Geol. Soc. Malaysia, Bulletin 9, Nov. 1977; pp. 1–16.

Mineralization in the Coast Plutonic Complex of British Columbia, south of latitude 55°N

G.J. WOODSWORTH and J.A. RODDICK
Geological Survey of Canada 100 West Pender Street
Vancouver, Canada V6B 1R8

Abstract: Compared with the flanking Insular and Intermontane Belts, the Coast Plutonic Complex contains few mineral deposits. Two quartz-vein gold camps, one massive sulphide body, and one ultramafic complex have accounted for 18% of the copper, 29% of the gold, and all the nickel produced from British Columbia. Mineral deposits and occurrences are concentrated in two segments of the Coast Plutonic Complex that are adjacent to two mineralized segments of the Intermontane Belt. Pyrite, chalcopyrite, sphalerite and galena are the dominant sulphides regardless of age or type of deposit. Small, lenticular replacement bodies in skarn and schist are the most common deposits. Many of these are situated along and near northwest-trending faults. Pyritic massive sulphide bodies occur in Paleozoic (?) to Early Cretaceous metamorphic rocks. Miocene porphyry copper and molybdenum deposits form a discontinuous chain running longitudinally through the Southern Coast Mountains. Older porphyry deposits are situated along and near the eastern margin and near the western margin of the southern Coast Mountains. Nickel-copper deposits are associated with an ultramafic complex at the southeast end of the Coast Plutonic Complex.

The distribution of mineral deposits among the lithologies of the Coast Plutonic Complex is similar to the distribution of accessory pyrite. Pyrite is abundant in pendant rocks, and about two-thirds of all known deposits occur in the pendants. In plutonic rocks pyrite is found mainly in hornblende-rich diorites and quartz diorites, particularly those showing extensive chloritization, epidotization, or pink hydrothermal alteration. Almost all mineral deposits hosted by plutonic rock are in quartz diorite and diorite, and the plutonic rocks adjacent to most pendants are also quartz diorite or diorite. Few deposits have been found in the Central Gneiss Complex or in plutons immediately east.

INTRODUCTION

Metallic mineralization is widespread throughout the Cordillera of British Columbia, but compared with the Insular Belt to the West and the Intermontane Belt on the east (Fig. 1) the Coast Plutonic Complex contains few mineral deposits and fewer still of economic importance. But between 1905 and 1974 mines in the Coast Plutonic Complex south of 55°N contributed about 18% of the copper, 29% of the gold, and all the nickel produced in British Columbia (Table 1). At present the only producing mine in the Coast Plutonic Complex is the Northair gold mine, which began production in 1976 at a rate of about 300 metric tons per day. This paper describes the known deposits in the Coast Plutonic Complex south of latitude 55°N. The locations of some mines and important prospects in and near the Coast Plutonic Complex are shown in Figure 2.

The Coast Plutonic Complex is a long narrow belt of plutonic and metamorphic rocks extending from northern Washington through the Coast Mountains of western British Columbia into southeast Alaska and Yukon Territory. Roddick and Hutchison (1972 and 1974) and Hutchison (1970) summarized the geology of the southern half of this belt and provided numerous references. Here it sufficies to note that the belt consists largely of intermediate and basic (logically migmatitic) discrete and coalescing plutons, bodies of gneiss and migmatite, and pendants of metamorphosed

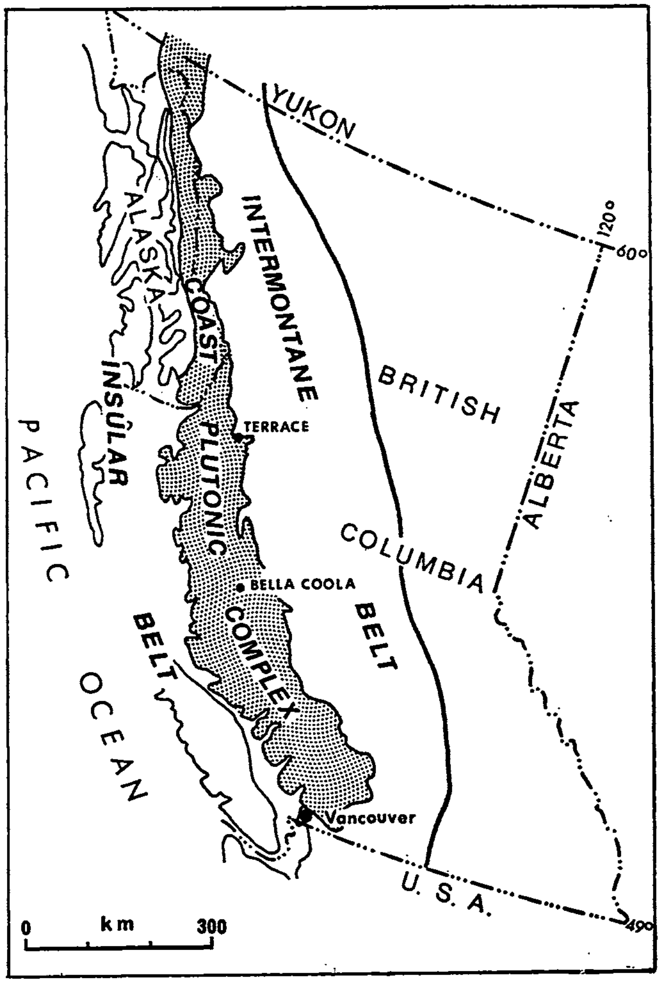

Fig. 1. Coast Plutonic Complex and flanking tectonic belts in British Columbia.

sediments and volcanics. Between latitudes 52° and 55°N a complex of migmatite, gneiss, and plutonic rock (the Central Gneiss Complex) forms the core of the Coast Plutonic Complex and may represent the oldest and most deeply exhumed rocks in the belt. The strata flanking the Coast Mountains are dominantly Mesozoic volcanic and sedimentary rocks, with minor Paleozoic material, which have been intruded by Mesozoic and Tertiary granitoid plutons.

The Coast Plutonic Complex has a pronounced asymmetry. Diorite and dioritic migmatites are most abundant in the western part of the belt; granodiorite and quartz monzonite may be more plentiful to the east. Metamorphic grade of the stratified rocks increases from greenschist facies in the western part of the belt to amphibolite (locally granulite) facies in the central and east-central parts. Rocks along both flanks

TABLE 1

METAL PRODUCTION AND MAJOR RESERVES IN THE BRITISH COLUMBIA COAST MOUNTAINS

	Ore Mined[1]	Gold[2]	Silver[2]	Copper[2]	Zinc[2]	Lead[2]	Nickel[2]	Molybdenum[2]
Massive sulphide bodies								
Britannia[4]	47 890	14.0	164.8	516 750	125 290	15 560	–	–
Ecstall[3]	7 260	4.5	?	58 000	167 000	?	–	–
Anyox	21 730	3.4	187.1	321 530	–	–	–	–
Vein deposits								
Bralorne-Pioneer[5]	7 260	118.0	22.7	–	–	–	–	–
Surf Inlet[3]	920	11.0	<0.1	2 720	–	–	–	–
Northair	420	6.0	45.5	1 180	22 490	9 440	–	–
Surf Point	60	0.6	<0.1	–	–	–	–	–
Porphyry deposits								
OK[3]	81 630	–	–	269 300	–	–	–	9 800
Ultramafic bodies								
Giant Mascot[6]	4 260	<0.1	<0.1	12 700	–	–	26 760	–
Others, mostly small veins	30	0.4	0.7	100	–	–	–	–
Total	171 460	157.9	420.8	1 182 280	314 780	24 860	26 760	9 800

1. Thousand metric tons
2. Metric tons
3. Proven and probable reserves
4. Other production: 445 metric tons cadmium
5. Other production: 7 metric tons WO_3
6. Other production: 141 metric tons cobalt

Compiled from Annual Reports of the B.C. Department of Mines and Petroleum Resources, and unpublished data.

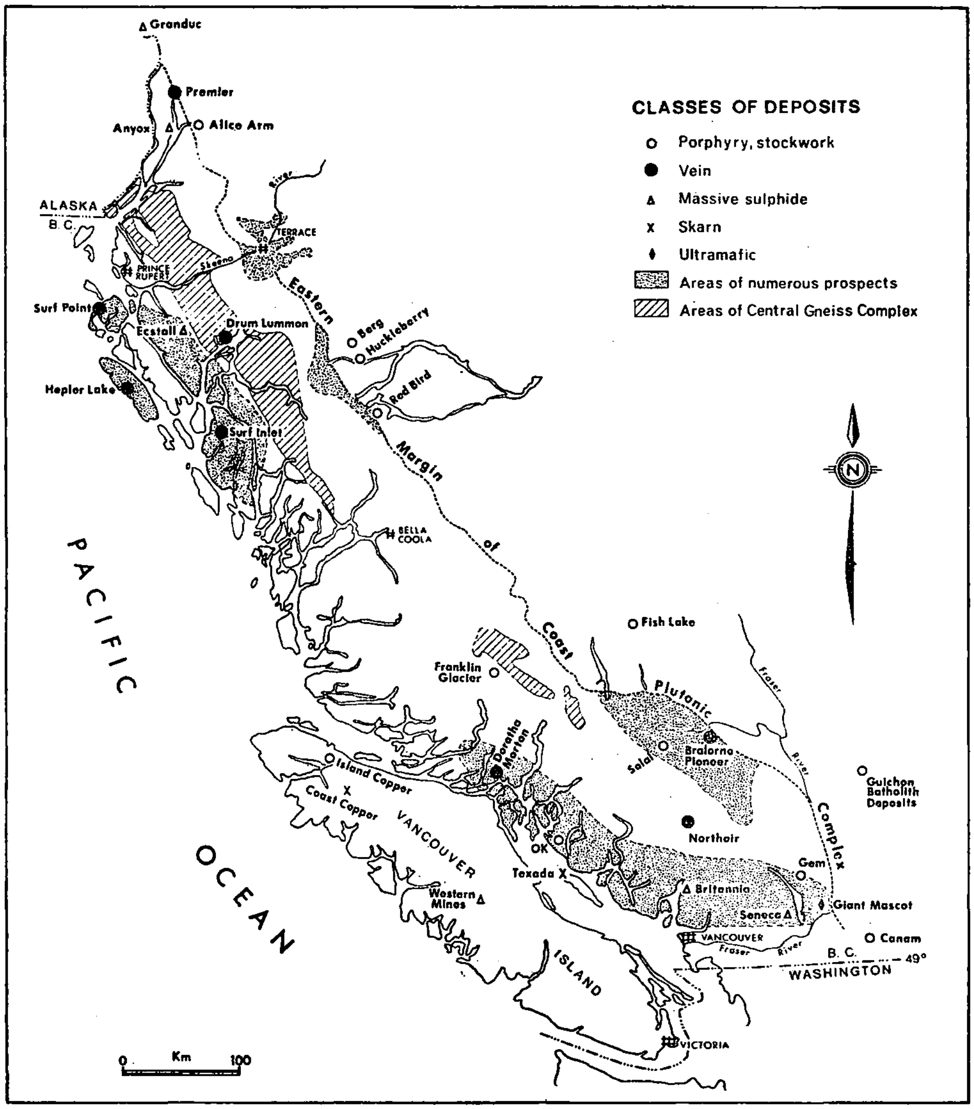

Fig. 2. Mines and some important prospects in and near the Coast Plutonic Complex. The stippled areas contain 85% of the known mineral deposits in the Coast Plutonic Complex. Only the largest areas of Central Gneiss Complex are shown.

have been affected only slightly by contact metamorphism; however, most of the western contact is under water. Potassium-argon dating of plutons yields predominantly Early Cretaceous (some Late Jurassic) ages on the west, Late Cretaceous in the central part of the belt, and early Tertiary to the east.

Few general surveys of mineralization in the Coast Plutonic Complex have been published. Excellent general descriptions and discussions of the metallogeny of the

Canadian Cordillera have been given by Sutherland Brown (1969 and 1974), Sutherland-Brown, *et al* (1971), and Wolfhard and Ney (1976). Woodsworth (1971) and Woodsworth, *et al* (in press) considered mineral deposits in parts of the central and southern Coast Mountains. Short descriptions of many individual mineral deposits are contained in the Annual Reports, and Geology, Exploration and Mining in British Columbia, both published by the British Columbia Department of Mines and in publications of the Geological Survey of Canada.

Skarn deposits, although abundant in the Coast Mountains, are economically unimportant, whereas the massive sulphide deposits are economically important although few examples are known. Most deposits, regardless of class, contain one or more of copper, gold, or molybdenum as the commodity of economic interest. Silver, zinc, and lead minerals commonly are present in subordinate amounts. Regardless of the deposit type, mineral assemblages almost always include one or more of pyrite, chalcopyrite, sphalerite, and galena as the dominant sulphide.

No tin or uranium minerals have been found in the Coast Plutonic Complex. Scheelite is present in very minor amounts in several vein deposits, and small amount was recovered from the Bralorne gold-quartz veins. Minute amounts of cinnabar occur in several Quaternary volcanic centres.

MASSIVE SULPHIDE DEPOSITS

The Britania massive sulphide deposit has accounted for almost all the copper, zinc, and silver produced from the Coast Mountains. Other examples include Ecstall, Seneca, and (just north of the area described in this paper) Anyox. All are dominantly pyritic lenses in pendant rocks included in the Coast Plutonic Complex.

The Britannia orebodies are in probable latest Early Cretaceous strata, near the top of a dacitic to andesitic pyroclastic sequence that is overlain by marine argillites Sutherland-Brown and Robinson, 1971). The orebodies are localized in a sheared zone that trends northwest through an area of andesitic and dacitic dyke swarms. Strata, sulphides, and dykes are thermally metamorphosed by a granodiorite pluton that gives K–Ar ages of about 90 m.y. Deposition of the volcanics and ore, shearing, and emplacement of the dykes all occurred within a time interval of only several million years.

All the massive sulphide deposits have a similar and simple mineralogy. Pyrite is by far the most abundant sulphide, followed by chalcopyrite and sphalerite. Minor galena and other sulphides are also present. The main massive orebodies at Britannia are zoned: chalcopyrite-rich cores are enveloped successively by an overlapping lower grade copper zone and a pyrite zone (Sutherland-Brown, 1975). Sphalerite is concentrated in the upper central parts of some orebodies. Stringer veins and lodes, and thin sheet-like bodies of chalcopyrite, pyrite, and quartz crosscut the schistosity in the sheared strata. Sutherland-Brown and Robinson (1971) and Sutherland-Brown (1975) concluded that most of the Britannia orebodies formed in a volcanic environment and strongly resemble the keiko ores of the Kuroko deposits. Only the sphalerite rich parts of the orebodies appear truly syngenetic.

The Seneca deposit, described by Thompson (1973) and Pearson (1974), is also similar to the Kuroko ores. Pyrite, sphalerite, and chalcopyrite occur in Middle Jurassic andesitic to rhyolitic pyroclastics and argillaceous breccias.

Several massive sulphide deposits form a cluster southeast of Prince Rupert. The Ecstall deposit, the best known, contains at least seven million metric tons of iron-zinc-copper material that is similar in mineralogy but lower grade than that at Britannia. Sulphides are concentrated in lenticular quartz-sericite schist horizons in amphibolite-grade strata of unknown age (Paleozoic?). The sulphides, recrystallized during metamorphism, form a faintly banded mosaic of equant pyrite grains with interstitial sphalerite, chalcopyrite, galena, and quartz. The Ecstall deposits were interpreted by Bacon (1953) as hydrothermal replacements of quartz-sericite schist, controlled by shearing and folding. A volcanic origin is also possible, but insufficient work has been done and the mode of origin remains speculative.

VEIN DEPOSITS

Sulphide-bearing veins, common in the Coast Mountains, show great variety of geologic setting, form, mineralogy, and economic importance. Some are transitional to other types of deposits. Economically important veins occur both in plutonic rock (Surf Inlet, Surf Point) and pendants (Northair). The important commodity in most veins is gold, generally in the form of native netal but also as tellurides in some veins in plutonic rock. The sulphide mineralogy of the veins is simple: pyrite is in almost all cases the most abundant sulphide with chalcopyrite, sphalerite, and other sulphides being important in many deposits.

The Surf Inlet and Surf Point mines are the only veins in plutonic rock that have produced significant amounts of ore. The Surf Inlet orebodies are quartz-pyrite veins along a complex north-trending fault zone (Dolmage, 1922; Gill and Byers, 1948). The veins are localized along and near the contact between a screen of schist and gneiss and the enclosing quartz diorite. Veins in both schist and quartz diorite appear to occupy fractures that apparently opened as late tensional features subsidiary to the main shears. At Surf Point veins are localized along an arch of foliation planes in a small quartz diorite stock (Smith, 1947, 1948). Vein gangue at both deposits is almost entirely milky quartz, intensely sheared at Surf Inlet. Pyrite is by far the most abundant metallic mineral; very minor chalcopyrite, molybdenite and other sulphides are also present. Microscopic gold is extremely rare in both mines. The few grains seen in samples from Surf Inlet appear insufficient to account for the high gold assays obtained from the pyrite, but no other gold minerals have been indentified. At Surf Point gold and silver occur mostly as sylvanite and hessite.

The Drum Lummon mine is an unusual small but high grade deposit. Sulphide mineralization is concentrated near the margins of irregular masses of pegmatitic quartz and K-feldspar that have developed in coarse-grained hornblende > biotite quartz diorite. Quartz forms the centre of the pegmatitic masses, and feldspar forms a zone between the quartz core and quartz diorite. Sulphides, mainly bornite and chalcocite, are concentrated in erratically distributed irregular pods that locally cut the quartz diorite. Native gold and silver were present in the upper levels of the workings.

The Northair mine is hosted by andesitic to dacitic pyroclastic pendant rocks of probable Early Cretaceous age which have been regionally metamorphosed to greenschist facies. Steeply dipping or vertical quartz-carbonate veins cut the schistosity of the host rocks at a small angle. The ore minerals, in order of abundance, are galena, sphalerite, chalcopyrite, pyrite, gold and argentite.

BRIDGE RIVER GOLD CAMP

The lode gold ores of the Bralorne and Pioneer mines in the Bridge River area were for many years the most important producers of gold in British Columbia. The best accounts of the geology of these orebodies are those of McCann (1922), Cairnes (1937), Joubin (1948), and Pearson (1975). The veins are hosted by Upper Triassic greenstone, dioritized greenstone, and sediments within the eastern margin of the Coast Plutonic Complex. The ore shoots are spatially and genetically related to Eocene dykes of "soda granite" and occupy tension fractures and reverse faults related to larger northwest faults. Veins are mainly milky quartz with minor pyrite, arsenopyrite, gold, scheelite, stibnite, and other minerals.

Woodsworth, *et al* (in press) described a distinctive zoning pattern in the Bridge River area. Two elongate centres of gold mineralization (one at Bralone) trend northwest within a larger area of antimony mineralization. The antimony zone is overlapped to the northeast by a cinnabar zone. In general, mineral assemblages characteristic of higher temperatures are closer to the main body of the Coast Plutonic Complex. The vein deposits near Terrace are somewhat similarly zoned, with molybdenite-scheelite-gold veins farther away. Woodsworth, *et al* (in press) suggested that the zoning in the Bridge River area may be due to mineral deposition under the influence of a regional thermal gradient decreasing outwards from the core of the Coast Plutonic Complex.

SKARNS AND OTHER REPLACEMENT DEPOSITS

Sulphide deposits in altered carbonate rocks are common in the Coast Plutonic Complex, but all are small and none has yielded significant production. The siliceous gangue generally contains varying amounts of calcite, epidote, garnet, actinolite and diopside. The ore mineralogy is varied. Pyrite, chalcopyrite and sphalerite are the most abundant sulphides in the majority of deposits, but pyrrhotite, galena, and arsenopyrite are major constituents of some deposits, and sparse molybdenite is also commonly present. Many of the sulphide-bearing skarns are situated near lineaments that trend northwest and are presumed to represent faults along many contacts between pendants and plutons.

The best known of these deposits are the Hepler Lake and nearby deposits on Banks Island (Holland, 1964). Mineral deposition occurred in tension fractures in brecciated skarn and in altered shear zones in granitoid rocks. The narrow pendants that host most of the ore may themselves be bordered by faults whose intersections may control high-grade pipe-like sulphide deposits. The skarns are unusual for the Coast Mountains in that gold and silver are present in economically interesting amounts. At least some of the gold and silver is present as tellurides associated with pyrite and arsenopyrite.

Small skarn deposits containing massive and disseminated magnetite and lesser chalcopyrite are common in both the western part of the Coast Mountains and south of Terrace. On Vancouver and Texada Islands, just southwest of the Coast Plutonic Complex, somewhat similar but larger skarns have produced important amounts of iron and copper (Sangster, 1969; Carson, 1968).

NICKEL DEPOSITS IN ULTRAMAFIC ROCKS

In the Coast Mountains, ultramafic rocks are restricted to the southeast corner of the Coast Plutonic Complex[1]. The Giant Mascot mine has been the only nickel produ-

[1]. The belt of mid-Cretaceous Alaskan-type ultramafic bodies in southeast Alaska has notbeen recognized to the south.

cer in the Canadian Cordillera and the only productive ultramafic body in the Coast Mountains. Recent descriptions of this mine include James (1965), Clarke (1969), and Christopher and Robinson (1975).

The orebodies are concentrated in a crudely elliptical ultramafic complex about 2 km across which is enclosed in granodiorite to diorite of the Late Cretaceous Spuzzum pluton. The ultramafic is dominantly pyroxenite, with lesser dunite and hornblendite. Most of the hornblendite is localized along contacts between the ultramafic complex and dioritic rocks of the Spuzzum pluton. Potassium-argon dates from the ultramafic body range from 119 to 95 m.y. (McLeod, *et al*, 1976) and are slightly older than dates from the enclosing Spuzzum pluton (103 to 77 m.y.; Richards and McTaggart, 1976).

Twenty-eight orebodies have been found in the main ultramafic mass. Sulphides, dominantly pyrrhotite with subordinate pyrite, pentlandite, chalcopyrite, and violarite, occur both as interstitial fillings among the silicates and as massive sulphide bodies. The orebodies are steeply plunging pipe-like bodies localized at the intersections of northwest and north to northeast-trending fault systems.

Although the sulphides are no doubt genetically related to the ultramafic complex, the mode of origin and emplacement of the ultramafic is unknown. Particularly puzzling is the relation between the ultramafic complex and the diorite of the Spuzzum pluton. The origin of this unique deposit remains obscure.

PORPHYRY DEPOSITS

Compared with the adjacent Insular and Intermontane Belts, porphyry and stockwork copper and molybdenum deposits are uncommon in the Coast Plutonic Complex. Unlike many porphyry deposits in the flanking belts none in the Coast Mountains has reached production. All porphyry and stockwork deposits within the Coast Plutonic Complex itself are situated in the southern part, but numerous important copper and molybdenum porphyries lie just east of the belt southeast of Terrace. Within the southern Coast Mountains three broad categories of porphyry deposits may be distinguished; copper-molybdenite-gold deposits at the northeast margin of the Coast Plutonic Complex; molybdenite deposits related to Micocene plutons, and copper-molybdenite deposits along the southwest flank of the Coast Mountains.

The limited data available for the copper-molybdenite-gold porphyries are summarized by Woodsworth, *et al* (in press). The deposits are silicified breccia zones in quartz monzonite and quartz diorite of possible early Tertiary age. Many cluster along the northeast margin of the Coast Plutonic Complex southeast of Taseko Lakes. Pyrite, chalcopyrite, and molybdenite are the only abundant sulphides; gold value average about 0.94 gram per metric ton.

Several porphyry molybdenite deposits are associated with a chain of high-level Micocene plutons that extends from the Cascade Mountains of Washington through the Coast Mountains to Bella Coola (Fig. 3) The best known of these deposits is Salal Creek (Stephens, 1972), dated at 8 m.y. (K–Ar on biotite). This quartz monzonite pluton is texturally zoned: a coarse-grained margin is intruded by a fine-grained core. Both sulphide and alteration mineral assemblages are concentrated in an arcuate zone centred on the contact between core and margin. Wall-rock alteration assemblages include propylitic, argillic, and potassic varieties, and the best mineralization is associated with the potassic alteration. Pyrite is more abundant than molybdenite,

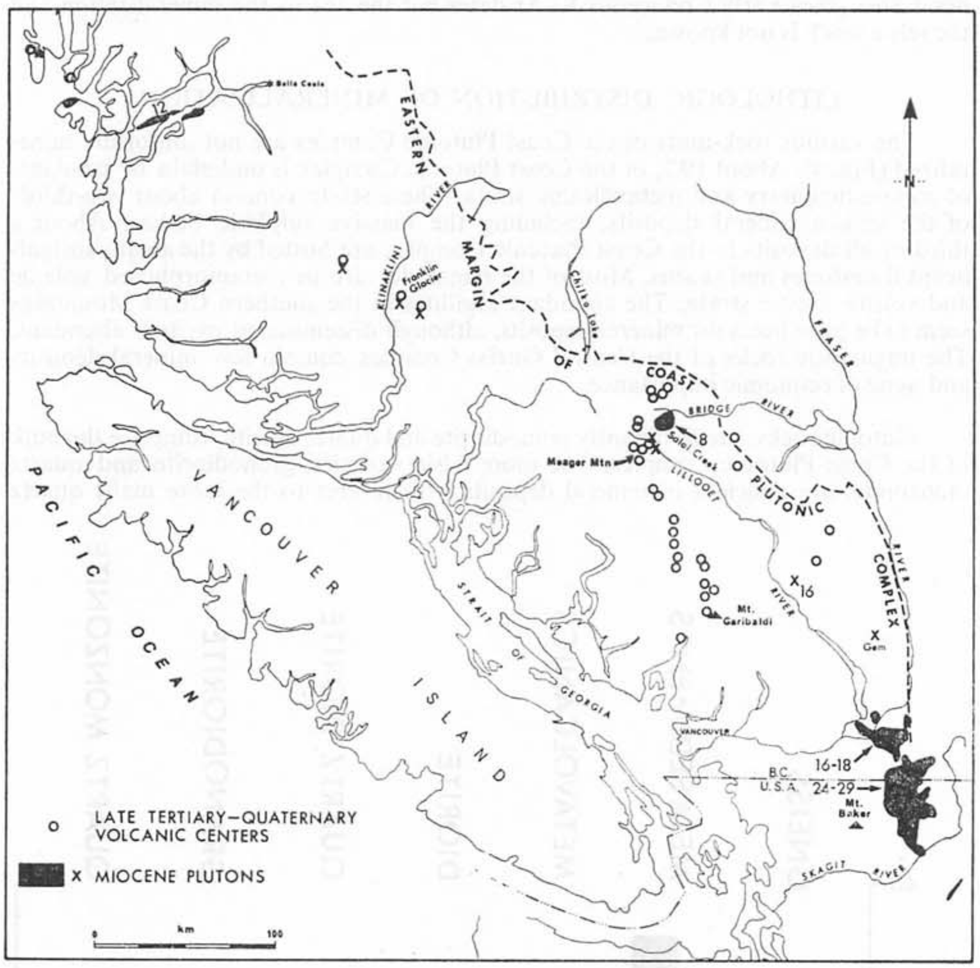

Fig. 3. Miocene and younger plutons, and late Tertiary-Quarternary volcanic centres in the southern Coast Plutonic Complex. Plutons whose areal extent is unknown or very small are indicated by an "X". Numbers give K-Ar ages in m.y. After Woodsworth, *et al* (in press).

and copper and gold values are very low. The Franklin Glacier deposit is probably similar in age; pyrite and chalcopyrite with lesser molybdenite are the most abundant sulphides. The Salal and Franklin Glacier deposits appear to be related genetically to Miocene and younger plutonism and volcanism, rather than to the Eocene and older plutonism characteristic of the Coast Plutonic Complex.

A northwest-trending chain of stockwork copper and molybdenite prospects extends for about 200 km along the west margin of the Coast Mountains. The best known is the OK deposit, which has drill-indicated reserves of 82 million metric tons of 0.33% copper and 0.02% molybdenite. Diorite of the Coast Plutonic Complex is cut by a felsic composite stock with a leuco-granodiorite core. Pyrite, chalcopyrite, and molybdenite are peripheral to the core. The Coast Plutonic Complex in this general area gives Early Cretaceous K–Ar dates but the age of the mineralization and the felsic stock is not known.

LITHOLOGIC DISTRIBUTION OF MINERALIZATION

The various rock-units of the Coast Plutonic Complex are not uniformly mineralized (Fig. 4). About 10% of the Coast Plutonic Complex is underlain by pendants of metasedimentary and metavolcanic strata. These strata contain about two-thirds of the known mineral deposits, including the massive sulphide bodies. About a third of all deposits in the Coast Plutonic Complex are hosted by the areally insignificant limestones and skarns. Most of the remainder are in metamorphosed volanic and volcanoclastic strata. The abundant argillites in the southern Coast Mountains seem to be poor hosts for mineral deposits, although disseminated pyrite is abundant. The migmatitic rocks of the Central Gneiss Complex contain few mineral deposits and none of economic importance.

Plutonic rocks, predominantly granodiorite and quartz diorite, comprise the bulk of the Coast Plutonic Complex. The more felsic varieties, granodiorite and quartz monzonite, are deficient in mineral deposits with respect to the more mafic quartz

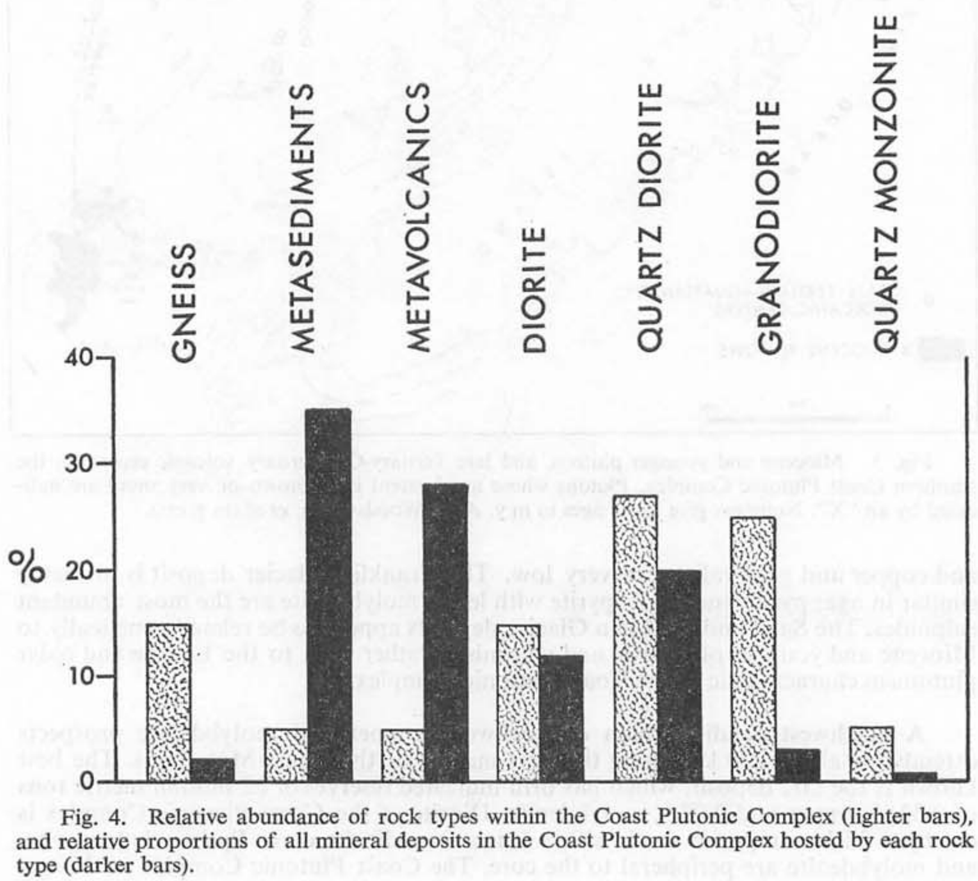

Fig. 4. Relative abundance of rock types within the Coast Plutonic Complex (lighter bars), and relative proportions of all mineral deposits in the Coast Plutonic Complex hosted by each rock type (darker bars).

diorite and diorite (Fig. 4). Although granodiorite and quartz diorite are roughly equal in abundance, quartz diorite hosts about five times as many mineral deposits as granodiorite.

The distribution of accessory sulphides among the various lithologies is similar to the distribution of mineral deposits. Pyrite, the most common accessory sulphide, is the dominant sulphide is most mineral deposits. Pyrrhotite, chalcopyrite, and molybdenite are also common as accessory minerals and as major constituents of many mineral deposits. Disseminated and fracture-controlled pyrite is abundant in many weakly metamorphosed pendant rocks; at higher metamorphic grades pyrrhotite is commonly the dominant sulphide. Generally sulphides are present throughout the pendants, although grain size tends to be greatest at pendant margins, giving the impression that sulphides are more abundant at the margins.

In plutonic rocks accessory pyrite is found mainly in hornblende-rich diorite and quartz diorite (Fig. 5), particularly those with extensive chloritization, epidotization, or pink hydrothermal alteration. Such rocks are hosts for most mineral deposits in plutonic rocks. Diorite and quartz diorite are also the most common plutonic rocks adjacent to mineralized pendants.

The Central Gneiss Complex is anomalous in that although accessory sulphides are widespread, mineral deposits are rare (Fig. 2). A similar anomaly was noted by

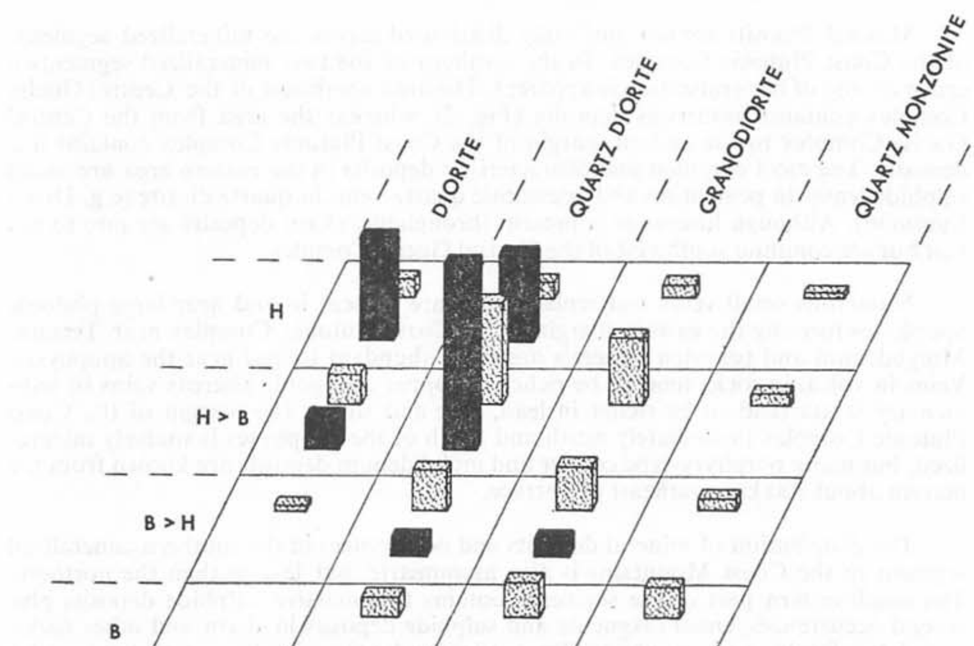

Fig. 5. The lighter bars represent the relative abundance in the Coast Plutonic Complex of each plutonic rock type according to the ratio of hornblende (H) to biotite (B). The darker bars represent the relative proportions of pyrite-bearing rocks (normalized to 100%) as a function of plutonic rock type.

Woodsworth (1971). His data suggest that the average copper contents of the rock units in the central Coast Mountains are ranked in the order: gneiss Complex > pendant rocks > diorite > quartz diorite > granodiorite = quartz monzonite. Except for the Central Gneiss Complex, this order is similar to the relative abundance of mineral deposits and therefore may not be coincidental. Although the Central Gneiss Complex contains above average amounts of ore metals and sulphur, mineral deposits failed to form. The reason is not known, but possibly these rocks dried out by loss of metamorphic fluids at temperatures above which chalcophile metal complexes are stable, inhibiting the large-scale transport of ore metals. Further, the high temperatures and pressures may have inhibited fracturing and channelling of the metamorphic fluids, thus restricting the extent to which the ore metals could be concentrated.

SPATIAL DISTRIBUTION OF MINERALIZATION

The distribution of mineral deposits in the Coast Mountains is not uniform either across the belt or along its axis (Fig. 2). In a longitudinal direction two relatively well-mineralized segments (49°–51°N and 52°–55°N) are separated by a relatively unmineralized area. Sutherland-Brown (1971) pointed out that most mineralization in the Canadian Cordillera coincides with two structural arches that cross the northwest tectonic grain of the Cordillera. The two mineralized segments of the Coast Mountains appear to be the westward extensions of the two heavily-mineralized segments of the Intermontane Belt to the east. The unmineralized segment of the Coast Mountains is flanked by a similarly barren area of the Intermontane Belt.

Mineral deposits are not uniformly distributed across the mineralized segments of the Coast Plutonic Complex. In the northern of the two mineralized segments a crude zoning of mineralization is apparent. The area southwest of the Central Gneiss Complex contains numerous deposits (Fig. 2), whereas the area from the Central Gneiss Complex to the eastern margin of the Coast Plutonic Complex contains few deposits. The most common and characteristic deposits in the eastern area are small sulphide lenses in pegmatites and pegmatitic quartz veins in quartz diorite (e.g. Drum Lummon). Although limestone is present throughout, skarn deposits are rare to the east but are common southwest of the Central Gneiss Complex.

Numerous small veins and replacements are present in and near large plutonic apophyses forming the eastern margin of the Coast Plutonic Complex near Terrace. Molybdenum and tungsten minerals are most abundant in and near the apophyses. Veins in volcanic rocks tend to be richer in copper and gold, whereas veins in sedimentary strata tend to be richer in lead, zinc and silver. The margin of the Coast Plutonic Complex immediately north and south of the apophyses is sparsely mineralized, but many porphyry-type copper and molybdenum deposits are known from the margin about 100 km southeast of Terrace.

The distribution of mineral deposits and occurrences in the southern mineralized segment of the Coast Mountains is also asymmetric, but less so than the northern. The southwestern part of the segment contains two massive sulphide deposits plus several occurrences, small magnetite and sulphide deposits in skarn and other rocks, a variety of veins (commonly auriferous) in pendants and adjacent plutons, and a discontinuous chain of copper-molybdenum stockwork deposits. The northeastern part of the segment contains Miocene porphyry-type deposits, small shear-controlled sulphide deposits, and the Giant Mascot nickel-copper ore-bodies. The Bridge River gold district is situated at the east margin of the Coast Plutonic Complex. Copper-molybdenum-gold occurrences lie along the east margin. Aside from the Northair ore bodies and nearby prospects, the central third of the southern segment contains few deposits or significant occurrences.

AGE OF MINERALIZATION

The ages of most mineral deposits in the Coast Mountains are not known. Most pendants are unfossiliferous, and K–Ar dating gives only minimum ages for the plutons.

The host rocks for massive sulphide deposits show a wide range of ages. At Britannia the host volcanics are almost certainly Early Cretaceous and ore deposition may, at least in part, have been contemporaneous with deposition of the strata. Host rocks for the Seneca deposit are probably Middle Jurassic; those at Anyox may also be Jurassic. A Paleozoic age is possible for the strata hosting the Ecstall deposits, but the actual age of mineralization is not known.

Vein deposits are found in pendant rocks ranging in age from Paleozoic (?) to Early Cretaceous, and the range in ages of the vein mineralization may be as great or greater. Metamorphic biotite from Lower Cretaceous strata hosting the Northair veins gives a latest Cretaceous K–Ar age; the veins are possibly early Tertiary. The auriferous veins of the Bridge Eiver district are of Rocene age (D.E. Pearson, personal communication), as might be the numerous vein deposits near Terrace. Most vein deposits in plutonic rock are in plutons that yield Cretaceous and Jurassic K–Ar ages; only a few veins are known from plutons dated as Tertiary. In no case is it known if the vein mineralization precedes or postdates the event recorded by the K–Ar clock.

Most skarn deposits in the southwestern part of the southern Coast Mountains are in pendant rocks that may be correlative, in part, with the Upper Triassic Quatsino Formation of Vancouver Island. Most skarn deposits on Vancouver Island are near contacts between the Quatsino Formation and mid-Jurassic plutons. Most dated plutons near skarns in the Coast Mountains give Cretaceous K–Ar ages.

Copper and molybdenum porphyry-type deposits just east of the Coast Plutonic Complex give Late Cretaceous and early Tertiary K–Ar ages. Stockwork copper-molybdenum deposits along the southwestern flank of the Coast Mountains are of unknown age, but the host Coast Plutonic Complex gives Early Cretaceous K–Ar ages. The Salal Creek molybdenite occurrences are associated with a chain of Miocene plutons giving K–Ar ages of 8 to 29 m.y.

RELATIONS BETWEEN MINERALIZATION AND PLUTONISM

Except for the massive sulphide deposits, mineralization in the Coast Mountains is conventially assumed to be related to cooling granitic magmas. According to this view, not shared by the authors, mineral deposition results from the interaction of metal-rich hydrothermal fluids and wall-rocks during and after emplacement of the magmas. Thus most ore deposits are genetically related to the nearby plutonic rocks. The data do not support such simple origins, however, and alternate interpretations are possible. Most ore deposits appear to have had long and complex histories that reflect the evolution of the plutonic rocks themselves. Only the porphyry deposits may have had a relatively simple origin resulting directly from intrusive atirity.

Many mineral deposits in the Coast Mountains show a strong northwest structural control. The dominant strike of most mineralized veins is north to northwest (Fig. 6). Some veins are localized along or near north to northwest fault systems (e.g.

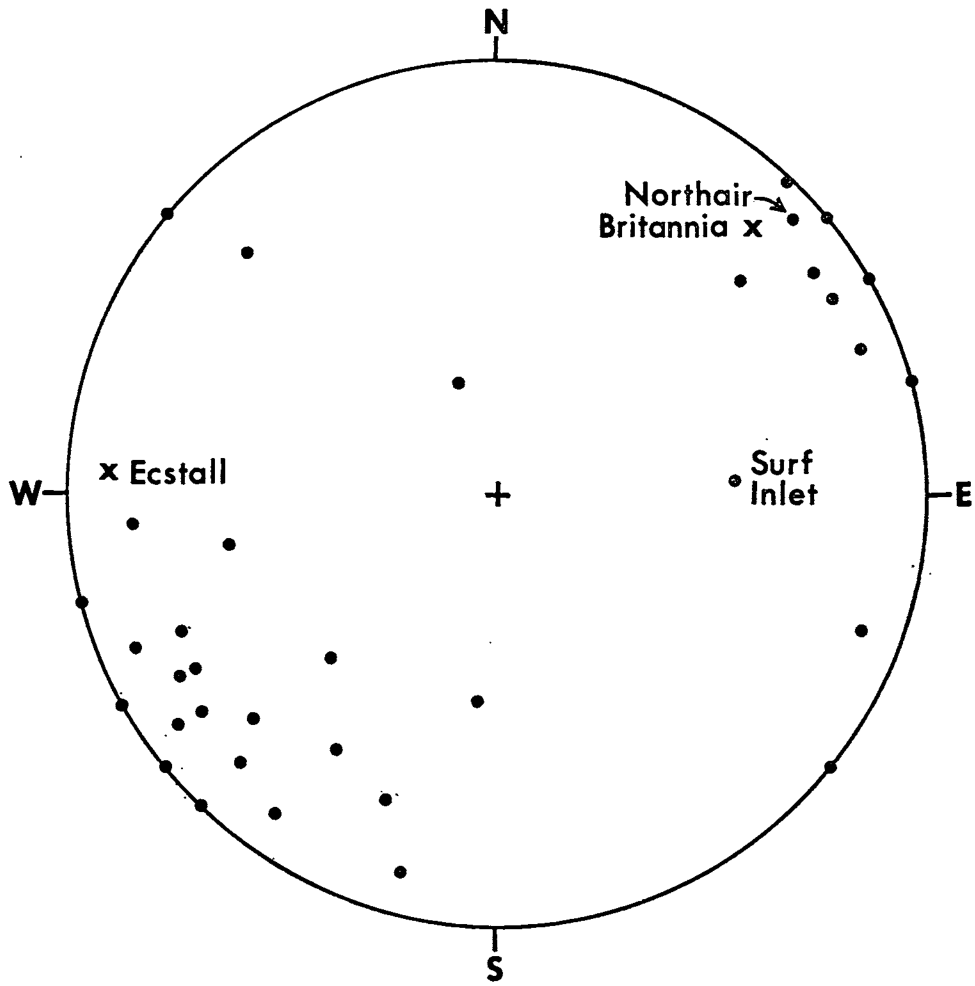

Fig. 6. Lower hemisphere equal-area projection of strike and dip of vein deposits in the Coast Plutonic Complex (dots). The "X" for Britannia represents the attitude of the Britannia shear zone; that for Ecstall represents the attitude of the ore bodies.

Surf Inlet, Bralorne); others are parallel or nearly parallel with bedding or schistosity in pendant strata (e.g. Northair). Many skarn deposits are situated near possible faults. Woodsworth (1971) noted that sediments from streams draining northwest-trending faults or lineaments are anomalously high in molybdenum compared with other areas of the central Coast Mountains. The northwest trend may represent a tectonic and plutonic event that has reworked and remobilized pre-existing mineral deposits.

Most plutons in the Coast Mountains are thought by the authors to have been emplaced as diapiric solids. Many contacts between plutons and pendants are faults; others may represent faults that have been healed by recrystallization. The proximity of many skarn and vein deposits to pluton-pendant contacts may reflect the narrow width of most pendants and the fault nature of many contacts rather than any direct connection between the mineralization and adjacent plutons.

The overall pattern of mineralization across the Coast Mountains is asymmetric, as is the distribution of plutonic rock types and metamorphic facies. Such asymmetry, together with the similarity of the sulphide assemblages in all deposits regardless of age or type, suggests a fundamental, long-lived control of mineralization that also controls the large-scale distribution of plutonic rocks and metamorphic facies. Possibly ore deposition is related to movements of metals and fluids along deep-seated northwest-trending fracture systems. Fluids may be derived from metamorphic processes operating at a deeper level. The transverse segmentation of mineralization in the Cordillera may, as suggested by Sutherland-Brown, *et al* (1971), be related to major fracture zones extending southwest across the Cordillera.

ACKNOWLEDGMENTS

We thank K.M. Dawson, Geological Survey of Canada, for helpful criticism of the manuscript. Illustrations were drafted by G.R. Dumas.

REFERENCES

BACON, W.R., 1953. Ecstall River. *British Columbia Dept. Mines, Ann. Rept. 1952*, 79–81.

CAIRNES, C.E., 1937. Geology and mineral deposits of Bridge River mining camp, British Columbia. *Geol. Surv. Can., Mem. 213*, 140 p.

CARSON, D.J.T., 1968. Metallogenic study of Vancouver Island with emphasis on the relationships of mineral deposits to plutonic rocks. *Ph. D. Dissertation, Carleton University*, 238 p.

CHRISTOPHER, P.A., and ROBINSON, J.W., 1975. Pride of Emory mine. in *British Columbia Dept. Mines Pet. Resour., Geology, Exploration and Mining in British Columbia 1974*, 105–113.

CLARKE, W.E., 1969. Giant Mascot Mines Limited: geology and ore controls. *Western Miners, 42*, June, p 40–46.

DOLMAGE, V., 1922. Coast and islands of British Columbia between Burke and Douglas Channels. *Geol. Surv. Can., Sum. Rept. 1921*, pt. A, 22–49.

GILL, J.E. and BYERS, A.R., 1948. Surf Inlet and Pugsley mines. in *Structural Geology of Canadian Ore Deposits*, Can. Inst. Mining Met., Jubilee Vol., 99–104.

HOLLAND, S.S., 1964. Bank, Banker, Isle, Omi, Waller. *British Columbia Dept. Mines Pet. Resour., Ann. Rept. 1963*, 21–23.

HUTCHISON, W.W., 1970. Metamorphic framework and plutonic styles in the Prince Rupert region of the central Coast Mountains, British Columbia. *Can. J. Earth Sci., 7*, 376–405.

JAMES, A.C.R. and EASTWOOD, G.E.P., 1965. Pride of Emory (Giant Mascot Mines Limited). *British Columbia Dept. Mines Pet Resour., Ann. Rept. 1964*, 137–142.

JOUBIN, F.R., 1948. Bralorne and Pioneer mines. in *Structural Geology of Canadian Ore Deposits*, Can. Inst. Mining Met., Jubilee Vol., 168–177.

MCCANN, W.S., 1922. Geology and mineral deposits of the Bridge River map-area, British Columbia. *Geol. Surv. Can., Mem. 130*, 115 p.

MCLEOD, J.A., VINING, M., and MCTAGGART, K.C., 1976. Note on the age of the Giant Mascot ultramafic body, near Hope, B.C. *Can. J. Earth Sci., 13*, 1152–1154.

PEARSON, D.E., 1974. Harrison, Lucky Jim. *British Columbia Dept. Mines Pet. Resour., Geology, Exploration and Mining in British Columbia 1973*, 125–128.

PEARSON, D.E., 1975. Bridge River map-area. *British Columbia Dept. Mines Pet. Resour., Geological Fieldwork, 1974*, 35–39.

RICHARDS, T.A. and MCTAGGART, K.C., 1976. Granitic rocks of the southern Coast Plutonic Complex and northern Cascades of British Columbia. *Geol. Soc. America Bull., 87*, 935–953..

RODDICK, J.A. and HUTCHISON, W.W., 1972. Plutonic and associated rocks of the Coast Mountains of British Columbia. *Int. Geol. Congr., Twenty-fourth Session, Canada, Guidebook A04–C04*, 71 p.

RODDICK, J.A. and HUTCHISON, W.W, 1974. Setting of the Coast Plutonic Complex, British Columbia. *Pacific Geology, 8*, 91–108.

SANGSTER, D.F., 1969. The contact metasomatic magnetite deposits of southwestern British Columbia. *Geol. Surv. Can., Bull., 172*, 85 p.

SMITH, A., 1947. Control of ore by primary igneous structures, Porcher Island, British Columbia. *Geol. Soc. Amer., Bull., 58*, 245–262.

SMITH, A., 1948. Surf Point and Edye Pass mines. in *Structural Geology of Canadian Ore Deposits*, Can. Inst. Mining Met., Jubilee Vol., p. 94–99.

STEHENS, G.C., 1972. The geology of the Salal Creek pluton, southwestern British Columbia. *Ph. D. Dissertation, Lehigh Univ.*, 177 p.

SUTHERLAND-BROWN, A., 1969. Mineralization in British Columbia and the copper and molybdenum deposits. *Can. Inst. Mining Met., Bull., 62*, Jan., 1–15.

SUTHERLAND-BROWN, A., 1975. Britannia Mine. *British Columbia Dept. Mines Pet. Resour., Geology, Exploration and Mining in British Columbia 1974*, 190–197.

SUTHERLAND-BROWN, A., CATHRO, R.J., PANTELEYEV, A., and NEY, C.S., 1971. Metallogeny of the Canadian Cordillera. *Can. Inst. Mining Met., Bull., 64*, May, 1–25.

SUTHERLAND-BROWN, A., and ROBINSON, J.W., 1971. Britannia mine. *British Columbia Dept. Mines Pet. Resour., Geology, Exploration and Mining in British Columbia 1970*, 233–246.

THOMPSON, R.I., 1973. Harrison, Lucky Jim. *British Columbia Dept. Mines Pet. Resour., Geology, Exploration and Mining in British Columbia 1972*, 102–114.

WOLFHARD, M.R. and NEY, E.S., 1976. Metallogeny and plate tectonics in the Canadian Cordillera. in *Metallogeny and Plate Tectonics*, Geol. Assoc. Can., Spec. Pap. 14, 361–392.

WOODSWORTH, G.J., 1971. A geochemical drainage survey and its implications for metallogenesis, central Coast Mountains, British Columbia. *Econ. Geol., 66*, 1104–1120.

WOODSWORTH, G.J., PEARSON, D.E., and SINCLAIR, A.J., in press. Metal distribution patterns across the eastern flank of the Coast Plutonic Complex, south-central British Columbia. *Econ, Geol.*