103P/6W
103P 120
884621

Kitsault (Lime Creek) molybdenum mine, northwestern British Columbia

C.J. HODGSON
Canada Tungsten Inc., Vancouver, British Columbia

Introduction

The Kitsault molybdenum mine is located 600 m above sea level on Lime Creek at the head of the inlet of Alice Arm, 140 km northeast of Prince Rupert, British Columbia (Fig. 1). The area of the mine is characterized by rugged topography and deeply incised creeks which drain into the Portland Canal - Observatory Inlet fjord system. Access is by air service or boat from Prince Rupert, or by secondary road from Terrace.

History

The deposit was first staked in 1911, at which time the main feature of interest was a polymetallic vein with values in silver located southeast of the molybdenum deposit (Woodcock and Carter, 1976). Turnbull (1916) was the first to describe the extensive zone of criss-cross quartz stringers with MoS_2 on the banks of Lime Creek which, although it clearly had the potential to contain a major deposit, was not then believed to be of commercial value.

Following sporadic work through the 1920s and early 1930s, the ground lay idle until 1959 when Kennco Explorations (Western) Ltd. commenced a program of systematic diamond drilling on the stockwork-type mineralization adjacent to Lime Creek. In late 1964, Kennco announced the presence of an orebody of 36 million tonnes averaging 0.23% MoS_2 which was to be put into production at a rate of 5450 tonnes per day under a new subsidiary, British Columbia Molybdenum Ltd., at a forecasted capital cost of $20 million (revised to $30 million).

Between January 1968 and April 1972, 10.4 million kg of molybdenum were produced from 9.3 million tonnes of ore, at an average mill recovery of 90%, and with an average mill head grade of 0.206% MoS_2. The ore was mined in an open pit with a waste to ore stip ratio of 1.5 to 1. The operation was terminated in 1972 due to weak molybdenum prices and escalating costs.

In May 1973, the deposit was purchased by Climax Molybdenum Corporation of British Columbia, Limited and in 1979 transferred to affiliate Amax of Canada Limited. In early 1979, following completion of detailed feasibility studies, Amax commenced construction of the 10 900 tonne per day Kitsault mine and mill complex based on a mineable open pit reserve of 95 million tonnes at an average grade of 0.192% MoS_2, sufficient for a mine life of 25 years. The original capital cost estimate was $143 million; it subsequently escalated to approximately $200 million.

Mine operations commenced in April 1981, and over a period of one and a half years a total of 4.25 million kg of molybdenum were produced from 4.56 million tonnes of ore. Operations were curtailed in November 1982 due to declining molybdenum prices. The mine has since been held on an extended care and maintenance basis.

Geology and Mineralization

The geology of the deposit has been described in previous papers (Woodcock and Carter, 1976; Steininger, 1985), to which the reader is referred for greater detail. No new geological information has been generated since curtailment of operations. The regional geological map in Figure 2 is adapted from that in the paper by Woodcock and Carter (op. cit). Molybdenite at Lime Creek is associated with the Lime Creek Intrusive Complex (Steininger, 1985), a small elliptical stock of diorite to quartz monzonite composition, measuring 450 m by 600 m in dimension, with a southeastern appendage about 400 m long (Fig. 2). The complex intrudes greywacke and argillite of the Jurassic Bowser Lake Group which, in a zone 300 m to 500 m wide adjacent to the complex, are metamorphosed to biotite hornfels changing outward to albite-epidote hornfels.

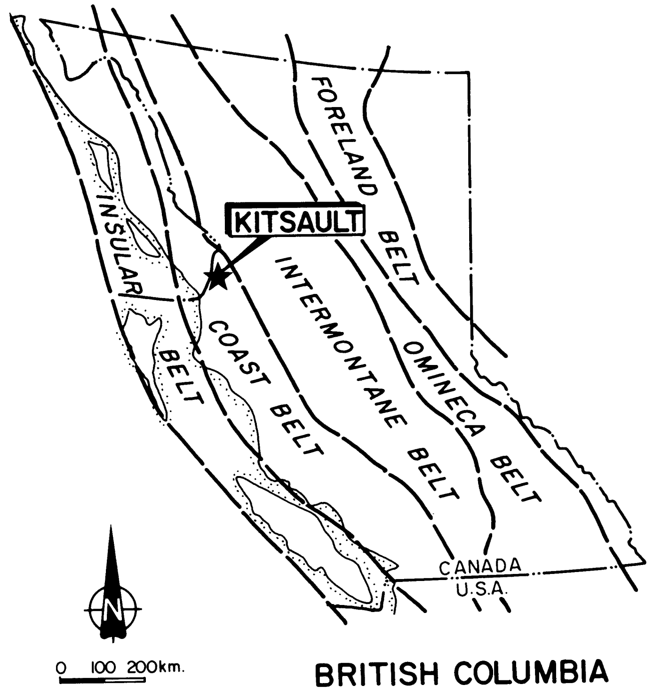

FIGURE 1. Location map of Kitsault property.

Molybdenite mineralization occurs in a ring-shaped stockwork zone. Based on the 0.1% MoS_2 isograd, the zone is 30 m to 180 m wide and 500 m to 600 m in outside diameter (Fig. 3). It follows roughly the north, east and west margins of the stock, while its southern limit passes through the centre of the stock. In cross-section, the zone is cylindrical and extends to a maximum depth of 250 m (Steininger, 1985). The centre of the annulus is occupied by barren quartz veins, while barren quartz-pyrite veins predominate outside the outer 0.1% MoS_2 isograd. Four main ages of molybdenum mineralization are recognized: early disseminations in aplite dikes, and late banded quartz-molybdenite veins. Throughgoing polymetallic quartz veins containing base metal sulphides and Pb-Bi sulphosalts as well as minor scheelite and molybdenite cut all other sulphide veins.

Hydrothermal alteration of variable intensity consists of vein envelopes of sericite at the outer margins of the ore zone, vein enve-

Astride the contact of the rhyolite plug with Hazelton Group volcanic rocks and the granodiorite quartz stockwork veins coalesce to form a high silica zone that mimics the shape of the top of the plug (Fig. 2). The high silica zone averages 40 m thick and contains trace fluorite, topaz, magnetite and biotite.

Hydrothermal alteration is fracture controlled. Vein alteration haloes rarely exceed a metre in width. Where veins are numerous, overlapping haloes form zones of pervasive alteration but deposit scale zonation has not been established. Within Hazelton Group rocks, hydrothermal alteration includes Na metasomatism, silicification and destruction of mafic minerals resulting in bleaching of the lithologies. Within the granodiorite sill alteration includes the development of pink potassic alteration which envelops magnetite, quartz, stockwork molybdenite, and pegmatitic quartz-molybdenite veins. Grey or greenish-grey phyllic alteration envelops magnetite, quartz and banded quartz-molybdenite veins. Three pulses of hydrothermal fluids are interpreted from the cross-cutting relationships of the alteration envelopes.

Economics

The distribution of molybdenite is unpredictable due to its erratic occurrence in pegmatitic and banded veins. The nugget effects of these high-grade veins caused non-reproducibility of assays from split core and problems in ore zoning using standard techniques. During 1979 to 1980, HQ core was drilled and entire lengths of core were crushed and split to obtain samples for assay that were representative and reproducible. Geological cross-sections were then constructed using computerized drill hole data from drill fans on sections at 30 m spacing above the 15000E cross-cut. Ore zones based on 0.1%, 0.2% and 0.3% MoS_2 cutoffs were interpreted on 23 cross-sections and MoS_2 grade was calculated using the assays and a tonnage factor. The ore zones were digitized and kriging techniques were used to establish MoS_2 grade within the ore zones on 30 m benches. From this a 20.6 million tonne reserve was defined grading 0.401% MoS_2 and 0.041% WO_3 at a 0.2% MoS_2 cutoff. Other areas containing similar swarms of veins are recognized on the property; however, they have not been tested by close-spaced drilling to define reserves.

Discussion and Conclusions

Glacier Gulch is a fracture-controlled Mo-W deposit spatially, temporally and genetically associated with Late Cretaceous to Early Tertiary Bulkley porphyritic quartz monzonitic intrusion. The quartz-molybdenite stockwork, one of the intrusion-centred vein assemblages, contains most of the molybdenum. Stockwork formation is attributed to recurrent fracturing during intrusive movement and hydrofracturing by hydrothermal fluids emitted from magma that formed the rhyolite plug and the Hudson Bay composite stock. Host rocks were domed and fractured and steeply dipping radial dikes, veins, fractures and joints indicate vertical orientation of the maximum principal stress during emplacement of the Hudson Bay Mountain stock. High-grade zones correspond to banded quartz-molybdenite in steeply dipping radial vein sets and moderately to gently dipping concentric vein sets. These banded veins are more abundant in the granodiorite sill in which a lack of structure and a contrasting competency with the Hazelton Group volcanic rocks allowed dilational fractures to develop better. High-grade zones also correspond to clots and rosettes of molybdenite in pegmatitic veins. These are believed to have formed under nearly static conditions as open-space fillings of tensional fractures which opened during one event. This large deposit has not been fully explored.

Acknowledgments

Thanks are extended to Climax Molybdenum Corp. of B.C. for providing the author with the opportunity to publish this article and the Northwest Territories Geology Division for its support.

REFERENCES

ATKINSON, D., 1983a. The Geology of Glacier Gulch, a porphyry molybdenum-tungsten deposit (abstract). Canadian Institute of Mining and Metallurgy, CIM Bulletin, 76, 857, p. 50.

ATKINSON, D., 1983b. The geology of Glacier Gulch — A porphyry molybdenum-tungsten deposit (preprint). CIM 8th District Meeting, 11 p.

BRIGHT, M.J. and JONSON, D.C., 1976. Glacier Gulch (Yorke-Hardy). *In* Porphyry Deposits of the Canadian Cordillera. *Edited by* A. Sutherland Brown. Canadian Institute of Mining and Metallurgy, Special Volume 15, p. 455-461.

CARTER, N.C., 1974. Geology and geochronology of porphyry copper and molybdenum deposits in west-central British Columbia. Unpublished Ph.D. thesis. The University of British Columbia, Vancouver, British Columbia, 236 p.

KIRKHAM, R.V., 1966. Glacier Gulch Molybdenum Deposit. British Columbia Department of Mines, Annual Report, p. 86-91.

KIRKHAM, R.V., 1969. A Mineralogical and Geochemical Study of the Zonal Distribution of Ores in the Hudson Bay Range, British Columbia. Unpublished Ph.D. thesis, University of Wisconsin, Wisconsin, 152 p.

KIRKHAM, R.V., McCANN, D.C., PRASAD, N., SOREGAROLI, A.E., VOKES, F.M. and WINE, G., 1982. Molybdenum in Canada - Part 2: MOLYFILE — An index-level computer file of molybdenum deposits and occurrences in Canada. Geological Survey of Canada, Economic Geology Report 33, 208 p.

KIRKHAM, R.V. and SINCLAIR, W.D., 1988. Comb quartz layers in felsic intrusions and their relationship to porphyry deposits. *In* Recent Advances in the Geology of Granite Related Mineral Deposits. *Edited by* R.J. Taylor and D.F. Strong. Canadian Institute of Mining and Metallurgy, Special Volume 39, p. 50-71.

SHANNON, J.R., WALKER, B.M., CARTEN, R.B. and GERAGHTY E.P., 1982. Unidirectional solidification textures and their significance in determining relative ages of intrusions at the Henderson Mine, Colorado. Geology, 10, p. 293-297.

WHITE, W.H., HARAKAL, J.E. and CARTER, N.C., 1968. Potassium-argon ages of some ore deposits in British Columbia. Canadian Institute of Mining and Metallurgy, CIM Bulletin, 61, No. 679, p. 1326-1334.

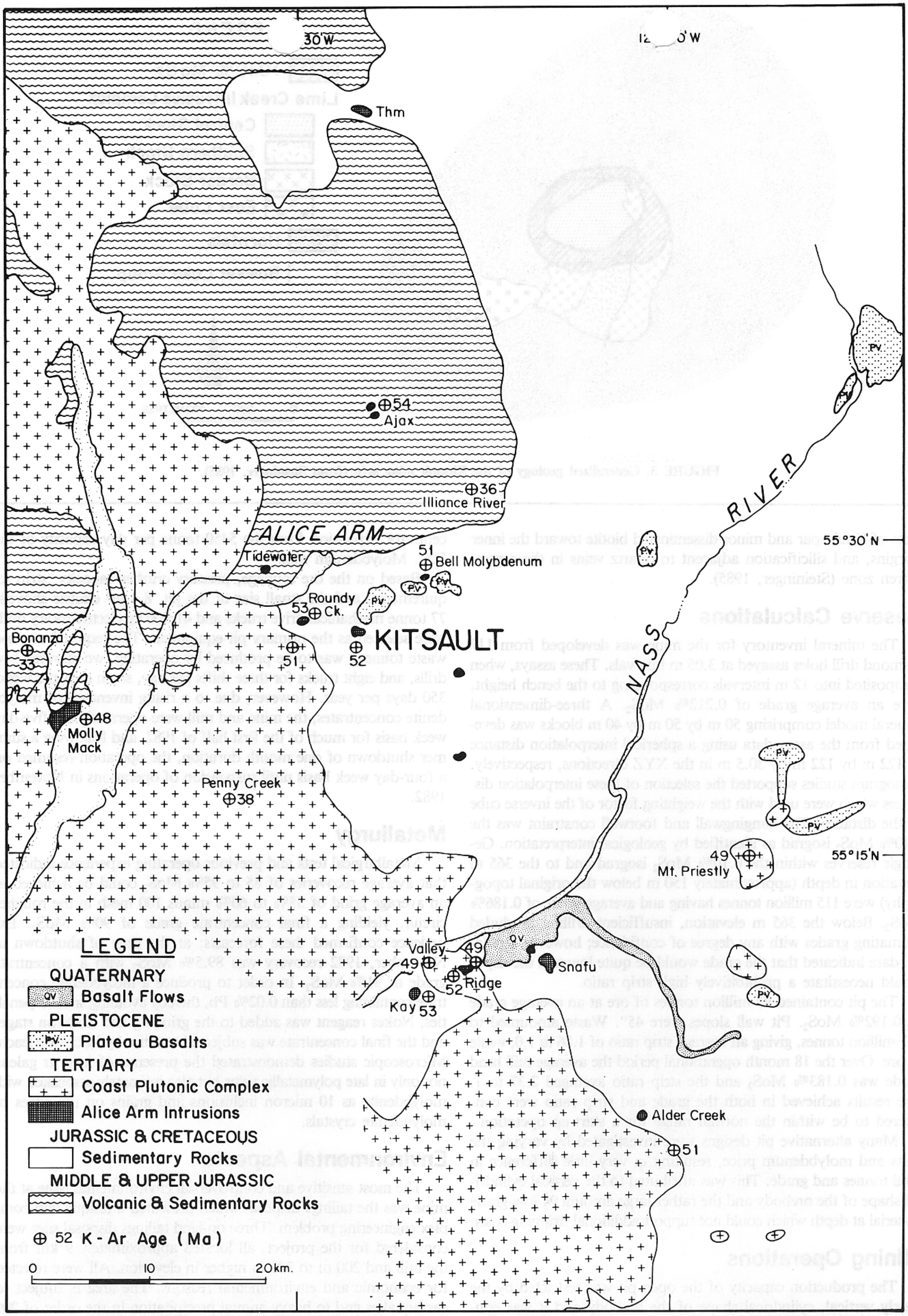

FIGURE 2. Geology of the Alice Arm area (after Woodcock and Carter, 1976).

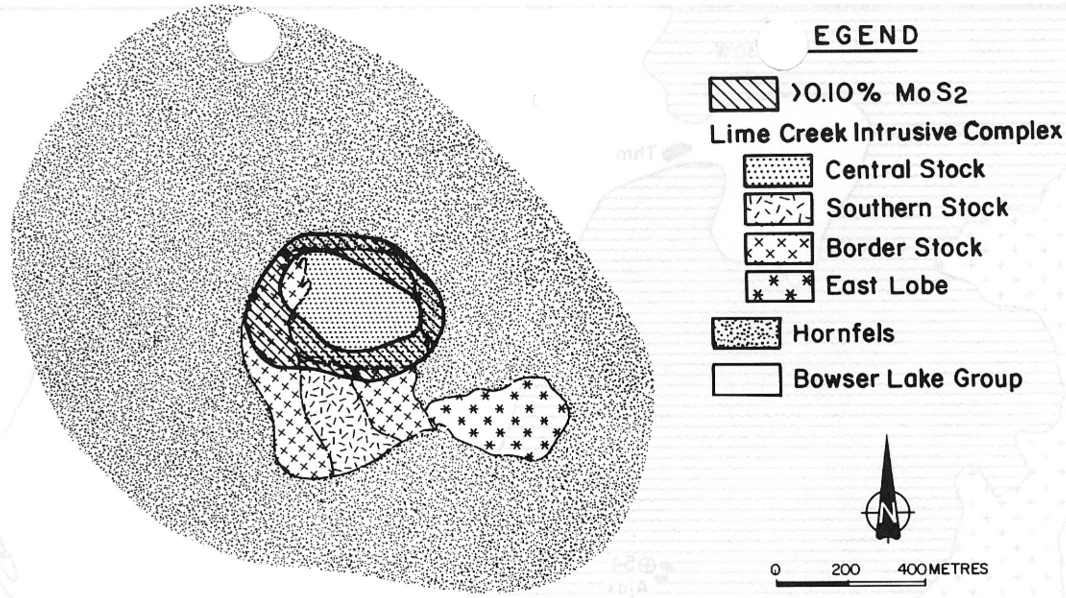

FIGURE 3. Generalized geology of the Kitsault mine area (from Steininger, 1985).

lopes of K-feldspar and minor disseminated biotite toward the inner margins, and silicification adjacent to quartz veins in the central barren zone (Steininger, 1985).

Reserve Calculations

The mineral inventory for the mine was developed from 117 diamond drill holes assayed at 3.05 m intervals. These assays, when composited into 12 m intervals corresponding to the bench height, gave an average grade of 0.212% MoS_2. A three-dimensional mineral model comprising 50 m by 50 m by 40 m blocks was developed from the assay data using a spherical interpolation distance of 122 m by 122 m by 30.5 m in the XYZ directions, respectively. Variogram studies supported the selection of these interpolation distances which were used with the weighting factor of the inverse cube of the distance. The hangingwall and footwall constraint was the 0.10% MoS_2 isograd as identified by geological interpretation. Geologic reserves within the 0.10% MoS_2 isograd and to the 365 m elevation in depth (approximately 150 m below the original topography) were 115 million tonnes having and average grade of 0.186% MoS_2. Below the 365 m elevation, insufficient drilling precluded estimating grades with any degree of confidence; however, available data indicated that the grade would be quite low and the depth would necessitate a prohibitively high strip ratio.

The pit contained 95 million tonnes of ore at an average grade of 0.192% MoS_2. Pit wall slopes were 45°. Waste amounted to 177 million tonnes, giving an average strip ratio of 1.86 to 1.0, waste to ore. Over the 18 month operational period the average mill head grade was 0.183% MoS_2 and the strip ratio averaged 2.37 to 1. The results achieved in both the grade and strip ratio were considered to be within the normal range for a start-up operation.

Many alternative pit designs were investigated by varying the costs and molybdenum price, resulting in very little difference in total tonnes and grade. This was attributed to the vertical cylindrical shape of the orebody and the rather large amount of low-grade material at depth which could not support additional stripping costs.

Mining Operations

The production capacity of the open pit was restricted by the nearly vertical, cylindrical shape of the orebody and it was considered unlikely that tonnages exceeding 10 900 per day could be sustained over long periods of time. This operating rate allowed maximum use of existing equipment and required minimum concentrator expansion from the 5450 tonne per day capacity of the B.C. Molybdenum mill.

Based on the ore tonnage, primary crusher capacity, strip requirements, and the small size of the pit, 8.4 m^3 electric shovels, 77 tonne mechanical drive trucks and 41 000 kg electric rotary drills were selected as the primary pit equipment. The required ore and waste tonnage was to be produced by operating two shovels, two drills, and eight trucks for three shifts per day, seven days per week, 350 days per year. However, due to a rising inventory of molybdenite concentrates, the mine and mill were operated on a five-day week basis for much of the first half of 1982, and following a summer shutdown of one month duration, the operation resumed on a four-day week basis until suspension of operations in November 1982.

Metallurgy

Metallurgical tests and previous operating experience indicated that average recoveries of 85 to 95% MoS_2 could be achieved at an average grind of 55% to 60% minus 100 mesh in the rougher circuit, yielding a final concentrate grade of 90% MoS_2. Experience confirmed these forecasts; at the time of shutdown in November, 1982 recovery was 89.5% MoS_2 with a concentrate grade of 91% MoS_2. In order to produce a molybdenite concentrate containing less than 0.02% Pb, thereby avoiding smelter penalties, Nokes reagent was added to the grinding and flotation stages and the final concentrate was subjected to a hot hydrochloric leach. Microscopic studies demonstrated the presence of lead as galena not only in late polymetallic veins but also intimately associated with molybdenite as 10 micron inclusions and grains on the edges of molybdenite crystals.

Environmental Aspects

The most sensitive and controversial environmental issue at the mine was the tailings disposal which presented a unique and complex engineering problem. Three on-land tailings disposal sites were considered for the project, all located approximately 9 km from the mill and 200 m to 300 m higher in elevation. All were rejected for economic and environmental reasons. The area is subject to earthquakes and to heavy annual precipitation in the order of 200 cm per year. With the possibility of heavy flash flooding after rainstorms, stability of tailings containments on land could not be assured at any economically feasible cost.

Marine disposal of tailings into the 365 m depths of Alice Arm was selected. Tailings were transported [illegible] cm polyethylene pipe over a distance of 7.25 km horizontally and a 460 m vertical drop from the mill to Alice Arm. Concrete drop boxes spaced every 50 m to 100 m along the tailings pipe maintained a grade of 0.8% and a fluid velocity of 1.8 m/sec. to 2.1 m/sec. The tailings were discharged 50 m below the surface of Alice Arm into the more tranquil deep waters not subject to wave action.

Systematic monitoring of metal content of both marine sediments and benthic marine species in Alice Arm conducted by Amax during and subsequent to the operating period confirmed the conclusions of the original studies, that the disposal system would have minimal impact on the ecological system of the inlet. The monitoring studies demonstrated that the distribution of deposited tailings has remained virtually unchanged since 1982; that a levelling off of metal contents in surface sediments occurred subsequent to cessation of mining as the layer of natural sediments covering the tailings deposits continued to increase in thickness; and that no progressive bioaccumulation of metals has occurred over time in the benthic marine species monitored. With equilibrium having been demonstrated over eight consecutive years (1982 to 1990), the monitoring program was suspended following the 1990 survey with the approval of both federal and provincial authorities.

Conclusions

During its brief productive life, virtually all operational parameters at the Kitsault mine were either as predicted from the feasibility study of within the normal range of variance expected for a start-up operation. As such, the Kitsault mine was a technical success from both an operational and environmental protection point-of-view. However, Kitsault is also an example of both the economic vulnerability of a relatively high-cost mining operation and the importance of timing with respect to mine development in order to capitalize on favourable market conditions.

The development of the mine was undertaken to enable Amax to meet its customers' requirements in the face of a world-wide shortage of molybdenum which appeared to be developing in the late 1970s. Unfortunately, by the time the Kitsault mine was operational in the early 1980s, the global economy had slipped into one of the deepest and most prolonged recessions in recent history. Molybdenum consumption was in sharp decline while production, due in part to the slow response of the principal producers, continued to rise. The resultant metal surplus translated directly into unsold inventory and sharply lower prices. In 1979, the year of commencement of construction, the average U.S. spot price for molybdenum was US$23.86 per pound. In November 1982, at the time of shutdown, the U.S. spot price was US$3.06 per pound. This compared to an operating cost per pound of molybdenum produced at Kitsault in 1982 of US$4.84, or $4.48 allowing for a silver credit of $0.36. Since shutdown, molybdenum prices have continued to remain depressed due to the large molybdenum inventories held during much of the 1980s and, more recently, to increased by-product production from porphyry copper deposits. For Kitsault, that particular window of economic opportunity was lost.

Decisions on whether and when to make the large capital expenditures necessary to bring large low-grade mines into production will never be easy. However, it is critical to the economic well-being of mining companies that they be able to capitalize on such narrow windows of opportunity. This will not be achievable unless governments streamline the approval process and remove the impediments contributing to the increasingly lengthy lead times which have become so common in obtaining approval for mine developments in Canada.

Acknowledgments

The writer is grateful to J.P. Campbell and J.J. Kalmet of Canada Tungsten Inc. for their helpful advice, to J.R. Woodcock and N.C. Carter for their critical reviews of the manuscript, and to Climax Canada Ltd. for their permission to publish this paper.

REFERENCES

DEVITT, J.C., 1981. Re-opening an open pit molybdenum mine - Kitsault Project. Mining Congress Journal, March, 1981, p. 23-29.

TURNBULL, J.M., 1916. British Columbia Department of Mines, Annual Report for 1916, p. 66.

STEININGER, R.C., 1985. Geology of the Kitsault molybdenum deposit, British Columbia. Economic Geology, 80, p. 57-71.

WOODCOCK, J.R. and CARTER, N.C., 1976. Geology and geochemistry of the Alice Arm molybdenum deposits. *In* Porphyry Deposits of the Canadian Cordillera. *Edited by* A. Sutherland Brown. Canadian Institute of Mining and Metallurgy, Special Volume 15, p. 462-475.