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MOLYBDENUM DEPOSITS OF THE ALICE ARM - TERRACE AREA
BRITISH COLUMBIA
CANADA

by

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INTRODUCTION

A great number of molybdenum deposits and occurrences are known along the eastern flank of the Coast Plutonic Complex throughout British Columbia. Perhaps the most significant concentration of these deposits is situated between latitudes 54 degrees and 56 degrees north, in the Alice Arm-Terrace area of west-central British Columbia (Figure 1). The greatest clustering appears to be centred around Alice Arm where the most significant deposit to date is the former producing British Columbia Molybdenum mine on Lime Creek.

Molybdenite mineralization was first recognized in this region in 1911 when mineral claims were staked on Lime Creek to cover part of what was later to become the British Columbia Molybdenum mine. Molybdenite was identified at several other nearby prospects and in 1916, 345 tonnes averaging 1.60 per cent molybdenite was mined at the Tidewater property north of Alice Arm (Figure 1).

Intense exploration for molybdenum in the late 1950's and early 1960's in this area by Kennco Explorations, (Western) Limited culminated in the definition of an ore deposit on Lime Creek (British Columbia Molybdenum). Mining and milling operations began in 1967 and were suspended in mid-1972 due to a depressed market for molybdenum. Production over the five-year period totalled 10 400 tonnes of molybdenum. Climax Molybdenum Corporation of British

Columbia Limited acquired the property in 1973 and have since been conducting geological and feasibility studies. Remaining reserves are estimated to be in the order of 50 million tonnes of slightly less than 0.20 per cent molybdenite.

Exploration throughout the Alice Arm-Terrace area in the 1960's resulted in work being done on a number of deposits and occurrences, most of which are shown on Figure 1. In 1975, U.S. Borax and Chemical Corporation announced the discovery of a potential ore deposit of more than 100 million tonnes with grades ranging from 0.20 to 0.35 per cent molybdenite at Quartz Hill east of Wilson Arm in southeastern Alaska (Figure 1). This deposit is roughly equidistant between Alice Arm and Ketchikan, Alaska. The recognition of this deposit led to renewed exploration for molybdenum deposits in southeast Alaska and reassessment of many known deposits in neighbouring British Columbia.

GEOLOGICAL SETTING

The geology of this part of west-central British Columbia is dominated by granitic and lesser metamorphic rocks of the Coast Crystalline Belt which borders Mesozoic volcanic and sedimentary rocks of the Intermontane Belt on the west.

Oldest rocks in the area shown on Figure 1 are gneissic rocks which occur within the Coast Plutonic Complex. These gneiss complexes, believed to be of pre-Permian age, have indistinct boundaries and grade into homogeneous plutonic rock.

The Mesozoic volcanic and sedimentary rocks range in age from Late Triassic to Early Cretaceous. Triassic limestone, mafic volcanic rocks, and acidic metavolcanic rocks are exposed principally in the Terrace area. Lower and Middle Jurassic fragmental volcanic and lesser sedimentary rocks have their greatest distribution in the Portland Canal-Alice Arm area. Marine to continental sedimentary rocks of Late Jurassic and Early Cretaceous age occupy most of the eastern part of the northern half of the area shown on Figure 1, which is roughly the southwestern extremity of the Bowser successor basin.

Quaternary basalt flows occur in the Alice Arm-Nass River area. Columnar basalt outliers of Pleistocene age are distributed principally south of Alice Arm while a very young (several hundred years) flow and associated cinder cones are situated south of Nass River.

Plutonic rocks, principally of Tertiary age, include the granitic rocks of the Coast Plutonic Complex which underlie much of the area shown on Figure 1 and which are part of a 1 700-kilometre cyrstalline terrane extending along the length of coastal British Columbia and southeastern Alaska. A great number of radiometric (K/Ar) age determinations indicate a predominantly Eocene (43 - 51 Ma) age for the granitic rocks along the eastern flank of the Coast Plutonic Complex.

Marginal to the east margin of the Coast Plutonic Complex are the small (less than 1 kilometre) quartz monzonite stocks of the Alice Arm intrusions (Carter, 1974). These are slightly older than Coast Plutonic Complex granitic rocks, with K/Ar ages ranging from 49 - 54 Ma.

Lamprophyre dyke swarms of Oligocene age (Carter, 1974) are prominent in the Portland Canal-Alice Arm area and in adjacent southeast Alaska (Smith, 1973). Felsic intrusions of similar age include the quartz monzonite stock which hosts the Quartz Hill molybdenum deposit in Alaska (Stephens et al., 1977/ Elliott et al., 1976). Similar young granitic intrusions are known in at least one locality in the Alice Arm area (Carter, 1974).

Three types of molybdenum deposits are recognized in the Alice Arm-Terrace area. These include deposits associated with Alice Arm intrusions, deposits associated with granitic rocks of the Coast Plutonic Complex, and deposits associated with felsic intrusions clearly younger than Coast Plutonic Complex granitic rocks. With the exception of the Quartz Hill deposit in southeast Alaska, the more significant deposits are those associated with the Alice Arm intrusions.

MOLYBDENUM DEPOSITS ASSOCIATED WITH ALICE ARM INTRUSIONS

Alice Arm intrusions most commonly occur in the form of small stocks generally not exceeding 0.8 kilometre in diameter. Porphyritic quartz monzonite is the dominant rock type and this distinguishes these molybdenum-bearing stocks from equigranular satellitic stocks related to the Coast Plutonic Complex. The stocks intrude siltstones and greywackes of the Bowser successor basin marginal to Coast Plutonic Complex (Figure 1). Many of the stocks apparently have been localized at or near intersections of east-northeast and north-northwest faults. A number of the intrusions are elongate in an east-northeast direction, suggesting emplacement along major fault zones, and some stock contacts are rectilinear in plan reflecting dominant fault and fracture patterns.

Evidence for forceful emplacement is also present, with sedimentary rocks arched and domed around some of the stocks. While the majority of Alice Arm intrusions occur as small oval or elongate stocks, some are sheet or sill-like in form and are related to small feeder pipes. Others take the form of northwest-striking dyke swarms, examples of which are found at Alder Creek and Molybdenum Creek (Figure 1). This distribution corresponds closely with remnants of Pleistocene and Recent basalts, suggesting that they have been localized along the same regenerated fault and fracture systems. The incidence of young volcanic activity near molybdenite deposits is not uncommon in the Canadian Cordillera.

Major geologic features of four deposits in the Alice Arm area are shown on Figure 2. In these and other deposits, quartz monzonite porphyry is the prevalent host rock. Phenocrysts range in size from 2 millimetres to 1 centimetre and include, in decreasing order of abundance, euhedral plagioclase, K-feldspar, and both euhedral and anhedral quartz eyes. Quartz monzonite porphyry is characteristically mesocratic, with both biotite and hornblende as primary mafic minerals. Leucocratic quartz-feldspar porphyry phases, of quartz monzonite to granite composition, also are prominent at most of the deposits and at some they constitute the bulk of the intrusive rocks. Muscovite is the mica mineral of this phase.

Some intrusions are zoned, most notably the intrusion that is host to the Lime Creek (British Columbia Molybdenum) deposit. Here, a core of quartz monzonite porphyry is bordered by more basic granodiorite and quartz diorite, which may be in part older than the quartz monzonite phase.

Most molybdenum-bearing stocks exhibit several stages of intrusion. The first stage forms the bulk of the stock and is represented by quartz monzonite and/or quartz-feldspar porphyry and lesser quartz diorite, such as at Lime Creek. This main phase may be intruded by fine-grained, equigranular alaskite that consists essentially of quartz, K-feldspar, and myrmekite. Alaskites, which are very common at the Lime Creek and Roundy Creek properties (Figure 2), occur as dykes and irregular masses and are host to better grades of disseminated and lens-like molybdenite mineralization.

Other inter-mineral intrusions include dykes and irregular lenses of intrusive breccia, best developed along the northern stock contact at the Lime Creek deposit (Figure 2). Angular fragments 1 to 2 centimetres in size, of both intrusive and country rock, are contained in a granulated matrix of quartz, plagioclase, and K-feldspar.

Several deposits feature intrusive phases that are very late in the intrusive-mineralization sequence. These also are quartz monzonite in composition. Examples include an unexposed plug at Lime Creek, the southwest portion of the Bell Molybdenum stock (Figure 2), and post-mineral dykes at some of the Nass River deposits (Figure 1).

Post-mineral lamprophyric and basalt dykes cut virtually all of the molybdenum-bearing stocks. These usually strike northeasterly, dip vertically, and truncate all pre-existing rocks and structures, including mineralized fractures.

Northwesterly striking faults that are younger than the plutons and lamprophyric dykes are found at the Bell Molybdenum, Roundy Creek, and Nass River deposits.

Sedimentary rocks adjacent to the Alice Arm intrusions have been thermally metamorphosed to biotite hornfels in an aureole which may extend outward from the stock contact for 100 to 150 metres. Biotite hornfels is a brown, indurated, fine-grained rock with a granoblastic texture that consists of quartz, minor feldspar, and abundant felted, brown biotite. Some cordierite and andalusite are developed in the hornfels adjacent to intrusive contacts.

Alteration patterns within and marginal to the molybdenum-bearing stocks are similar to those of other porphyry deposits. At many of the deposits, a central zone of potassic alteration is partially coincident with molybdenite mineralization. At Lime Creek, the most intense potassic alteration occurs in a circular zone in the northern part of the stock (Figure 2). Rock within this core of intense alteration is laced with barren quartz veinlets rimmed by secondary K-feldspar, so that the original quartz monzonite porphyry has been converted to a rock consisting mainly of quartz and K-feldspar. In the outer part of this alteration zone is an annular zone of molybdenite mineralization where secondary K-feldspar is restricted to the margins of quartz-molybdenite veinlets. Other deposits also feature secondary K-feldspar, but not to the same degree as at Lime Creek. Secondary biotite, an alteration of primary hornblende, is present to a limited degree in several of the deposits. At Lime Creek, this alteration of hornblende, particularly in the quartz diorite, may be in part deuteric. At Roundy Creek, the potassic alteration zone contains quartz-muscovite veins.

The potassic zone at most deposits is gradational outward to a phyllic (quartz-sericite-pyrite) zone. Where coincident with the margins of the plutons, it is superimposed on the effects of thermal metamorphism. This zone is represented at many deposits by a bleaching of the biotite hornfels to a cream or light green colour marginal to fractures and quartz veinlets and is due to the development of very fine-grained quartz, sericite, and some epidote. This type of alteration may be weakly developed, as at many of the deposits, or so intense that the original biotite hornfels has been largely transformed to a buff or light green-coloured rock within a zone several tens of metres outward from the stock contact, as at the Lime Creek and Ajax deposits. Pyrite is a common constituent in this alteration zone, occurring both in quartz veinlets and as disseminations. The intensity of pyritization may be related in part to thermal metamorphism, which involves the formation of pyrite and pyrrhotite in the hornfels.

Better grades of molybdenite mineralization in the Alice Arm intrusions are dependent on structural and lithologic controls. Fracturing and attendant quartz-molybdenite veining are best developed near stock contacts. Later alaskite intrusive phases may contain disseminated to nearly massive molybdenite. The ore zone at Lime Creek is annular or ring-shaped in plan, occurring in the northern half of the stock (Figure 2), with molybdenite occurring as selvages in a network of east-northeast and west-northwest quartz veinlets. A similar style of mineralization occurs at most of the other deposits.

Disseminated molybdenite is contained in the alaskite intrusive phase at the Lime Creek deposit. At Roundy Creek, the alaskite contains nearly massive lenses, pods, and parallel bands of molybdenite, and much of this is in the form of feather-like intergrowths with the feldspar. Disseminated rosettes of molybdenite occur in leucocratic quartz-feldspar porphyry phases at the Tidewater and Kay properties.

Most of the deposits exhibit several stages of quartz-molybdenite, pyrite, and quartz-pyrite veining. Virtually all of the Alice Arm molybdenite deposits feature late-stage polymetallic quartz-carbonate veins which contain pyrite, galena, sphalerite, tetrahedrite, chalcopyrite, minor molybdenite, and, at Lime Creek, four silver-lead-bismuth sulphosalts.

Pyrite halos may extend outward from the molybdenite zone for 150 to 300 metres. Where exposed, the pyrite zone is weathered to a prominent gossan, particularly at the Ajax and Snafu properties.

A number of samples for K/Ar age determinations were analysed for Alice Arm intrusions to date the age of intrusion and mineralization (Carter, 1974, 1976). Samples were collected from main mineralized intrusive phases, and, where possible, late intrusive phases which exhibited definite cross-cutting relationships with the main phase. Post-mineral porphyry phases were also sampled. Locations and ages obtained for some of the samples are shown on Figure 2. Also shown are locations and results of samples collected from biotite hornfels, lamprophyre dykes, and young basalt flows. Ages within the intrusives range from 49 to 54 Ma and indicate the age of molybdenite mineralization to be virtually congruent with the age of intrusion.

To date, deposits in the immediate Alice Arm area have undergone the most intense investigation. Major features of several of these deposits are briefly outlined as follows.

Tidewater

The Tidewater deposit is situated 1.6 kilometres north and 6.4 kilometres west of the head of Alice Arm Inlet (Figure 1). Limited underground mining between 1916 and 1931 resulted in the recovery of 5 920 kilograms of molybdenite from northeasterly striking quartz veins in sedimentary rocks some 274 metres south of a small (610 by 460 metre) stock of quartz monzonite porphyry.

Exploration work in the 1960's included 550 metres of underground diamond drilling and 290 metres of drilling in the quartz monzonite porphyry stock. The latter work indicated sporadic molybdenite mineralization near the south contact of the stock in 1-centimetre-wide quartz veinlets that occur in both hornfelsed sedimentary rocks and quartz monzonite porphyry.

Bell Molybdenum

The Bell Molybdenum property is situated 10 kilometres southeast of Alice Arm (Figure 1). Discovered in 1965, the property was tested by 5 465 metres of diamond drilling in 1966 and 1967, which indicated 32.2 million tonnes having an average grade of 0.11 per cent molybdenite.

Molybdenite mineralization is associated with an elliptical stock of quartz monzonite porphyry, elongate in a east-northeast direction and measuring 670 by 335 metres. The stock intrudes a sequence of dark grey to black siltstones and greywackes, which are thermally metamorphosed to biotite hornfels a distance of 365 to 460 metres outward from the stock contact (Figure 2).

Quartz monzonite porphyries of the stock include three major types. The main type, leucocratic quartz monzonite porphyry, occupies the central part of the stock. In this type, 2 to 4-millimetre phenocrysts of quartz, oligoclase, and perthitic orthoclase make up 30 per cent of the rock, and are set in a fine-grained matrix of quartz and feldspar. Original biotite is bleached to a mixture of chlorite and sericite.

Near the stock contact and in dykes peripheral to the stock, the leucocratic quartz monzonite porphyry is gradational to a quartz monzonite or granodiorite porphyry. This rock contains a more calcic plagioclase, a lesser amount of orthoclase, and fresh biotite and hornblende.

The southwestern part of the stock is composed of a crowded 'quartz-eye' porphyry of distinctive appearance. Phenocrysts, which make up 50 per cent of the rock by volume, include 4-millimetre quartz anhedra, 2 to 4-millimetre euhedral crystals of plagioclase, and randomly distributed 1 to 2-centimetre euhedral crystals of perthitic orthoclase. The distinguishing feature of this phase is its relative lack of alteration. A similar porphyry was encountered at depth in a drill hole near the central part of the stock, where it appeared to have a gradational contact with the leucocratic quartz monzonite porphyry. The relative lack of quartz veinlets and fractures and attendant mineralization suggests that the 'quartz-eye' quartz monzonite porphyry represents a late, possibly post-mineral, intrusive phase.

Two varieties of basic dykes cut the granitic rocks of the stock. These include a fine to medium-grained porphyritic lamprophyre consisting of plagioclase, hornblende, and clinopyroxene, and fine-grained basalt and andesite dykes that are locally vesicular and which may be related to young lava flows nearby. Both varieties generally have a northeasterly strike and are about 0.5 metre wide.

A large horse of hornfelsed sedimentary rocks within the stock, measuring 300 by 60 metres, parallels the long direction of the stock (Figure 2) and is cut by numerous porphyry dykes. Drilling information suggests that this block of country rock decreases in size with depth.

Major faulting preceded the period of intrusion and intersections of east-northeast and north-northwest faults and fractures were undoubtedly important in the localization of the stock. Later movement along these faults, particularly the north-northwest set, is documented by the apparent offsetting of the stock contacts along two major faults (Figure 2) and by the presence of numerous post-mineral shears noted in drill core.

Molybdenum mineralization occurs in both the quartz monzonite porphyry and biotite hornfels adjacent to the central and eastern stock contacts (Figure 2).

Molybdenite occurs mainly as selvages to steeply dipping quartz veinlets, 0.5 to 1 centimetre thick, which follow major fracture directions. Four stages of quartz veining and mineralization have been noted. A first stage of barren quartz veinlets is followed by the second, most important stage, consisting of quartz-molybdenite-pyrite veinlets that are steeply inclined. These are offset locally by flat quartz-molybdenite veins and hairline fractures. The final stage consists of 2-centimetre and larger veins of quartz and carbonate that contain variable amounts of pyrite, pyrrhotite, galena, and sphalerite. A 25-centimetre-wide quartz-carbonate vein containing pyrite, pyrrhotite, galena, and sphalerite was noted in a shear zone in argillaceous sediments 460 metres east of the stock.

Prospecting in 1969 disclosed the presence of a hornfels zone with numerous quartz veinlets some 1 400 metres southeast of the main stock. Climax Molybdenum Corporation of British Columbia Limited optioned the property and in 1976 and 1977 carried out 5 400 metres of diamond drilling on this zone and the main stock. Drilling in the new zone, which is partly capped by Pleistocene basalt, intersected intrusive rocks at a depth of about 200 metres. Only weak molybdenite mineralization was encountered.

Roundy Creek

This property is situated south of Alice Arm Inlet on Roundy Creek, 2.4 kilometres from tidewater (Figure 1).

The property was originally discovered in the early 1900's. Exploration and development work between 1965 and 1971, primarily by Sileurian Chieftain Mining Company Limited, consisted of 9 300 metres of diamond drilling and 780 metres of underground development. The property was purchased by Climax Molybdenum Corporation of British Columbia Limited in 1975.

Molybdenum mineralization is associated with an elongate, small composite intrusion of quartz monzonite porphyry. The intrusion is partly stock-like and partly sill-like. It has been segmented by northwest faults along and adjacent to Roundy Creek (Figure 2).

The intrusion consists of a number of similar but distinguishable phases. The most widespread of these is a leucocratic 'quartz-eye' quartz monzonite porphyry that forms the core of the intrusion. The rock contains only minor biotite, and sericite is the chief micaceous mineral. Where intensely sheared and fractured, the 'quartz-eye' quartz monzonite porphyry grades into brecciated quartz monzonite in which feldspar phenocrysts are partially shattered and the many randomly oriented fractures are coated with chlorite, sericite, carbonate, and molybdenite. The 'quartz-eye' quartz monzonite porphyry is apparently gradational to biotite-quartz monzonite, which is most abundant in the central and border areas of the intrusion.

Dykes and irregular masses of fine-grained white alaskite cut all the aforementioned rock types. Alaskites consist of a fine-grained mosaic of quartz, sodic plagioclase, granophyre, and some sericite. In some areas, the alaskite is gradational to a quartz-feldspar porphyry.

A late intrusive phase seen in one of the underground levels and a few drill holes forms narrow dykes of fine-grained, light grey biotite-quartz monzonite. This last phase contains only trace amounts of molybdenite.

Narrow hornblende and biotite lamprophyre dykes that strike northwestward and dip steeply cut all granitic rocks and mineralized veinlets and fractures. Many terminate at, or are offset by, northwesterly trending faults (Figure 2).

Sedimentary rocks have been metamorphosed to biotite hornfels in a zone, roughly 60 metres wide, surrounding the intrusion. Structural relationships of the intrusion are complex. Drill evidence indicates inward-dipping lower intrusive contacts, suggesting that parts of the intrusive may be sheet-like in form surrounding a central feeder pipe. The eastern segment is apparently tabular in section.

Two zones of molybdenum mineralization are known within the intrusion (Figure 2). The eastern segment is host to uniform grades of molybdenite, occurring as selvages in numerous randomly oriented quartz veinlets and as fracture fillings. Drilling has indicated the presence of 7 million tonnes of 0.11 per cent molybdenite in this zone. High-grade molybdenum mineralization occurs in the central and southern part of the intrusive, where drilling and underground work has indicated 1.35 million tonnes of 0.347 per cent molybdenite in the southern zone and some 35 000 tonnes grading 0.668 per cent in a small zone to the north.

In both zones, higher grades of molybdenum mineralization are contained in alaskites. In the upper underground heading, closely spaced 1 to 2-centimetre bands of molybdenite are oriented crudely parallel to the trend of an enclosing alaskite body and appear to be an integral part of the magmatic crystallization. In addition, 1-centimetre rosettes of molybdenite are uniformly distributed within the alaskite. Molybdenite also occurs in numerous randomly oriented hairline fractures with chlorite in brecciated quartz monzonite and in closely spaced 0.5 to 1-centimetre-wide quartz veinlets in alaskites and leucocratic 'quartz-eye' quartz monzonite porphyries.

Drilling and underground exploration indicate that the zones of molybdenum mineralization are lens-like in form and extremely erratic in lateral and vertical extent. The distribution of the higher grade zones suggests that they are spatially related to the intrusive centre or feeder pipe.

<u>Ajax</u>

The Ajax property is on the east slope of Mount McGuire, 13 kilometres northeast of Alice Arm (Figure 1).

Lead-zinc-silver mineralization, peripheral to the molybdenite zone, was explored by prospectors in the early part of the century. Newmont Mining Corporation carried out some 8 100 metres of diamond drilling on the property between 1965 and 1967.

A sequence of sedimentary rocks with minor interbedded volcanic rocks which form part of the eastern limb of the northwest-trending anticlinal structure are intruded by four small closely spaced stocks of quartz monzonite porphyry (Figure 2). These four stocks are grouped together in an elliptical area oriented northwesterly and measuring 900 by 750 metres. The stocks, of varying sizes (Figure 2), are roughly rectilinear in plan and continue downward to the limits of drilling without merging into one intrusive body. However, the area between the stocks is laced with a network of dykes of similar composition.

The largest stock and the one immediately northwest of it are composed of leucocratic white to pink quartz-feldspar porphyry. The other two intrusive bodies, which are essentially a network of closely spaced east-northeast and north-northwest dykes, are of similar composition, but differ from the quartz feldspar porphyries by being medium grey in colour and by having a biotite content of between 7 and 10 per cent.

Northeasterly striking dykes of fine-grained hornblende and biotite lamprophyre, about 2 metres wide, occur south and east of the quartz monzonite porphyry stocks. These dykes weather a brown colour, have chilled contacts, and are of post-mineral age.

Contact metamorphism associated with the intrusion of the porphyry stocks has converted argillaceous sedimentary rocks to brown and purple-coloured biotite hornfels in an area 900 metres outward from the stock. Within an inner zone, 150 to 300 metres from the stocks, secondary bleaching has converted biotite hornfels to a light green rock consisting essentially of sericite and quartz. East to the stocks and near the outer limits of the bleached zone, a narrow band of limestone has been skarnified.

Sedimentary and volcanic rocks underlying Mount McGuire are part of the steep east limb of a regional anticline. East and west of the porphyry stocks, strikes are uniformly north-northwest, whereas attitudes north and south of the stocks are contorted. Attitudes adjacent to the stocks indicate the presence of a large dragfold, modified by doming, associated with the intrusion of the stocks.

Most creeks on Mount McGuire follow faults which strike north-northwest and east-northeastward. The importance of major faults and fracture patterns in governing the orientation of contacts and dyke trends is reflected by the rectilinear nature of the stock contacts.

Sulphide mineralization exhibits a zoning pattern which, near the outer limits of the biotite hornfels zone, consists of sparse pyrrhotite as disseminations and in widely spaced fractures. Proceeding inward toward the intrusive complex, hairline fractures contain chlorite and pyrrhotite. Nearer the intrusive complex, these fractures become wider and are filled with quartz, which carries pyrrhotite as well as coatings and minute bands of molybdenite.

Sulphide minerals constitute less than 2 per cent (by volume) of the rock, with pyrrhotite in the major amount. Molybdenite is always associated with quartz and occurs in the pyrrhotite-bearing veinlets and in the hairline fractures as stringy lenses or smears along shears. Molybdenite is usually concentrated along selvages of the veinlets, The quartz veins or quartz stockwork are present in both intrusive rocks and in the contact zone of the hornfels. Very minor amounts of scheelite have been noted within the quartz veinlet zone or associated with garnet skarn within areas of hornfels.

Exploration work to date on the property precludes any definition of potential grade or reserves of molybdenite.

Lime Creek (British Columbia Molybdenum)

The Lime Creek deposit is situated 6.5 kilometres south of Alice

Arm (Figure 1). Since cessation of mining operations in 1972 and the acquisition of the property by Climax Molybdenum Corporation of British Columbia Limited, several thousand metres of diamond drilling has been completed in the area of the open pit.

Molybdenite mineralization at Lime Creek is associated with a small elliptical stock, of quartz monzonite to quartz diorite composition, which intrudes siltstones and greywackes. The main stock is 1 000 metres in diameter and composed largely of porphyritic rocks. An eastern appendage to this body, about 500 metres long, is composed of quartz diorite with normally zoned plagioclase (An_{42-45}). Several of the geochemical patterns suggest that this more basic eastern appendage is an old phase of the intrusive system.

The main stock is composed of granitoid rocks of several types and ages, with a central zone of quartz monzonite porphyry. Several phases of quartz monzonite porphyry can be distinguished in the central part of the stock on the basis of texture and crosscutting relationships. The rock is essentially medium grained and leucocratic, with euhedral to subhedral phenocrysts of normally zoned plagioclase (An_{25-30}) and poikilitic K-feldspar making up the major part of the rock. Hornblende and biotite are the chief mafic minerals.

Quartz diorite, which forms much of the western and southeastern parts of the main stock, is a medium-grained, white to grey, massive rock with sparse phenocrysts of plagioclase. Fine-grained secondary biotite has replaced the hornblende crystals in much of the rock. In places, large K-feldspar crystals have formed, many over 1 centimetre across. These megacrysts contain relicts of plagioclase and mafic minerals. Similar poikilitic megacrysts also occur in the quartz monzonites.

Dykes and lenses of white to pink equigranular alaskite intrude the quartz monzonite porphyries and the quartz diorite, particularly in the contact areas of the main stock. This rock consists essentially of anhedral quartz and K-feldspar, and commonly contains disseminated crystals or rosettes of molybdenite and occasionally crystals of fluorspar. The molybdenite mineralization of this type significantly enhances the grade of the stockwork deposit.

Intrusive into all rock types and apparently confined to the northern half of the main stock are irregular lenses and dykes of relatively fine-grained quartz monzonite and granodiorite porphyry, and intrusive breccias. These are of inter-mineral age and commonly contain angular fragments of biotite hornfels, quartz monzonite porphyry, quartz diorite, and alaskite in a fine-grained granulated matrix.

The latest granitic phase is a post-molybdenite quartz-feldspar porphyry that truncates the northeast part of the stock at depth. This rock type, observed only in drill core, apparently terminates the ore-grade mineralization of the northeastern part of the ore zone.

Lamprophyre dykes, varying in width from 1 to 10 metres, cut all rocks in the main stock, but are especially abundant near the eastern contact. These dykes, which occur in northeasterly trending swarms, include both biotite and pyroxene varieties and have sharp chilled contacts.

Emplacement of the stock was accompanied by contact metasomatism of the greywackes to biotite hornfels. The hornfels contains up to 30 per cent biotite near the Lime Creek stock. Outward, the biotite content drops to zero at the 'biotite line,' 500 to 1 000 metres away from the stock. Adjacent to the stock, subsequent hydrothermal alteration has converted some of the biotite to sericite.

Hydrothermal alteration is represented largely by quartz, orthoclase, and sericite. These minerals form an almost circular zone of intense alteration centred in the northern half of the Lime Creek stock. Within the central part of the zone, the hydrothermal alteration trends toward a complete replacement of the pre-existing rock by quartz and orthoclase in varying proportions, both as veinlets and as pervasive alteration. Any plagioclase remnants within this zone are completely sericitized. The secondary orthoclase rims mineralized quartz veinlets and occurs as grains (up to 5 millimetres) replacing plagioclase in the rock matrix.

Argillic and sericite alteration of plagioclase feldspar is relatively intense in and adjacent to northeasterly striking faults and shears within all parts of the alteration zone.

The zone of molybdenite mineralization is a ring structure, slightly elliptical in outline and elongated east-west (Figure 2). This ring occurs within and outward from the intense quartz-orthoclase alteration zone. The annular mineralized zone conforms roughly to the north, east, and west contacts of the stock, whereas the southern part of the zone cuts across the stock at its midpoint. The ring of mineralization has its best grades adjacent to the hornfels contact. Molybdenite content decreases toward the centre of the zone, so that a barren core contains only traces of molybdenum.

Molybdenite mineralization occurs along the boundaries of 0.3 to 0.6-centimetre quartz veinlets, and in hairline fractures. Disseminated molybdenite is found only in the alaskites. Quartz veinlets are closely spaced and appear randomly oriented in a stockwork pattern, but as a general rule the majority of the veins are vertical and strike north-northeast. Recent mapping of the pit by geologists of Kennecott Copper Corporation (Giles and Livingston, 1975) and Climax Molybdenum Corporation of British Columbia Limited indicates four separate but superimposed substages of molybdenite mineralization followed by a polymetallic vein stage. The first substage is related to the alaskite dykes and is represented by disseminations and rosettes and by fracture fillings of molybdenite. The second and third substages are represented by quartz-orthoclase-pyrite-molybdenite veinlets in a closely spaced stockwork pattern in the northern parts of the stock and the adjacent biotite hornfels. Subsequently, quartz monzonite breccias were intruded, and these are in turn cut by banded quartz-molybdenite veins up to 0.3 metre thick.

Higher grades of molybdenite mineralization occur in areas of intense fracturing and faulting, particularly in the northeast contact area of the stock. However, the intensity of fracturing has also provided channelways for the later lamprophyre dyke swarms, thus reducing the overall grade in this area.

The final stage of mineralization is represented by polymetallic quartz veins up to 1 metre wide. These occur in two conjugate fracture sets that cut the molybdenite zone. A north-northeast set is generally predominant. However, in places the northwest set is predominant and in other places both sets are present. The quartz veins contain pyrite, galena, sphalerite, molybdenite, tetrahedrite, chalcopyrite, fluorite, ankerite, dolomite, and a variety of lead bismuth sulphosalts, including the rare mineral neyite.

Pyrite occurs as disseminations along and within the stock. Pyrite of the fractures has been introduced with many substages. It can occur in quartz veins, in quartz-molybdenite veins, and by itself. Total pyrite content forms an annulus or halo partly overlapping the molybdenite ring.

Deep drill holes within the stock have encountered anhydrite. Deeper holes also indicated a decrease in hydrothermal alteration at depth (Giles and Livingston, 1975).

MOLYBDENUM DEPOSITS ASSOCIATED WITH COAST PLUTONIC COMPLEX GRANITIC ROCKS

Numerous molybdenite showings occur near the eastern margin of the Coast Plutonic Complex. While none of these can be considered to be an economic deposit, considerable exploration work has been done on a number of them.

As illustrated on Figure 1, molybdenite deposits of this type occur close to the eastern contact of the Coast Plutonic Complex and in satellitic stocks marginal to it. The principal rock types are mesocratic to leucocratic equigranular granodiorite and quartz monzonite. Molybdenite may occur in late differentiates including aplite and pegmatite dykes and stringers or in widely spaced quartz-filled fractures and drusy quartz veins or as rosettes on dry fractures.

Satellitic stocks of the Coast Plutonic Complex may be several kilometres in diameter such as Mount Priestly and Seven Sisters (Figure 1) or less than 1 kilometre as at the Big Joe, Kit, and Kendal properties. Principal rock types are quartz diorites and granodiorites which are locally porphyritic and are cut by stringers and dykes of aplite. The stocks intrude Late Jurassic-Early Cretaceous siltstones and greywackes which have been converted to biotite hornfels only a short distance outward from the intrusive contacts.

Best molybdenite mineralization at the Big Joe property occurs in widely spaced, 1-centimetre, quartz-filled fractures or as disseminations in aplitic phases near and marginal to stock contacts. At Mount Priestly, minor molybdenite is disseminated on dry fractures within the quartz diorite intrusive. At the Kendal property, molybdenite occurs in fractures with pyrite and chalcopyrite.

A K/Ar age determination on biotite from the Mount Priestly stock yielded an age of 51 Ma.

Molybdenite occurrences within but near the eastern contact of the Coast Plutonic Complex have their greatest concentration in the Terrace area (Figure 1). Three of these, the Pitman, Kokanee, and Lady Luck properties, have been explored by diamond drilling. The Kokanee and Pitman molybdenite showings are best developed in equigranular to porphyritic granodiorites near their contacts with volcanic country rocks. Granodiorites are commonly cut by aplitic and pegmatitic phases. At the Kokanee showing, molybdenite occurs in quartz-filled fractures rimmed by secondary K-feldspar, as rosettes with pyrite in drusy white quartz veins tens of centimetres wide, and as disseminations in K-feldspar-rich sections. Better molybdenite values at Pitman occur in intensely silicified and feldspathized sections with pyrite in both the intrusive and volcanic country rocks.

The Lady Luck deposit is an iron-copper-zinc skarn deposit with minor molybdenite occurring in both the skarn zones and in epidote-veined biotite diorite.

K/Ar ages for samples collected from granitic rocks of this part of the eastern flank of the Coast Plutonic Complex range from 48 to 51 Ma, somewhat younger than the mean age of 53 Ma determined for the Alice Arm intrusions. Although within the limits of analytical error, these consistently younger ages over a relatively large geographic area suggest that the eastern flank of the Complex was emplaced a measurable amount of time after the intrusion of the Alice Arm plutons.

MOLYBDENUM DEPOSITS ASSOCIATED WITH FELSIC INTRUSIONS

Four intrusions with associated molybdenite mineralization, all clearly younger than the granitic rocks of the Coast Plutonic Complex, are known in this part of northwestern British Columbia and southeast Alaska.

Of these, the U.S. Borax and Chemical Corporation's Quartz Hill deposit, near Wilson Arm in southeast Alaska, is the most significant (Figure 1). A potential ore deposit in excess of 100 million tonnes grading 0.20 to 0.35 per cent molybdenite is associated with a high level felsic pluton which intrudes metamorphic gneisses and granitic rocks of the Coast Plutonic Complex (Elliott et al, 1976). The intrusion is one of two stocks and related dykes which occur in a 20-kilometre belt.

The stock hosting the molybdenite mineralization is composite, consisting of several varieties of biotite granite and granite porphyry, quartz monzonite, and quartz latites and rhyolites (Stephens et al, 1977). Molybdenite mineralization occurs in quartz stockworks and, according to Stephens et al (1977), is directly related to silica flooding. Northeast-striking lamprophyre dykes cut the granitic intrusions and related mineralized stockworks. Quaternary basalt flows and associated fragmental rocks occur as isolated remnants 15 to 20 kilometres southwest of the deposit.

Two intrusives with molybdenite mineralization and which cut Coast granitic rocks are known in adjacent British Columbia. The Molly Mack prospect 25 kilometres southwest of Alice Arm (Figure 1) displays coarse-grained molybdenite disseminated in a small zone of biotite granite within a stock of leucocratic quartz monzonite porphyry. At the Penny Creek prospect 25 kilometres south of Alice Arm, rosettes of molybdenite are contained in a biotite-quartz monzonite. A small remnant of Quaternary basalt caps Coast Plutonic Complex granitic rocks nearby.

The Kitimat River prospect is situated 50 kilometres southeast of Terrace (Figure 1). Here, a multiple phase quartz feldspar porphyry of quartz monzonite composition intrudes equigranular Coast granitic rocks and a small roof pendant of volcanic rocks. Molybdenite is related to the quarty feldspar porphyry and later aplite and porphyry phases. Post-mineral porphyry phases are also evident.

K/Ar age determinations are available for three of these deposits. A United States Geological Survey age of 26 Ma was obtained for the Quartz Hill deposit (Stephens et al, 1977). The Molly Mack occurrence has an apparent age of 48 Ma while the Penny Creek prospect yielded a biotite age of 36 Ma. The Penny Creek and Quartz Hill intrusives are clearly younger than the average 50 Ma age for Coast granitic rocks and the Molly Mack age is slightly younger.

There are undoubtedly a number of intrusions of similar age within the Coast Plutonic Complex which have not yet been recognized.

CONCLUSIONS

Three types of Tertiary molybdenite deposits are known in the Alice Arm-Terrace area of British Columbia. Of these, the deposits associated with Eocene Alice Arm intrusions are the most significant. The discovery of the Quartz Hill deposit in southeast Alaska suggests that other young molybdenum-bearing intrusions probably exist within the Coast Plutonic Complex.

Elliott et al (1976) suggest areas of crustal extension in southeast Alaska, as evidenced by lamprophyre dyke swarms, may be good prospecting areas for younger, high level plutons. This hypothesis may also be applied to the Alice Arm district where not only lamprophyre dyke swarms are prevalent, but also abundant evidence of Quaternary volcanism. The three principal types of molybdenum deposits are also concentrated along this apparent east-west zone.

REFERENCES

Carter, N.C. (1965): Geology of the Lime Creek Area, Minister of Mines and Petroleum Resources, B.C., Ann. Rept., 1964, pp. 21-41.

.... (1967): Ajax, Minister of Mines and Petroleum Resources, B.C., Ann. Rept., 1966, pp. 44-46.

.... (1968a): Moly, Minister of Mines and Petroleum Resources, B.C., Ann. Rept., 1967, pp. 44-47.

.... (1968b): Snafu, Valley, Ridge, Kay, Guias, Minister of Mines and Petroleum Resources, B.C., Ann. Rept., 1967, pp. 50-52.

.... (1972): Roundy Creek, B.C. Ministry of Mines and Petroleum Resources, Geology, Exploration and Mining, 1971, pp. 122-124.

.... (1974): Geology and Geochronology of Porphyry Copper and Molybdenum Deposits in West-Central British Columbia, unpublished Ph.D. Thesis, University of British Columbia.

.... (1978): Geology and Geochronology of Porphyry Copper and Molybdenum Deposits in West-Central British Columbia, B.C. Ministry of Mines and Petroleum Resources, Bull. 64 (in press).

Carter, N.D. and Grove, E.W. (1972): Geological Compilation Map of the Stewart, Anyox, Alice Arm, and Terrace Areas, B.C. Ministry of Mines and Petroleum Resources, Prelim. Map No. 8.

Elliott, Raymond L., Smith, James G., and Hudson, Travis (1976): Upper Tertiary High-Level Plutons of the Smeaton Bay Area, Southeastern Alaska, United States Geological Survey, Open File Report 76-507.

Giles, D.L. and Livingston, D.E. (1975): Geology and Isotope Geochemistry of the MoS_2 Orebody of the Lime Creek Stock, Alice Arm, British Columbia, Econ. Geol., Vol. 70, Abst., p. 245.

Stephens, J.E., Senter, L.E., Smith, P.R., and Snook, J.R. (1977): Geology of the U.S. Borax Quartz Hill Molybdenum Property, Southeast Alaska, abst., CIM, District 6 Second Annual Meeting, Victoria.

Woodcock, J.R., Bradshaw, B.A., and Ney, C.S. (1966): Molybdenum Deposits at Alice Arm, British Columbia, Tectonic History and Mineral Deposits of the Western Cordillera, CIM, Special Vol. No. 8, pp. 335-339.

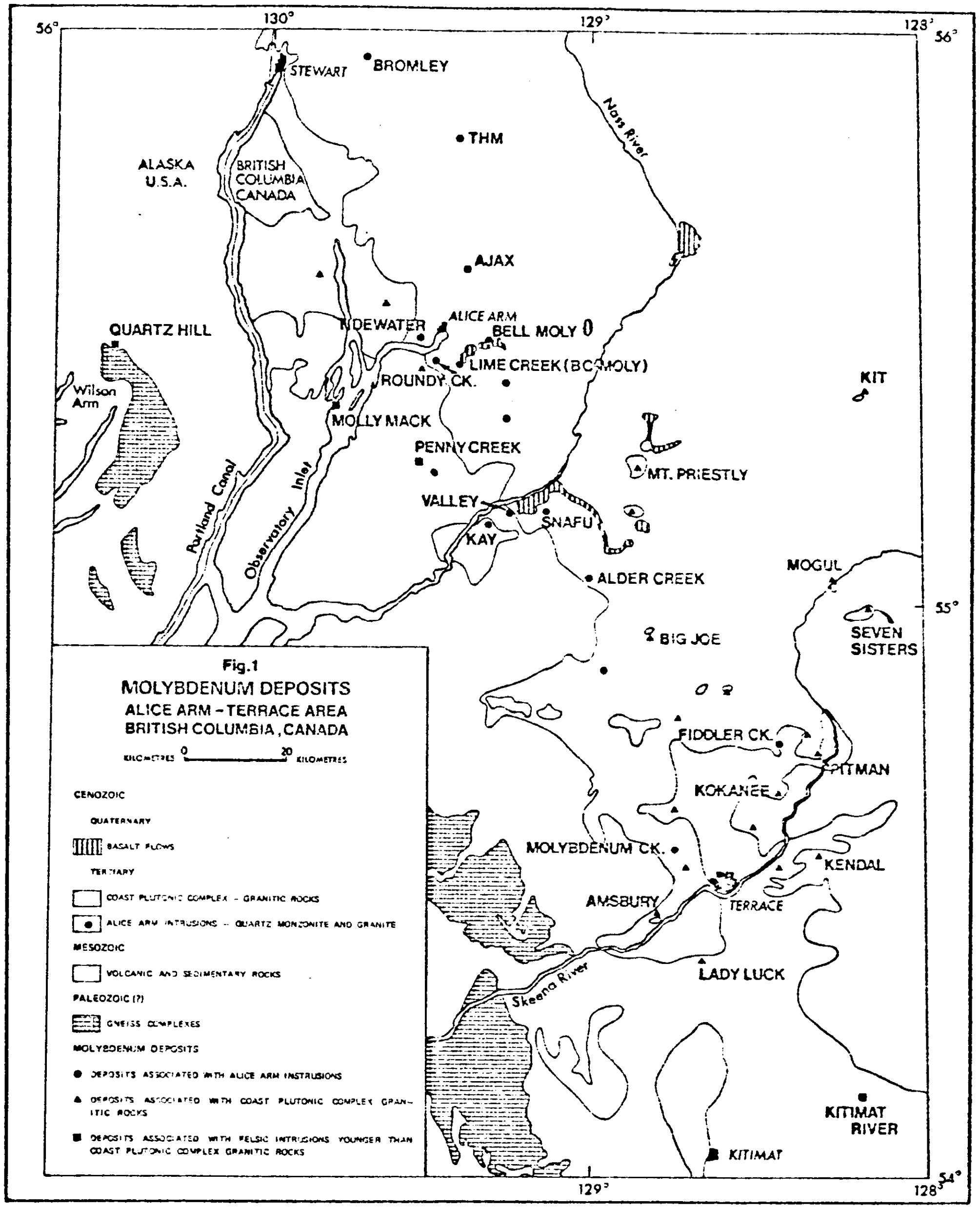
Woodcock, J.R. and Carter, N.C. (1976): Geology and Geochemistry of the Alice Arm Molybdenum Deposits, CIM, Special Vol. 15, Porphyry Deposits of the Canadian Cordillera, pp. 462-475.

ABSTRACT

A great number of molybdenum deposits occur along the eastern flank of the Coast Plutonic Complex in the Alice Arm-Terrace area of British Columbia. The region includes one former producing mine and several potential producing mines.

Three types of molybdenum deposits of Tertiary age are known including deposits associated with the Eocene Alice Arm intrusions, deposits related to granitic rocks of the eastern margin of the Coast Plutonic Complex, and deposits associated with Oligocene (?) felsic intrusions within the Coast Plutonic Complex.

Known molybdenum deposits have their greatest distribution in the Alice Arm area where they are coincident with lamprophyre dyke swarms and Quaternary basalt remnants.


56°
130°
129°
128°
56°
STEWART
BROMLEY
THM
Nass River
ALASKA
U.S.A.
BRITISH
COLUMBIA
CANADA
AJAX
QUARTZ HILL
TIDEWATER
ALICE ARM
BELL MOLY
LIME CREEK (BC MOLY)
ROUNDY CK.
KIT
Wilson
Arm
MOLLY MACK
PENNY CREEK
MT. PRIESTLY
Portland Canal
Observatory Inlet
VALLEY
SNAFU
KAY
ALDER CREEK
MOGUL
55°
BIG JOE
SEVEN
SISTERS
Fig.1
MOLYBDENUM DEPOSITS
ALICE ARM - TERRACE AREA
BRITISH COLUMBIA, CANADA
KILOMETRES 0 20 KILOMETRES
CENOZOIC
QUATERNARY
BASALT FLOWS
TERTIARY
COAST PLUTONIC COMPLEX - GRANITIC ROCKS
ALICE ARM INTRUSIONS - QUARTZ MONZONITE AND GRANITE
MESOZOIC
VOLCANIC AND SEDIMENTARY ROCKS
PALEOZOIC (?)
GNEISS COMPLEXES
MOLYBDENUM DEPOSITS
DEPOSITS ASSOCIATED WITH ALICE ARM INSTRUSIONS
DEPOSITS ASSOCIATED WITH COAST PLUTONIC COMPLEX GRANITIC ROCKS
DEPOSITS ASSOCIATED WITH FELSIC INTRUSIONS YOUNGER THAN COAST PLUTONIC COMPLEX GRANITIC ROCKS
FIDDLER CK.
PITMAN
KOKANEE
MOLYBDENUM CK.
KENDAL
AMSBURY
TERRACE
LADY LUCK
Skeena River
KITIMAT
RIVER
KITIMAT
129°
128°
54°

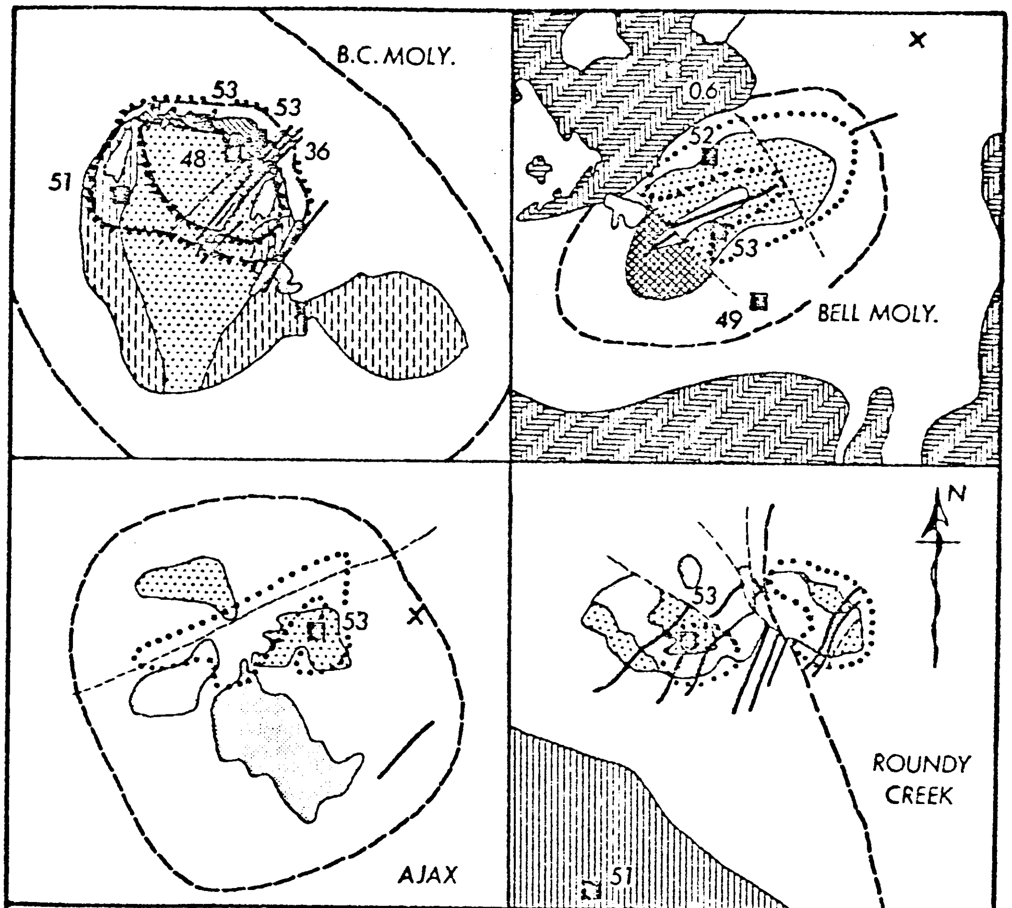


FIG.-2 MOLYBDENUM DEPOSITS, ALICE ARM

QUATERNARY
BASALT
TERTIARY—OLIGOCENE
LAMPROPHYRE DYKES
INTRUSIVE ROCKS—EOCENE
COAST COMPLEX—GRANODIORITE
LATE QUARTZ MONZONITE PORPHYRY
INTRUSIVE BRECCIA
× Ag-Pb-Zn Showing
K-Ar Sample

ALASKITE, LEUCOCRATIC QUARTZ FELDSPAR PORPHYRY
QUARTZ DIORITE
QUARTZ MONZONITE—GRANODIORITE PORPHYRY
JURASSIC—CRETACEOUS
BIOTITE HORNFELS
LIMIT OF BIOTITE HORNFELS
MoS_2 MINERALIZATION

0 500 1000
SCALE-METRES