan deposit:

i) As described above, tourmaline alteration forms the large "tourmalinite pipe," which has a horizontal area of about one km2 and extends for at least 500m into the footwall under the western part of the Sullivan deposit, and also forms small discontinuous bodies.

ii) Chlorite-pyrrhotite alteration, which occurs principally as a semi-conformable body at the contact of the massive sulphides and footwall tourmalinite.

iii) Chlorite-albite-pyrite alteration is most abundant within a 900m x 900m x 150 m volume in the immediate hanging wall of the Sullivan deposit vertically above the tourmalinite pipe.

iv) Pyrite-carbonate alteration. Immediately below the body of hanging wall albite-chlorite-pyrite alteration, but of lesser lateral extent, pyrrhotite, sphalerite and galena of the main sulphide body have been replaced by a pyrite-chlorite-carbonate assemblage which is most intense in the "iron-rich core."

v) Carbonate alteration. Especially near the southern part of the transition zone, Waste Bands and to a lesser extent the Ore Bands, are heavily impregnated with calcitic carbonate.

vi) Muscovite (sericitic) alteration occurs both in the hanging wall and the footwall of the Sullivan deposit, forming an envelope around the entire deposit, and also occurs along the extent of the Sullivan Corridor.

vi) Various other alteration types of only local or sporadic extent, including chlorite-biotite-garnet and carbonate-muscovite near the eastern margin of the tourmalinite zone and silicification near zones of muscovite-altered tourmalinite.

These various types of alteration span the history of ore-forming events at Sullivan, and most are not directly related to the main ore-forming event itself. Only the chlorite-pyrrhotite alteration has been linked to the main ore-forming event. The chlorite-albite-pyrite, pyrite-carbonate, and carbonate alteration are all probably linked to the emplacement of the Mine Sill.

Sills and dykes

The Mine Sill, which is one of the tholeiitic gabbroic Moyie Sills, was emplaced about 500 metres stratigraphically below the eastern part of the Sullivan deposit, but cuts across stratigraphy along a fault structure that is presumed to form the western edge of the Sullivan sub-basin. Dyke-like apophyses from the sill are also observed.

Lamprophyre dykes, of presumed Cretaceous age cut the deposit in various places.

Zonation

There is a strong, semi-concentric zonation of the Sullivan orebody about the vent complex, in terms of thickness as well as grade, composition and mineralogy of the ores.

Thickness

The Sullivan deposit thins in all directions away from the central part of the vent complex. Thickness of the Waste Bands tend to mimic the thickness of the overlying Ore Band. The "A" and "B" Waste, although generally thickest on average just east of the northern part of the Transition Zone, show the same range of thicknesses in all parts of the Bedded Ores.

Metal Zonation

The Sullivan Deposit as a whole is strongly concentrically zoned with respect to Pb:Zn ratios, which gradually decrease away from the feeder zones along the trends of the northerly trending faults that mark the boundaries of the Vent Graben of the

Vent Complex. Tin and copper is concentrated along the same hydrothermal upflow zones marked by the highest Pb:Zn ratios.

Ore Genesis

There has been consensus that Sullivan is a sea floor deposit since the publications by Ethier et al. (1976) and Hamilton et al. (1982). It is generally agreed that the sequence of events that have impacted the present geological characteristics of the deposit are:

1. Hydrothermal eruption (mud volcano activity) involving partly consolidated sediment to form the Footwall Conglomerate.
2. Formation of the Chaotic Breccias and the Footwall bedded Sequence basin during collapse of the surface due to tectonic extension and/or crater formation.
3. Upflow of hydrothermal fluids that formed the tourmalinite pipe.
4. Venting of hydrothermal fluids, together with intermittent mud volcano activity, that formed the sulphide body, the upflow being concentrated along the bounding faults of the Vent Graben and continuing up to the time of the HU stratigraphic level.
5. Upflow of hydrothermal fluids to form the albite-chlorite alteration and the pyrite-carbonate of the Iron Core and presumably the pyrite-carbonate replacement along the Kimberley Fault.
6. Metamorphism during the ca1350 Ma East Kootenay Orogeny, and deformation/metamorphism during the 65-165Ma Jurassic Paleocene thrusting, has recrystallized and mineralogically reconstituted both wall rocks and sulphides.

However, there is still much debate as to a consistent and rational explanation of all features of the deposit. Not the least is whether Sullivan ores, particularly the Bedded Ores, are metalliferous sediments of a brine pool, or whether they represent a subsurface impregnation of unconsolidated sediment. A sedimentary origin is supported by the stratigraphic variation of sulphur and carbon isotopes and the visual similarity of the Bedded Ores to the Red Sea brine pool metalliferous sediments. A subsurface replacement model is supported by the strongly discordant metal zonation pattern, and the rapid lateral change in mineralogy of the Bedded Ores, both of which are not consistent with a totally sedimentary origin. The two views are not incompatible – zone refinement takes place in the subsurface as hydrothermal products accumulate on the sea floor. ■

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The Biggest Blast

A single, calculated blast broke loose 506,000 tons of ore, setting an all-time record

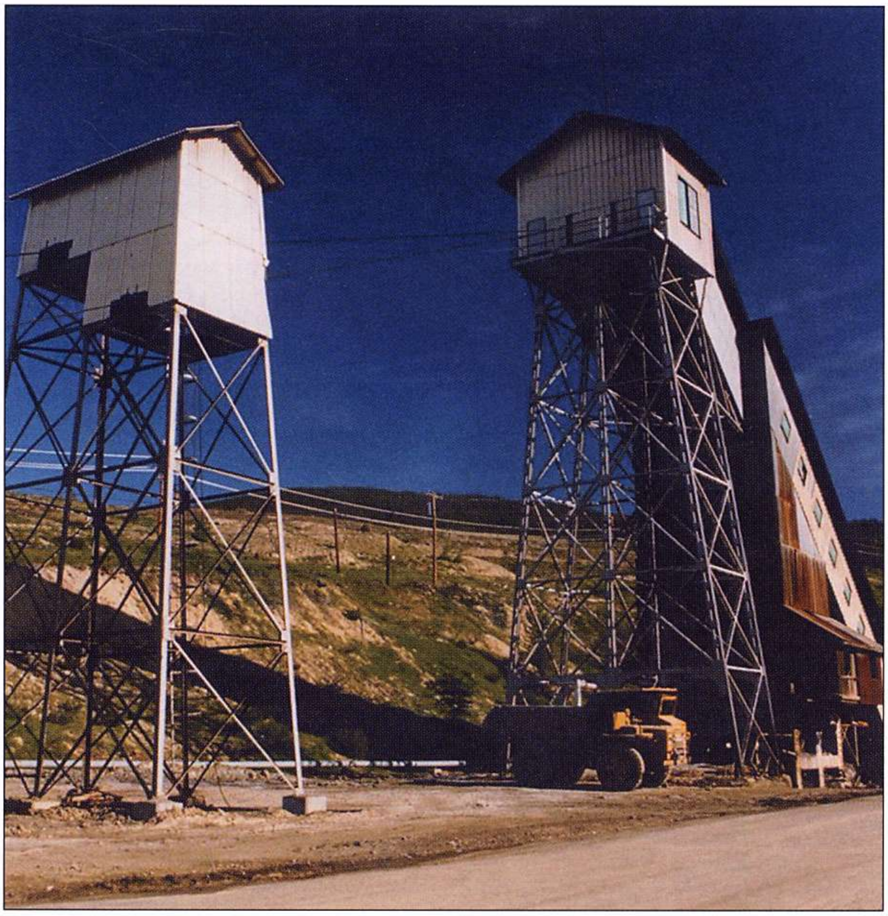
By Robert Simpson

Underground blasting was old stuff at the Sullivan Mine – it was done every day. But on August 15, 1953, the biggest blast of them all was set off. A single blast broke 506,000 tons of ore – an all-time record for Sullivan and also the largest known tonnage broken in a single blast underground in North America.

The ore blasted a T-shaped pillar that measured 92 metres (300 feet) high, 92 metres (300 feet) long and (76 metres) 150 feet wide. Strangely enough, the 31 tons of explosive which was used in this blast to loosen the record breaking tonnage of ore, was six tons less than the previous record blast fired at the Sullivan Mine two years prior, which loosened 271,000 tons of ore.

"Larger underground blasts have recorded since 1953, but the engineering and blasting technology used at the Sullivan mine was cutting edge. The mine was one of the first to combine pillar mining techniques and such a large blast," says Ron LeRue, a University of Toronto Mining Historian.

The first pillar blast at the Sullivan was done in 1943. Prior to this the Sullivan was mined mainly in large



open stopes or cavities. Miners carried out a daily drilling-blasting routine in these large excavations. The ore fell by gravity into ore passes below. By this method large tonnages were taken from the mine. At intervals, a large block of ore was left to act as a pillar or a support to prevent caving. In the interest of safety in the mine, these large excavations were filled with surface material, which left large pillars of ore spotted throughout the mined area.

To recover the ore from these pillars, an opening was driven into the pillar and long drill holes fanned out from tunnels to completely honeycomb the block of ore. Then in one single blast the ore is broken up.

In the 1953 blast base, the 45,000-square-foot ore body was severed by five parallel tunnels – raises and down holes were driven up to the ore from these tunnels. From the tunnels, long blast holes were drilled into the ore body providing the best possible distribution of the explosives.

The drilling of the holes for this blast took 2,090 man-shifts. There were 90,000 feet of diamond drill holes and another 20,000 feet of percussion drill holes. Altogether there were 2,250-diamond drill and 1,000 percussion drill holes loaded with explosives. Each hole was then primed with a delay electric blasting cap. The proper delay was inserted into each hole so that it could be fired in the correct rotation. There were 18 different delays, and the total time for all 18 intervals was only three quarters of a second apart.

After all the holes had been loaded and primed, the detonator wires were connected in a series of 50. Then each group of 50 caps was connected in parallel to the main blasting lines. The loading priming and hooking up of all the caps and series took a total of 450-man shifts.

"A blast the size of the one detonated in 1953 required a great deal of preparation and co-ordination, and remains on the record books because of the role it played in advancing underground mining techniques," says LeRue. ■

Prospecting School Partnership

BCYCM's H.V. Warren School of Prospecting Joins Forces with BCIT

Granduc, Faro, and Highland Valley are just some of the big names in our industry that in part owe their discovery to the volunteer instructors who have contributed to BC & Yukon Chamber of Mines Prospecting School. Since 1918, it has offered an intensive outline of the many facets of Prospecting to all that care to learn. Tom McQuillan, Al Kulan, and "Spud" Huestis, the prospectors who discovered these ore deposits, all took the skills they were taught here in Vancouver and transformed some of our vast wilderness into great sources of wealth.

The school's namesake, Harry Warren, was the principle proponent of the course over a span of 50 years! Combining efforts with others from the Geoscience faculty at U.B.C., the course was taught at Point Grey High School until the early 80s when more industry volunteers were solicited and it moved to the downtown campus of Vancouver Community College and then on to the Dunsmuir Seniors Centre. The content of the course has remained relatively constant through the years. For two hours a night, two nights a week, over a three month span, students are walked through the fundamentals of geology, ore deposits, exploration methods, and business considerations.

Annual course attendance has averaged in the 40-50 student range, with events such as the $800 gold price and the flow through shares boom pushing the records of attendance to well over 100. The general public, investor relations personnel, and administrative staff from exploration oriented businesses have all completed the course and taken away a solid understanding of both mineral exploration and mining.

In 1961, the British Columbia Institute of Technology (BCIT) introduced its first mining course. The Chamber helped out the cause then by producing and distributing several thousand copies of a very popular brochure entitled "A Career for You in Mining." BCIT's Mining Technology Department currently offers a well respected and recognized diploma program. Students spend an intensive two years covering geology, exploration techniques, mineral deposits, mining methods, surveying, AutoCAD and GIS, assaying, mineral processing, and more. The similarities in subject matter with the BCYCM's Prospecting School are readily apparent, and our joining of resources can only result in benefits for all people involved. Students will gain a BCIT credit, a tax deductable course fee, and the great resources of BCIT's teaching facilities at the Burnaby campus; including rock and mineral suites, map sets, and working examples of various exploration tools. Our Volunteer instructors may also appreciate this as they won't need to lug their own rock sets out to class!

Several other courses are being planned, including an advanced field-based prospecting school in conjunction with the BC Geological Survey and a course on the mineral exploration business aimed at brokers and investors. Professional development throughout our industry is a role that our Membership is very well suited to fill, and the partnership lays down a good foundation for future growth in this area.

If you wish to recommend this course to interested parties, direct them to either www.chamberofmines.bc.ca, or www.mining.bcit.ca for further details and registration information. ■

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