PROPERTY FILE

92GNW036

008073

Owner: NEW JERSEY ZINC EXPLORATION COMPANY (CANADA) LTD., 905, 525 Seymour Street, Vancouver 2.

Metal: Copper.

Description: Chalcopyrite and some pyrite occur disseminated or as irregular lenses and masses in metasediments of the Goat Mountain Formation, about one-quarter mile east of the Coast Intrusives contact. Silicification usually accompanies the chalcopyrite, but pyrite may occur without silica.

Work done: Electromagnetic survey, 2.3 line-miles covering Bell 1, 2, and 17.

References: *Minister of Mines, B.C.*, Ann. Rept., 1917, p. 276; *Geol. Surv., Canada*, Mem. 158, p. 113; Assessment Report 2665.

HOWE SOUND

BRITANNIA MINE (No. 67, Fig. F)

By A. Sutherland Brown and J. W. Robinson

Location: Lat. 49°36.6′ Long. 123°08.5′ (92G/11E)
The Britannia mine is on the east side of Howe Sound, 40 miles by road north of Vancouver.

Owner: ANACONDA AMERICAN BRASS LIMITED, Britannia Beach.

Metals: Copper, zinc (*see* Table 1 for production).

Description:

Introduction

Sixty-six years of nearly continuous operations have not exhausted the ore reserves of the Britannia mine nor has study over that period revealed with certainty the structure or stratigraphy of the mine. Significant orebodies such as the 040 (No. 10) continue to be found and the potential for finding others is good. The geology of the mine has been carefully studied for much of the period of exploitation, and substantial records kept. Most of the available mine has been remapped and drill core relogged by Anaconda geologists since acquiring the property in 1963. In addition, elaborate geological and geochemical research projects have been conducted. However, as different interpretations of some aspects of the geology are still possible, it is obvious that the Britannia orebodies are a very complex geological situation.

The following description is primarily concerned with the surface geology of an area of the Britannia Shear Zone that is particularly well exposed. It was studied with the hope of rapidly acquiring an acquaintance with the geology of the mine. A total of four weeks in 1969 and 1970 were spent mapping the surface and visiting underground. The manager and geological staff of the mine extended every help, including extensive discussions and joint visits to many of the critical localities. The geology as here described does not necessarily coincide with that of the Anaconda staff. It is hoped that a definitive article on the geology of Britannia will be published by Anaconda geologists.

Geological Setting

The Britannia mine occurs in a pendant of mainly volcanic rocks intruded by several plutons (*see* Fig. 24 and Bostock, 1963). The stratified sequence (Gambier Group) is dominated by pyroclastic rocks of andesitic to dacitic character which are intercalated near the top and overlain by dark marine shales and siltstones. In a separate but lithologically similar pendant 6 miles south of Britannia, H. W. Tipper, of the Geological Survey of Canada, has recently collected Albian ammonites. Potassium-argon analysis on the Squamish Batholith that intrudes the Britannia pendant on the north gives an apparent age 92±4 million years (White, 1968). Formation of the ore deposits and intrusion of a dacite dyke swarm predate the

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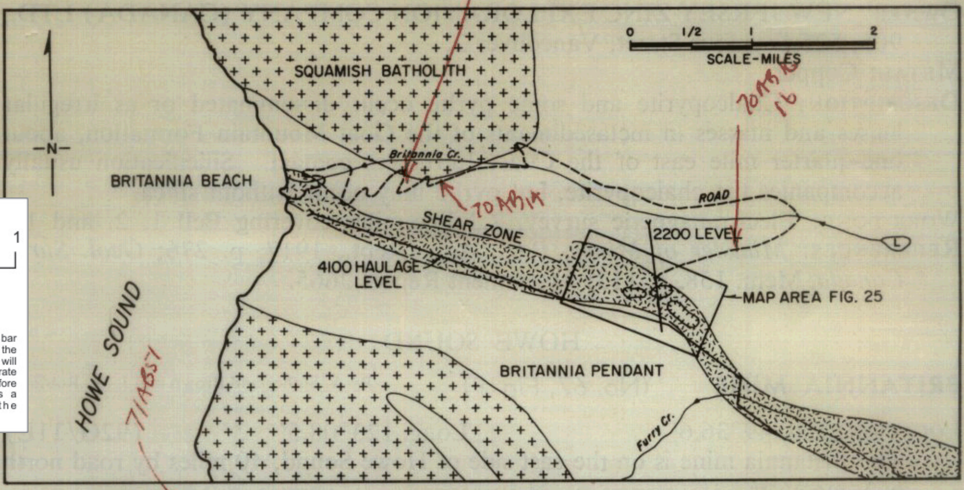

Figure 24. Britannia mine index map.

intrusion of this pluton. The volcanic pile north of the Britannia mine is tilted southward about 20 degrees as a monoclinal panel. This monocline is transected to the south by a northwesterly trending belt of intense deformation, one-quarter to one-half mile wide, that has been called the Britannia Shear Zone. The orebodies of the Britannia mine occur within this deformed belt.

Detailed Geology

The geology of the central portion of the shear zone is shown on Figure 25. Except for the Victoria and Empress, most of the orebodies that reach the surface do so within this area. Exposure and access are both relatively good. This area contains both margins of the shear zone and relatively good correlation can be made with rocks in both walls, although some problems of correlation exist with the sequence north of the map on the road to the area from Britannia Creek. On the basis of present work, stratigraphic thicknesses are approximate.

The intense development of schistosity of rocks within the shear zone makes correlation with those beyond difficult in the field. It is fundamental to the present interpretation that these correlations can be made. The key to the correlations is partly structural in that units can be traced around a plunging anticlinal nose within the shear zone, and partly stratigraphic in that a distinctive marker occurs in similar sequences in both walls and the anticlinal nose. The initial discussion of the stratigraphy assumes the correlations are valid and emphasis is placed on the character of the relatively undeformed rocks. The deformation and alteration are described subsequently.

Stratigraphy

There are two stratified sequences exposed in the map-area: a lower pyroclastic one and an upper shale-siltstone one which are cut by many large dykes. The older stratified sequence is composed of pyroclastic flow rocks of dacitic character called crystal-rich tuff breccia on Figure 25. These are light grey-green rocks normally lapilli grain size (2 to 20 millimetres) that are charged with chalky plagioclase crystals in matrix and clasts. They are compact rocks with a primary foliation but without bedding planes (*see* Plate XIIA). The foliation results from a high percentage of lenticular fragments, the most prominent of which are white or wispy black. These typical rocks grade rarely to somewhat coarser ones in which the

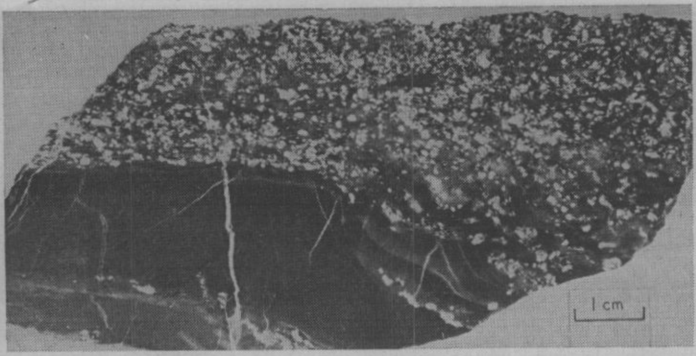

Plate XIA.—Britannia mine. Plagioclase crystal tuff truncating black argillite laminæ with minor plagioclase clasts. Marker beds from footwall northeast of Jane Basin.

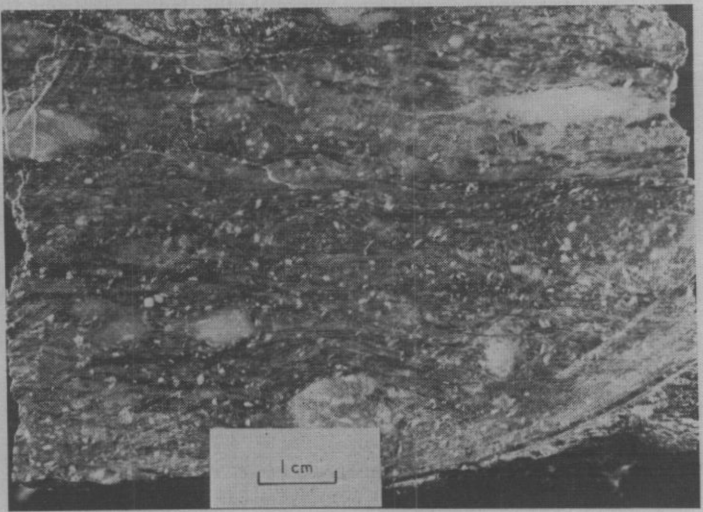

Plate XIB.—Britannia mine. Chlorite mottled schist with remnant plagioclase crystals in porphyritic clasts and in matrix and white crowded dacite porphyry clasts. From 4950 level near 040 orebody. Compare with Plates XIC, XIIB, and XIIC.

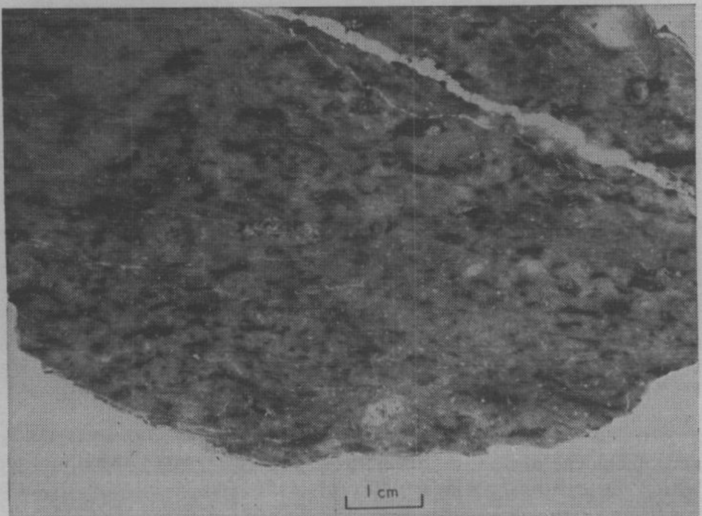

Plate XIC.—Britannia mine. Chlorite mottled schist with some white crowded dacite porphyry clasts but no recognizable plagioclase, Gordon Gallup pit.

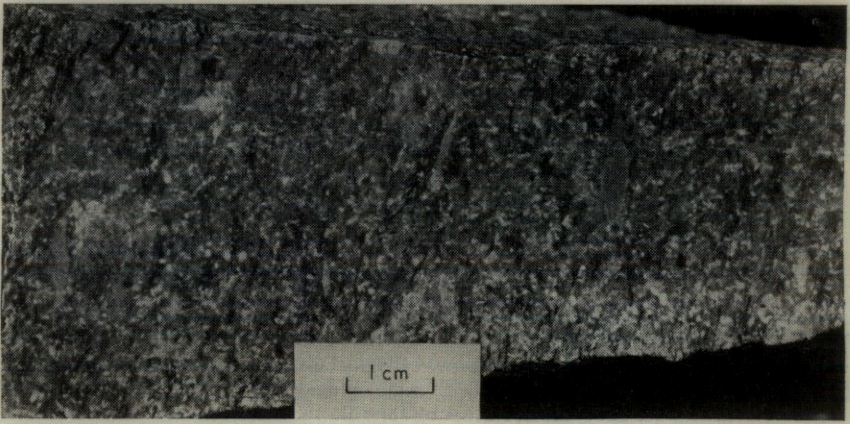

Plate XIIA.—Britannia mine. Undeformed crystal-lithic lapilli tuff from 500 feet south of hangingwall shear near Barbara pit.

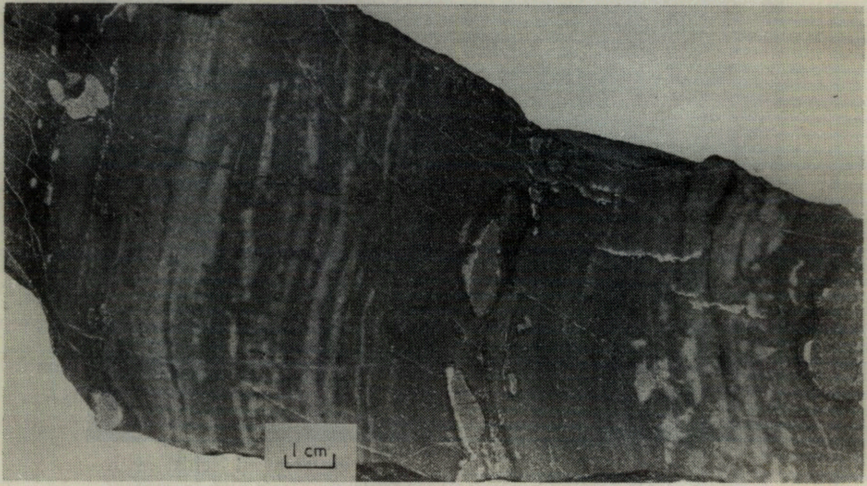

Plate XIIB.—Britannia mine. Altered green argillite with disseminated pyrite (white dots) and nodules of pyrite and quartz (light to dark grey). Lighter grey areas are bleached laminæ from near hangingwall and Fairview zinc orebody.

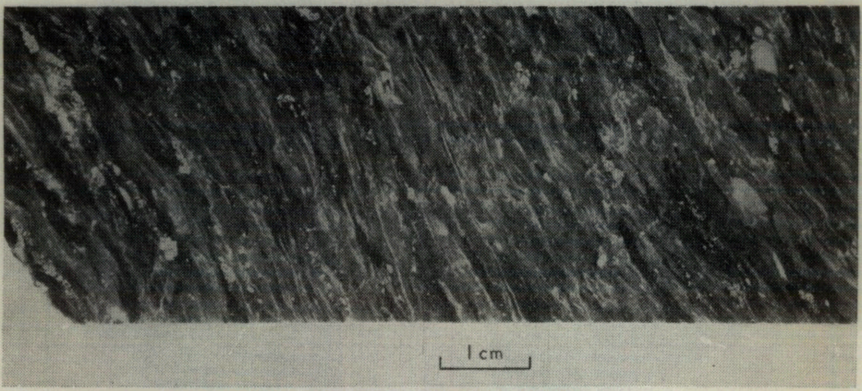

Plate XIIC.—Britannia mine. Highly deformed chlorite mottled schist now composed of chlorite and muscovite wisps, lenses of mosaic quartz, and clots of cubic pyrite. Drill core from near 040 orebody.

primary foliation is not as prominent, or more commonly, to crystal-lithic tuffs with coarse sand-sized clasts. These invariably are well foliated and dominated in appearance by chalky plagioclase. They also commonly contain prominent dark wispy fragments and grade at the top of the pyroclastic sequence into distinctive beds which consist of intercalated black argillite and plagioclase crystal tuffs (*see* Plate XIA). These may be regularly interbedded, convoluted, or disaggregated by soft rock deformation. Within the pyroclastic sequence there may also be minor intercalations of black or green argillite or volcanic sandstone. Fragments of argillite also form a normal component of the pyroclastic flow rocks. The sequence of crystal tuff and successively overlying mixed crystal tuff and argillite, and well-bedded grey and green argillite, is considered the marker beds which outline the structure.

Overlying the marker beds is a sequence of black argillite and siltstone with minor intercalations of dark- to light-coloured greywacke and minor tuff. The black argillite and siltstone are relatively featureless, poorly bedded, but commonly cleaved. Intercalations of greywacke may show graded bedding, shale sharpstones, and minor slump structures.

The apparent local stratigraphic section is:

Top	Feet
Black argillite, siltstone, etc.	500±
Intercalated grey and green argillite	0–50
Mixed crystal tuff and black argillite	10–25
Plagioclase crystal tuff	25–50
Dacitic pyroclastic flows with minor argillitic interbeds	400+
Base	

Within the small area of Figure 25 there are obvious facies changes evident in regard to the marker and adjacent beds, with considerable variation in thickness as indicated in the table. It is unlikely that they would be useful very far beyond the map-area. Nevertheless, the transition from pyroclastic to sedimentary strata is invariably indicated by some part of the marker sequence within the map-area.

Intruding the stratified sequence are two major dyke sequences and a group of small late basic dykes. The early dyke intrusions are composed of dark grey-green andesites that commonly have a slightly mottled texture that reflects a fragmental nature. They may also contain abundant quartz and chlorite amygdules. The andesite bodies have complex field relationships. Some are intrusive thin lineal dykes whereas others form large wedge-shaped bodies of ambiguous relations. Even though formed of fragmental andesites, some seemingly are intrusive whereas others may be local pyroclastic flow domes. In the latter case they would have to occur as intercalations within the argillite sequence with such an initial distribution that they are now not present south of the anticlinal axis. They are clearly almost contemporaneous with the pyroclastic flow rocks and may be highly deformed and mineralized.

The second group are porphyritic dacites that are massive grey-green rocks with about 15 per cent plagioclase phenocrysts 1 to 2 millimetres long. Some have a flow foliation indicated by fluxion arrangement of phenocrysts and small inclusions, and uneven distribution of phenocrysts. Some are only microporphyritic but in general they have a characteristic appearance and texture. They are either not deformed or only slightly so on their margins. Their emplacement postdates major mineralization but they have a close spatial and structural relationship to orebodies. Both groups of major dykes are rare north of the shear zone.

Late dykes are common but volumetrically insignificant and include lamprophyre, basalt, and andesite. The lamprophyre is a dense brownish black rock with lenticular shiny black amygdules. The basalt is fine dense black rock and the andesite a dark-grey aphanitic rock.

On the map (Fig. 25) two other units are shown within the shear zone called chlorite mottled schist and quartz (chlorite) sericite schist. The former is believed to be the schistose equivalent of the dacitic crystal-rich tuff breccia as discussed later. The quartz (chlorite) sericite schist can be shown to have several origins. In general, it is produced by isochemical metamorphism of black argillite, but it is also formed, in part, by intense ductile shear of andesite or chlorite mottled schist. In particular, the westernmost outcrops of andesite were mapped in the field as quartz sericite schist but found on petrographic examination to be andesite. Also some of the bands within the chlorite mottled schist that appear to be quartz sericite schist are likewise probably highly deformed chlorite mottled schist. However, much of the schist appears to be altered black or grey-green argillite, especially that on the margin of the shear zone.

Petrography

Petrographic examination of the least deformed and altered representatives of the various rock types reveal the following:

1. Dacitic tuff breccias have the following range of compositions:

	Per Cent
Plagioclase crystals (oscillatory zoned An_{55-30})	10–30
Lathy equigranular plagioclase dacite and crowded dacite porphyry	2–10
Plagioclase phenocrysts in microcrystalline matrix	30–60
Chlorite fragments	10–20
Siltstone fragments	0– 5

The average size of fragments is estimated to be about 4 millimetres. As the average size decreases the percentage of plagioclase clasts increases somewhat, but even the finest crystal tuffs have as many lithic fragments as plagioclase clasts. The texture of the various volcanic fragments can be quite variable, but all are closely alike in total composition, and are probably dacites. The chlorite fragments are characteristic elements composed of pure, fairly coarse, aligned penninite chlorite, with or without plagioclase crystals. They normally have wispy shapes that are commonly moulded to adjacent stronger clasts. They may represent altered pumiceous fragments or possibly even more altered shale fragments.

The texture and composition of undeformed specimens are akin to that of submarine pyroclastic flow rocks (Fiske, 1963). The composition of the bulk of clasts is uniform, even though the texture varies. The plagioclase that occurs as clasts or as phenocrysts of lithic clasts is similarly zoned and of the same andesine to oligoclase composition. The foliated flow-moulded textures, together with wispy chlorite (pumice?) fragments indicate a probable pyroclastic flow origin just as the intercalation with marine shales also suggests marine origin.

The petrography of the crystal tuffs is similar to that of the tuff breccia but with finer average size and slightly higher concentrations of plagioclase clasts that in some cases show considerable abrasion. The petrography of the mixed tuff and argillites is identical to that of its component parts.

2. The black shales and siltstones are composed principally of a very fine clay and chlorite paste that commonly has an incipient preferred orientation. In this matrix a variable amount of angular feldspar silt clasts are embedded, together with opaque organic matter, ores, and leucoxene. Most of the shales have at least 5 per cent silt clasts and 5 to 10 per cent combined opaque matter. Greywackes

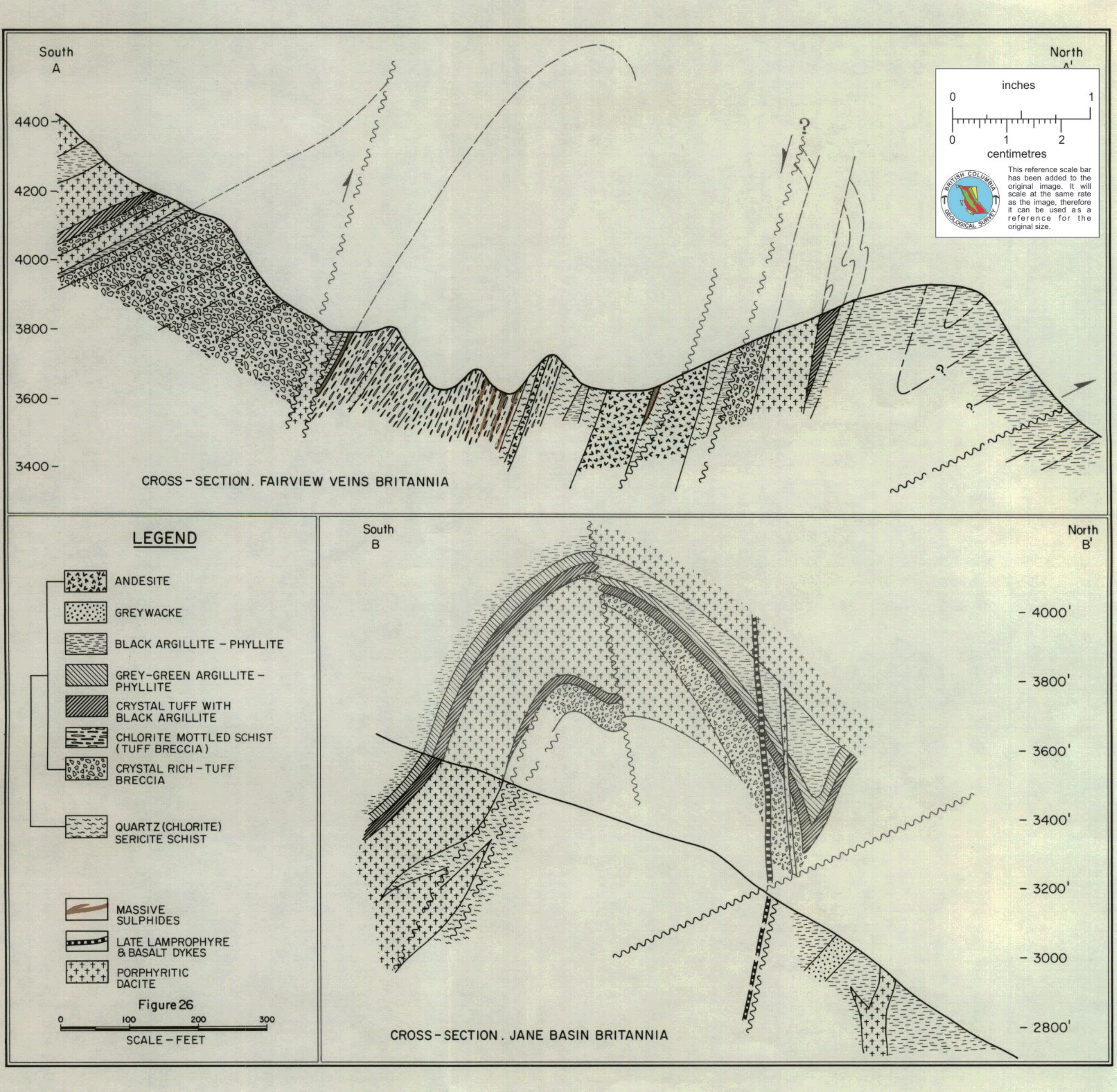
South
A
North
A'
4400
4200
4000
3800
3600
3400
?
?
?
CROSS-SECTION. FAIRVIEW VEINS BRITANNIA
LEGEND
ANDESITE
GREYWACKE
BLACK ARGILLITE - PHYLLITE
GREY-GREEN ARGILLITE - PHYLLITE
CRYSTAL TUFF WITH BLACK ARGILLITE
CHLORITE MOTTLED SCHIST (TUFF BRECCIA)
CRYSTAL RICH - TUFF BRECCIA
QUARTZ (CHLORITE) SERICITE SCHIST
MASSIVE SULPHIDES
LATE LAMPROPHYRE & BASALT DYKES
PORPHYRITIC DACITE
0
100
200
300
SCALE - FEET
South
B
North
B'
4000'
3800'
3600'
3400'
3200'
3000
2800'
CROSS-SECTION. JANE BASIN BRITANNIA

Figure 26

have a similar composition but are coarser with abraded plagioclase laths and angular to rounded quartz dominant in a minor pasty matrix.

3. The grey to greenish-grey argillites are similar to the shales with more plagioclase clasts and without significant organic matter. In addition, some spheroidal particles of unknown origin occur that are composed of quartz, carbonate, and a zeolite, and are about 0.3 millimetre in diameter.

4. All "andesite" specimens were found to be quite highly altered and deformed. They are composed of completely sericitized plagioclase phenocrysts and quartz chlorite amygdules in a finer-grained matrix of chlorite and sericite in which are recognizable small sericitized plagioclase laths and minor quartz, leucoxene, and pyrite. Most but not all specimens appear to have a fragmental texture. They are called andesites in contrast to the dacites because of the seemingly more mafic character.

5. Dacite porphyries are composed as follows:

	Range	Average
Phenocrysts		
Plagioclase (oscillatory zoned An_{48-44})	15–30	22.3
Augite	1–5	2.0
Matrix		
Plagioclase	55–65	60.7
Chlorite	2–15	9.0
Quartz	1–5	2.0
Ilmenite and leucoxene	3–4	3.7
		99.7

Somewhat rounded stubby phenocrysts of slightly zoned andesine, 1 to 3 millimetres long, with smaller augite phenocrysts occur in a trachytic to felted matrix dominated by small (0.1±millimetre) plagioclase laths but containing some quartz, ilmenite, or leucoxene, and a trace of potash feldspar.

6. Lamprophyre dykes have a composition as follows:

	Per Cent
Phenocrysts	
Plagioclase ($An_{54}\pm$)	2
Biotite	0.25
Matrix	
Plagioclase (An_{54-30})	40
Potash feldspar	38
Hypersthene	7
Chlorite-biotite	9
Opaques	2
Brown glass	1.75

Fresh, stubby, normally zoned plagioclase, with minor biotite phenocrysts, and lenses of altered brown glass occur in a trachytic matrix of slim plagioclase laths, hypersthene, and opaque minerals with interstitial potash feldspar.

Chemistry of Volcanic Rocks

The following table lists silicate analysis for least-altered specimens of porphyritic dacite, crystal-lithic tuff, chlorite mottled schist, and andesite. The major oxides have been recalculated to 100 per cent for more ready comparison, and

SO_3, P_2O_5, CO_2, and H_2O of the original analysis listed below. Comparison with Nockolds' tables (1954) indicates a good correlation between his average dacite and that of Britannia. In addition, the crystal-lithic tuff correlates well with his dacite, considering the possibilities for fractionation during pyroclastic eruption. Furthermore, the correlation of tuff and chlorite mottled schist is also good, with the destruction of the feldspars seemingly reflected in the chemistry (*see* later). The andesite is the least-altered specimen collected by the writer, but it is far from fresh. It is neither a typical andesite nor is it a basalt. For an andesite it is high in MgO and Na_2O and low in K_2O.

Chemical Analyses of Volcanic Rocks of Britannia Pendant

	1 Dacite 70AB5	2 Crystal Tuff 70AB36	3 Chlorite Mottled Schist 69AB8	4 Andesite 70AB25	5 Average Dacite	6 Average Andesite
SiO_2	62.10	69.27	66.56	51.59	63.58	54.20
TiO_2	1.00	0.64	0.62	1.56	0.64	1.31
Al_2O_3	16.88	16.42	15.44	20.43	16.67	17.17
Fe_2O_3	1.16	0.76	0.51	1.72	2.24	3.48
FeO	5.92	2.80	3.45	7.19	3.00	5.49
MnO	0.15	0.07	0.22	0.12	0.11	0.15
MgO	2.84	2.76	6.25	8.56	2.12	4.36
CaO	5.20	2.45	1.14	3.74	5.53	7.92
Na_2O	3.41	3.64	2.96	4.48	3.98	3.67
K_2O	1.28	1.08	2.63	0.62	1.40	1.11
P_2O_5	0.20	0.13	0.13	0.78	0.17	0.28
SO_3	0.12	0.01	0.19	2.41	0.56	0.86
H_2O-	0.02	0.03	0.04	0.05	—	—
H_2O+	4.64	3.96	1.68	5.84	—	—
CO_2	0.01	0.01	0.01	0.02	—	—

Analyses 1 to 4 by S. W. Metcalfe and R. S. Young, British Columbia Department of Mines and Petroleum Resources.

1—Dacite, from northwesternmost part of Figure 25.
2—Coarse crystal-lithic tuff, 400 feet south of Barbara pit.
3—Chlorite mottled schist, 4950 level east of 040 orebody.
4—Andesite, dyke in wall of Jane Basin, 200 feet north of Mammoth Bluff.
5—Average dacite, Nockolds, 1954, p. 1015.
6—Average andesite, Nockolds, 1954, p. 1019.
Analyses 1 to 4 with major oxides recalculated to 100 per cent.

Structure

The strata of the Britannia pendant north of the shear are tilted southward about 20 degrees in a gently warped monoclinal panel. This uniform dip is abruptly transformed at the Britannia Shear Zone where these rocks are highly deformed in a fault-bounded anticline and subsidiary syncline within the map-area (*see* Figs. 25 and 26). The anticlinal nose is quite clearly shown on the west slope of the Jane Basin where it plunges westward at 22 degrees. The marker beds of crystal tuff and argillite can be traced around the nose and on either limb beyond the marginal faults. The distorted and highly schistose core is filled principally with schistose fragmental andesite, sericite schist, and with chlorite mottled schist that is thought to be metamorphosed crystal-rich tuff breccia. Significant minor folds in green argillites, that appear equivalent to those of the marker bed sequence, show that the beds in the southern margin of the schist zone face south and that the anticlinal hinge lies to the north. In the core of the schist zone, bedding is rarely identified with certainty and the hinge zone cannot be located. The average dip of schistosity is somewhat steeper on the northern part of the schist zone so that it may there face northward. Certainly beyond the footwall fault the indications are that the marker beds are overturned and facing north. Beyond them the argillites should be folded in a syncline of which there is some evidence north of the plunging anticlinal nose.

The bounding faults do not appear to be continuous throughgoing faults but rather an *en echelon* sequence. This is suggested underground and can be inferred from the map (Fig. 25). The hangingwall fault(s) dip southward at about 70 degrees. Faults exposed near the footwall of the shear zone dip from 60 degrees to vertical.

An additional fault which is judged to be fairly important is exposed on the lowest hairpin turn. Here it strikes north 60 degrees west and dips 25 degrees southward. It is a small thrust that carries the overturned limb with marker beds and crystal tuff and tuff breccia over the argillite sequence with intercalated greywacke. Its continuity and its relation to the footwall fault are not known.

Both dyke sequences seem to be spatially related on the shear zone, being rare at a distance from it but very abundant within and adjacent to it. Intrusion of both pre-dates at least the latest movement. Because of their common fragmental nature, high vesicularity, and similarity to flow rocks in the pendant, the andesites appear to have been most likely intruded at shallow depth during the formation of the volcanic and sedimentary pile. The dacites are in general not schisted even in the core of the anticline, but the margins of the dyke in the hangingwall shear are highly cleaved in some localities. The large dacite wedges in the hangingwall show a flow structure coincident with bedding attitudes of the stratified rocks in some localities but highly contorted in others. Within the shear zone a common feature of the dacites is that they follow the schistosity as narrow dykes until a certain point where they blossom out into an enlarged crescentic body that commonly hoods over some orebodies. This is paradoxical, for the dacites must have been intruded late in the interrelated folding and faulting process.

Metamorphism and Alteration

Regional metamorphism in Britannia Pendant—All the rocks except the late basic dykes have been subjected to a low grade of regional dynamothermal metamorphism of greenschist facies. Changes due to this metamorphism include incipient (or minor) alteration of plagioclase to clinozoisite, mafic minerals to penninite or other chlorites, glass to very fine stilpnomelane, and minor prehnite in amygdules.

Dynamic metamorphism in Britannia Shear Zone—Dynamic metamorphism and hydrothermal alteration have had a more dramatic effect on the character and composition of the rocks than the regional metamorphism, particularly within the shear zone. All rocks within the shear zone have an intense second foliation. Progressive increase in the development of schistosity can be observed in the walls on approach to the shear zone, especially toward the hangingwall. In the latter case a parallel erasure of bedding in crystal-rich tuff breccias can be seen. In much of the shear zone bedding attitudes cannot be observed, but intercalations commonly indicate that bedding and schistosity are quite closely parallel. The rocks of the shear zone, except for the dacite porphyries and late dykes, are schists with a marked, flattened fabric with steeply west-raking lineation common. This is particularly noticeable in the chlorite mottled schist in which the chlorite mottles are commonly very thin lenses (for example, 15 by 8 by 1 millimetre), with the plunge of long dimension about 45 degrees and rake about 60 degrees in the vicinity of the East Bluff orebody.

Microscopically the development of schistosity is first evident as very fine new sericite that grows in the slight matrix of fragmental rocks. It wraps around fragments with an average orientation of that of the developing schistosity. More intense development arises with further growth of sericite, especially along "channels" between fragments accidentally oriented in the schistosity. Then new growth of sericite and chlorite in fragments occurs together with flattening of very fine-grained lithic fragments, moulding of weak fragments about strong clasts, and development of some schistose bands through fragments accidentally placed to connect earlier "channels." Increasing intensity involves boudinage and rotation of some strong clasts and further development of micas, particularly in a network of bands. Further increase involves not only coarse growth of micas and further flattening but also the breaking down of the feldspars. The latter is accomplished first by disruption of twin patterns, erasure of oscillatory zoning, and replacement by albite and quartz. This is followed by complete granulation, flattening, and replacement by mosaic quartz. The rocks immediately south of the hangingwall fault have reached the stage of incipient destruction of feldspar.

It is suggested by this study that the crystal-rich tuff breccia and crystal tuff are, in fact, the same stratigraphic unit as the chlorite mottled schist. This was suspected in the field, but the general lack of plagioclase phenocrysts and clasts in the latter made correlation uncertain (*see* Plates XIB and XIC).

The alterations evident microscopically of the titanium minerals is also interesting. Traces of ilmenite are found with leucoxene in a few of the freshest specimens of dacites outside the shear zone. All other rocks have leucoxene outside the shear zone, but within many have a mixture of very fine porphyroblastic sphene as well as leucoxene. One specimen of quartz sericite schist contained capillary rutile as well as sphene and leucoxene.

Hydrothermal alteration—Some of the effects of the dynamic metamorphism are difficult to separate from those of hydrothermal metamorphism, involving as they do growth of similar micas and replacement of feldspars by quartz. However, the intense hydrothermal alteration is much more local and appears to be imposed on rocks that already have attained the intense schistose-flattened fabric.

Surrounding the sulphide orebodies, the host rocks, commonly chlorite mottled schist or andesitic tuff, are affected by an outward grading alteration. Around and between the massive sulphide lenses remnant rocks are composed almost entirely of quartz, pyrite, and muscovite and minor chlorite. Not uncommonly, textures indicative of the original chlorite mottled schist, etc., are evident, but the chlorite mottles are partially or wholly replaced by muscovite. Elsewhere, particularly on the fringe areas, chlorite mottles are evident. These rocks are cut by pyrite or quartz pyrite veins of several generations. Outward from the suphide bodies the intensity of the silicification decreases gradationally and its mode changes from complete replacement to ramifying fine veinlets. In a parallel way pyrite also decreases, but muscovite-sericite, chlorite, and clinozoisite increase to proportions characteristic of the shear zone remote from sulphide bodies. Anhydrite, gypsum, and erratically distributed barite are found in discrete veins and disseminations in a zone roughly coincident with that of intense silicification.

Thermal metamorphism—The Squamish Batholith is exposed south of Britannia Creek on the road to the Jane Basin within a mile of Howe Sound (*see* Fig. 24). Here argillite and dacite continuous with those of the map-area are visibly thermally metamorphosed. Microscopic examination of the dacite shows the matrix has been recrystallized into a coarser polygonal mosaic of quartz and feldspar, and mafic minerals are replaced by fine felted brown biotite which also is incipiently developed in feldspar phenocrysts.

Sulphide mineralization—The sulphide orebodies of Britannia are highly heterogeneous mixtures of sulphides, remnant altered host rocks, and discrete veins. The parts that are predominantly sulphides have a characteristic braided appearance that results from the juxtaposition of lenticles of varying mineralogy separated by schistose mica bands and intersected by discrete quartz-sulphide and sulphide veins. Alternatively, the braided appearance results from original lenticular quartz-rich and mica-rich bands cut by a variable network of sulphide bands. Not uncommonly within orebodies, horses of less replaced rock exist in which the characteristic textures of the chlorite mottled schist or andesite can be recognized.

The main mineralogy of orebodies is simple and fairly constant. Pyrite is by far the most abundant mineral, with less chalcopyrite and sphalerite and minor erratically distributed galena, tennantite, or tetrahedrite. The main nonmetallic minerals include quartz and muscovite (chlorite), anhydrite, and siderite. The textures are highly variable and no particular study has been made of them. However, a common texture is one in which dense bands 1 to 4 inches wide of granular pyrite averaging about 0.5 millimetre in diameter, with scattered 2 to 3-millimetre grains, and very minor interstitial quartz and chalcopyrite, grade outward through cubic pyrite (0.5 millimetre) with significant interstitial quartz and chalcopyrite to wider quartzose bands with disseminated pyrite and clots of amœboid chalcopyrite. This may be cut by smaller bands almost discrete enough to be called veins, but without much continuity, that consist of sphalerite, lesser chalcopyrite, and quartz, with nests of galena and tennantite.

On the fringe of orebodies, rather similar pyrite veins exist that in their centre are practically devoid of quartz. The central zone of dense granular pyrite grades outward into the surrounding rock, with decreasing quantities of disseminated pyrite. These pyrite veins chiefly follow schistosity, but may bifurcate and transect schistosity at any angle for considerable distances.

Some of the grey-green argillites within the shear zone contain significant quantities of pyrite with traces of chalcopyrite. The appearance of these rocks is such that a syngenetic origin of the sulphides is possible (*see* Plate XIIB). Sulphide-rich layers are intercalated with the phyllitic argillites and may occur as laminæ or as nodules composed of almost solid pyrite with an incomplete zone of quartz near their outer rim. Some nodules resemble sharpstones, others resemble worm tubes. Planes of schistosity and fracture may also be coated with fine pyrite. The sulphide-rich beds are, as far as known, quite local in the vicinity of the top of the East Bluff and Fairview zinc orebodies. The latter is a sheet-like mass a few feet wide of concentrated pyrite, sphalerite, chalcopyrite, quartz, and barite that is parallel to metamorphic foliation. It contains few textures that offer evidence of its origin. The localized distribution as well as some of the features of the sulphide-rich beds are more likely indicative of replacement than syngenetic deposition, but the possibility of the latter is not eliminated.

The main massive orebodies, Bluff, East Bluff, No. 5, No. 8, and 040 or (No. 10), all show a marked zonal structure (*see* Figs. 27 and 28) in which they have one or more high-grade chalcopyrite cores enveloped successfully by a lower-grade zone and overlapping pyrite and siliceous zones. The plan of the 040 orebody on 4950 level shows this well, although it is less regular than some of the other orebodies. Zinc-rich ore tends to occur in the upper central parts of massive bodies and as almost separate sheet-like masses like the Fairview zinc vein. In section the main orebodies have a crude lens-like shape oriented within the schistosity and are commonly connected to a steeply plunging root which may or may not be of ore grade (*see* Fig. 27). The long dimension of the Bluff ore lenses plunges about 45 degrees to the west. The plunge increases in the western and eastern orebodies. It is of interest that, although the individual orebodies plunge steeper than the crest of the

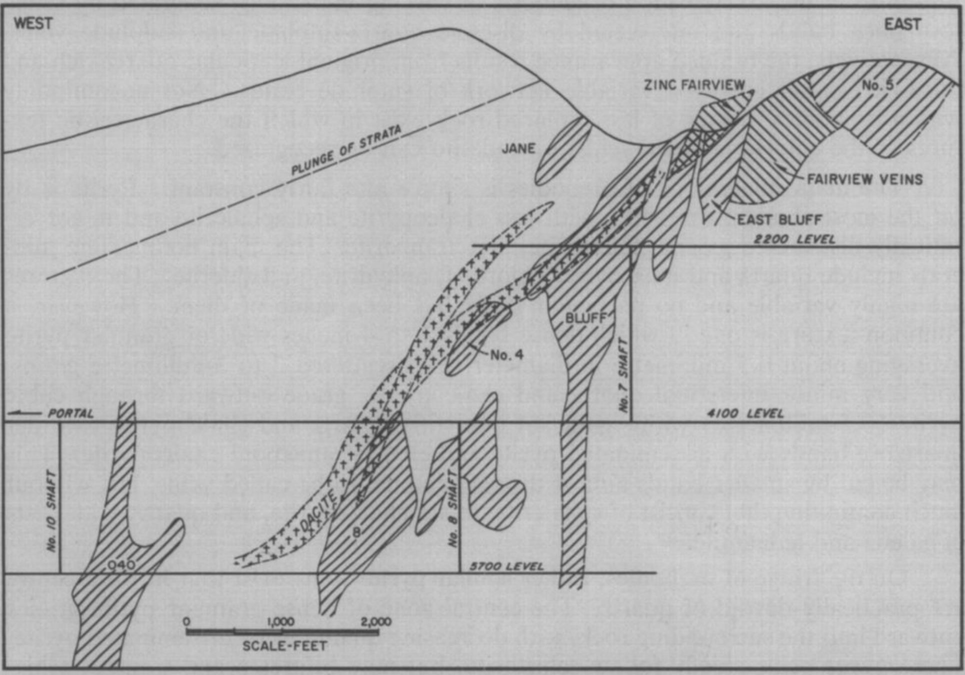

Figure 27. Projected longitudinal section, western orebodies, Britannia.

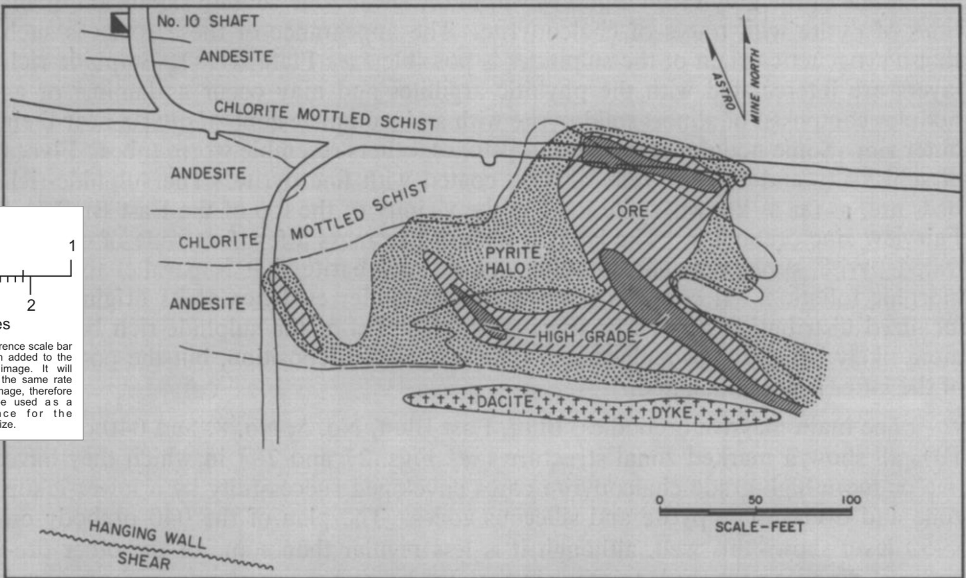

Figure 28. Sketch of the 040 orebody, 4950 level, Britannia.

anticlinal srtucture, the over-all top of the ore zone plunges about the same as the latter and is crudely coincident with the base of the argillite sequence.

The other orebodies such as the Fairview, Empress, and Victoria are stringer lodes and veins composed of thin sheet-like masses of chalcopyrite and pyrite with some quartz that appear generally parallel to the schistosity but actually cut across schistosity in plan at a small angle. The tops of these orebodies are eroded so that one cannot guess whether they, too, might have had an upper limit at the argillites.

Environment of Ore Deposition

Much more study would be necessary to come to firm conclusions regarding the environment of ore deposition. Certain factors that are known are important, however, in any analysis of the environment. These include the following:

(1) The ore deposits are situated in a volcanic pile of intermediate composition, near the top of a pyroclastic accumulation that is overlain by a marine shale sequence.

(2) The near surface ore deposits are situated within a belt of ductile shear associated with a sharp anticlinal flexure to the south of a monoclinal panel.

(3) The ore deposits are situated in a concentration of an andesitic and dacitic dyke swarms and were formed between the period of intrusion of these two.

(4) Plutonic rocks thermally metamorphose the dacitic dykes that postdate ore deposition.

(5) The orebodies occur in several rock types and have a plunge much greater than the strata.

(6) The rocks in which the orebodies occur are a rapidly accumulated pyroclastic and sedimentary unit and a clastic dyke sequence.

(7) The orebodies are generally concentrically zoned and highly siliceous.

(8) With the possible exception for the sulphide-rich fine-grained phyllites over the Fairview zinc orebody, the gross and detailed textures of the massive sulphide orebodies are indicative of replacement after the development of schistosity.

From these observations one may conclude that the orebodies are chiefly replacement deposits formed in a volcanic site and that the sharp flexure, dyke swarms, and ore deposits are all probably genetically related. The deposit has great similarity to the Keiko ore of Japanese Kuroko deposits. A source of the sulphides might be a series of solfataras localized by the developing flexure and related to the intrusion of the dyke swarms.

WORK DONE:

During 1970, development work in the Britannia mine consisted of 13,179 feet of drifting and crosscutting, 3,322 feet of raising, 24,854 feet of diamond drilling, and 734 feet of shaft sinking.

Load-haul-dump diesel trackless haulage equipment was introduced for most short-haul development, stope preparation, and production work. Mining was completed in the No. 4 shaft section and the hoisting equipment was removed from the shaft in August.

The first stage of the No. 10 shaft sinking was completed to a point 113 feet below the 5700 level, making the total length of the shaft 1,914 feet from the back of the sheave wheel to the sump. A 1,000-horsepower, four-rope, semi-automatic Koepe hoist with two 7-ton 140-cubic-foot Sala ore skips was installed in the No. 10 shaft. A separate double-deck service cage capable of carrying 40 men was installed in the third compartment. The No. 10 mine was put into production during October. The underground crushing plant, conveyors, and measuring pockets on 5700 level of the No. 10 shaft were put into operation at the end of November.

A 150-horsepower ventilation fan was installed on 4100 level. Two 500-kva. utilized substations were installed at No. 10 shaft on 2500 and 5700 levels. A jaw crusher driven by a 200-horsepower motor was installed at the bottom of No. 10

shaft. Twenty-five hundred feet of three-conductor No. 1 A.W.G., 7,000-volt power cable was installed from the 4100 load centre to the 5700 level at No. 10 shaft.

REFERENCES: *B.C. Dept. of Mines & Pet. Res.*, G.E.M., 1969, p. 193.
BOSTOCK, H. H. (1963): Squamish, *Geol. Surv., Canada,* Map 42-1963.
BURTON, C. C. J. (1969): The Relation of Structure to Mineralization at Britannia Mine, abstract of a talk at C.I.M.M., British Columbia Section, Meeting, Kimberley, October 1969.
FISKE, R. S. (1963): Subaqueous Pyroclastic Flows in the Ohanapecosa Formation, Washington, *G.S.A.*, Bull., Vol. 74, pp. 391–406.
GREENLEE, B. B. (1970): The New "040" Orebody of Anaconda Britannia Mines, *Western Miner,* May 1970, pp. 38–40.
IRVINE, W. T. (1948): Britannia Mine, *C.I.M.M.*, Spec. Vol. No. 1, pp. 105–109.
JAMES, H. T. (1929): Britannia Beach Map-Area, British Columbia, *Geol. Surv., Canada,* Mem. 158.
NOCKOLDS, S. R. (1954): Average Chemical Compositions of Some Igneous Rocks, *G.S.A.*, Bull., Vol. 65, pp. 1007–1032.
RAMSEY, BRUCE (1967): Britannia, The Story of a Mine, *Britannia Beach Community Club.*
WATERMAN, G. C. (1970): An Old Mine Breathes New Life, *Western Miner,* June 1970, pp. 62–65.
WHITE, W. H. (1968): Granitic Rocks of Southwestern British Columbia, *UBC,* Dept. of Geology, Rept. No. 6, pp. 13–17.

NEW WESTMINSTER MINING DIVISION

PITT RIVER

DD (MARGARET) (No. 3, Fig. F)

LOCATION: Lat. 49°36.5′ Long. 122°44′ (92G/10E)
On Boise Creek, 4 miles west of Pitt River at 1,650 feet elevation.
CLAIMS: DD 1 to 20.
ACCESS: From Highway 7 by ferry up the Pitt River to the north end of Pitt Lake, thence by logging-road and trail.
OWNER: B & T MINES LTD., 3567 West 27th Avenue, Vancouver 8.
METALS: Copper, molybdenum.
DESCRIPTION: Chalcopyrite and molybdenite occur in veins and as disseminations in altered and granitized sediments(?) and volcanics.
WORK DONE: Topography mapped; surface geological mapping, 1 inch equals 200 feet and geochemical soil survey, 316 samples covering DD 1 to 4, 7 to 10, 13, 14, 17, and 18 claims.
REFERENCES: *B.C. Dept. of Mines,* Bull. 9, pp. 58–61; *Minister of Mines, B.C.,* Ann. Rept., 1967, pp. 67, 68; Assessment Reports 1100, 2794.

STAVE LAKE

KF (No. 4, Fig. F)

LOCATION: Lat. 49°35′ Long. 122°05′ (92G/9E)
At approximately 5,600 feet elevation, 11 miles northeast of the north end of Stave Lake.
CLAIMS: KF 1 to 84.
ACCESS: By air.

BRITANNIA MINE*

BY W. T. IRVINE†

The Britannia ore deposits are approximately 20 miles north of Vancouver, and occur in a prominent ridge facing Howe sound. A large iron-stained bluff first attracted the serious attention of early prospectors. This, upon investigation, proved to be the outcrop of a large copper orebody. The highest outcrops were 4,300 feet above sea-level.

The original discovery was made in 1888, but no real development took place until 1902. The first mining was done in what came to be known as the Jane orebody, and some production was obtained from this in 1905. Underground exploration led to the discovery of several other orebodies.

The first main adit, the 1,050-foot level, was driven to tap the ore at an elevation of 3,300 feet above sea-level. During succeeding years, however, long adits were driven from points lower down on the mountain side. These, with connecting shafts, followed the ore to horizons well below sea-level. The lowest working has now reached to 880 feet below sea-level.

The property has been in almost continuous operation since its original exploitation in 1905. Until the end of 1944, 732,414,420 pounds of copper and 261,125 ounces of gold had been produced from the mine.

OREBODIES

Gambier.

The Britannia area(1) is underlain by Mesozoic rocks of the Britannia group which form a roof pendant in the Coast Range batholith. The orebodies occur in a sheared part of the pendant, the favourable host rocks being chlorite and sericite schists. The ore is believed to have been deposited by solutions emanating from the batholith.

Eight individual orebodies have been discovered, and these occur either as stringer-lodes, massive replacements, or a combination of the two. Although the principal sulphides are pyrite and chalcopyrite, heavy concentrations of sphalerite occur in some sections. Large amounts of quartz are present, the gangue consisting principally of quartz and schist.

GENERAL STRUCTURE

Steeply dipping rocks of the Britannia formation, which is the lowest part of the Britannia group, are intensely sheared along a zone having a northwest strike and steep dip to the southeast. This shear zone has a

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*The writer is indebted to officials of the Britannia Mining and Smelting Company, Limited, or permission to publish this article.

†Geologist, Britannia Mining and Smelting Company, Limited.

PROPERTY FILE

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maximum width of 2,000 feet, and has been traced for a length of several miles. The rocks involved in the shear zone were originally flows, tuffs, agglomerates, and slates. The shearing converted these to schists.

Within the shear zone, a strong thrust fault has developed(2). This is parallel with, and lies near, the footwall of the shear zone. The fault has been traced along its strike for 9,000 feet, and is known to be continuous in depth, with a relatively uniform dip. The orebodies are all located near, and in, the hanging-wall of this fault(3).

The fault zone consists of highly fissile sericite to talcose schist, accompanied by gouge seams. In the hanging-wall of this zone there is a large lens of relatively competent quartz-chlorite sericite schist, which is known locally as 'green mottled schist'. In the lower parts of the mine this lens reverses in dip, and is thus encountered on the footwall side of the fault zone.

STRUCTURAL CONTROLS

Fracturing occurred in the more competent zones along the hanging-wall of the fault, permitting the ore solutions to ascend until structural conditions were reached that were favourable for ore deposition. These favourable conditions varied in the different sections of the mine and thus resulted in different types of orebodies.

Bluff and No. 5 Orebodies

One type of favourable structure occurred in or near folds that had developed along the thrust fault. This folding occurred where exceedingly incompetent lenses of slate adjoined the fault plane. During the folding the incompetent rocks on the footwall of the thrust fault yielded by flow or by movement along shear planes. The competent green mottled schist or the hanging-wall of the fault became fractured and brecciated in the region of the folds. Mineralizing solutions penetrated these brecciated zones, partly silicified the host rock, and deposited small quantities of sulphides. The resulting competent siliceous masses were reopened by later stresses. Strong fracture zones were developed and these permitted ore solutions to deposit sulphides in sufficient quantities to form lenticular masses of ore. The Bluff and No. 5 orebodies were deposited in this manner. The feeder zones of these two orebodies have been traced to depth. They consist of columns of fractured and mineralized schists extending downward directly below the main ore lenses. There is sufficient mineral content in the feeder column below the Bluff orebody to constitute ore for a depth of over 1,000 feet below the main ore mass. The feeder column below the No. 5 orebody, however, is not sufficiently mineralized to yield ore below the main body.

Fairview, Empress, and Victoria Orebodies

A different type of structure caused the localization of the Fairview, Empress, and Victoria orebodies. These are stringer-lode deposits and consist of series of chalcopyrite stringers, which occur in sheet-like masses. They lie slightly in the hanging-wall of the main thrust fault and occur in the green mottled schist, or, in the case of the Victoria deposit, in sheared fragmentals and flows containing lenses of green mottled schist. As compressive stresses developed, the competent schist in the hanging-wall of the fault failed along parallel planes of shearing. Movement along these planes caused crumpling and bridging with resultant openings, which allowed circulation of ore solutions. The mineralization was concentrated in a series of parallel stringers that were arranged along each plane of rock failure. The deforming stresses apparently lessened with depth and the stringer lodes diminished in both width and length.

The Fairview and Empress deposits resemble one another in that each adjoins a large siliceous mass, the Fairview lying just east of the Bluff siliceous zone and the Empress just east of the No. 5 zone of silicification. A suggested reason for the localization of the Fairview and Empress fracture systems is that the large siliceous masses served as buttresses for compressive stresses that acted upon the adjoining schists to produce a fracture pattern.

In the case of the Victoria deposit, the fracture system was apparently localized by the presence of the lenses of green mottled schist in the sheared fragmentals and flows. The heterogeneity produced by the contrasting competency of the green mottled schist and the fragmentals and flows created a favourable condition for fracturing as compared with more homogeneous surrounding areas.

No. 8 Orebodies

The No. 8 orebodies were localized by structural controls that differed from the foregoing examples. These orebodies are near the intersection of the main thrust fault and the hanging-wall of the lens of green mottled schist, in sheared tuffs and agglomerate . Movement along the thrust fault caused fracturing of the schist on its hanging-wall. Mineralizing solutions penetrated upward along these fractures, depositing little of their load until a sheared fragmental member was encountered in which the permeability was apparently ideal for circulation and replacement. This resulted in massive replacement by quartz, pyrite, and sphalerite, concentrated in three, large, steeply dipping lenses, arranged along the same strike and separated by as much as several hundred feet of unmineralized, sheared, fragmental rock. A partial silicification of the surrounding schist resulted in a broad siliceous zone enveloping the mineralized lenses. Later stresses caused a series of northwest-trending fractures to develop in the extremely brittle replaced lenses, and to a less degree in the surrounding siliceous zone. Ascending copper-rich solutions then penetrated these fractured zones, depositing chalcopyrite as stringers in the pyrite-sphalerite lenses, and also forming small, irregular, stringer-lode deposits in the fractured siliceous schist adjoining the main lenses. The No. 8 orebodies exposed to date thus consist of three large lenses of massive sulphide replacement containing copper and zinc in commercial quantities. Each lens is in turn surrounded by a number of smaller copper ore shoots.

SUMMARY

The Britannia orebodies have been localized by structural controls associated with movement along a strong thrust fault and depending on the presence near the fault of rock that would be competent in comparison with weak schists contained in the fault zone or its footwall. A search for possible new orebodies must take these factors into account.

REFERENCES

(1) JAMES, H. T., *Britannia Beach Map-area, British Columbia;* Geol. Surv. Can., Mem. 158, 1929.

(2) EBBUTT, Frank, *Relationship of Structure to Ore Deposition at Britannia Mine;* Can. Inst. Min. and Met., Trans., Vol. 38, 1935, pp. 123-133.

(3) IRVINE, W. T., *Geology and Development of the No. 8 Orebodies, Britannia Mines, B.C.;* Can. Inst. Min. and Met., Bull., March 1946, pp. 191-214.

FIGURE 1.

BLOCK DIAGRAM SHOWING
THE VARIOUS BRITANNIA
OREBODIES