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GEOLOGY OF THE BRITANNIA DISTRICT, B.C.

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The Britannia district is 25 miles north of Vancouver in a "roof pendant" of andesitic to dacitic volcanic and sedimentary rocks enclosed by several plutons of the Jurassic-Cretaceous Coast Range batholith. The pendant is one of many similar generally northwest trending pendants in the batholith. The pendant rocks, herein assigned to the Britannia group, have been correlated on lithologic and structural similarities with the ? Jurassic Gambier group which outcrops a few miles to the south. The Britannia ore bodies are in a complexly deformed belt, called the Britannia shear belt, which trends west-northwest across the pendant. The shear belt may be a remnant of a major structural zone, now exposed in scattered pendants along the northwest-trending axis of the Coast Range batholith.

STRATIGRAPHY

The volcanic rocks are typical of the calc-alkaline suite of intermediate to acidic pyroclastic volcanism. Andesite flows, flow breccia, pyroclastic rocks, and related clastic sedimentary rocks and argillite are widespread in the Britannia and Gambier groups. Centers of pyroclastic dacitic volcanism occur in both groups, and host all ore bodies and major sulfide occurrences. A general stratigraphic section through a dacitic center is in the Jane Basin area:

top		thickness
Andesite	flow breccia, flows, coarse pyroclastic rocks	200+ft(70+m)
Argillite	black, locally with coarse volcanic fragments, siltstone interbeds common.	900ft(300m)
Dacite	coarse lithic tuff, plagioclase phenocrysts common, regions of very abundant large dacite fragments common; in part capped by crystal tuff and fragmental argillite	500ft(160m)
Andesite	complex sequence of fine to medium tuffs, finely bedded pyritic sediments; sericite schist variously derived from these rocks, fine dacitic tuffs and sediments, and argillite	450ft(140m)
Dacite	coarse lithic tuff, non-porphyritic, coarse dacitic fragments uncommon; more uniform than younger dacitic unit, but they are difficult to distinguish in moderately to strongly deformed areas	400ft(120m)

In contrast the section on Goat Ridge about a mile north of the Jane Basin and away from the dacitic center is as follows:

top		thickness
Argillite, Siltstone	well bedded, locally cherty	60+ft(20+m)
Andesite, Basalt	flows, in part pillowed, local hyaloclastic sedimentary rocks, local to widespread argillite interbeds	400ft(120m)
Argillite	well bedded, black, locally with dacitic fragments, probably stratigraphic equivalent to argillite near top of Jane Basin section	600ft(190m)
Andesite	massive flows and/or intrusions to the north, coarse pyroclastic rocks to the south with local units with very abundant coarse dacitic fragments, local sedimentary interbeds	1000ft(330m)

As is to be expected in this type of environment, local and regional stratigraphic variations are large, and the absence of continuous reliable marker units has hampered stratigraphic and structural interpretation.

EARLY DEFORMATION (D_0, D_1, D_2)

The earliest deformation in the Britannia and Gambier groups, D_0, produced open, concentric, flexural-slip folds, F_0, with subhorizontal to gently plunging west-northwest trending axes. Axial plane foliation is absent, and rocks were at most only slightly metamorphosed. At Britannia, two major F_0 were formed, the Britannia anticline, and to the north, the Britannia syncline. These folds have been in part strongly modified to obliterated by later deformation.

The next deformation produced the Britannia and other smaller shear belts. In the Britannia shear belt, rocks were deformed by several episodes of inhomogeneous strain, and were recrystallized to S-tectonites with phase assemblages equivalent to those of the lower greenschist facies of regionally metamorphosed rocks. The shear belt is a region of dynamic metamorphism in which energy for recrystallization was derived mainly by friction during deformation.

The first episode of shearing deformation, D_1, was the most intense. Parallel orientation of sericite and chlorite plates and flattened lithic fragments produced a foliation, S_1. Numerous folds, F_1, were formed with S_1 as axial plane cleavage. F_1 are close, similar folds with axial planes trending west-northwest and slightly overturned to the north. Axes plunge gently to moderately to the west, with local reversals to shallow easterly plunges. The axial plane of the shear zone roughly corresponds to the axial plane of the Britannia anticline. The surficial trace of S_1 makes an angle of between 0 and 40° to the axis of the shear belt; the angle increases with increasing distance from the axis of the belt.

The second episode of shearing deformation, D_2, produced a foliation, S_2, which cuts and folds S_1 into steeply west plunging folds, F_2. S_2 is best developed in rocks in which S_1 is also well developed. S_2 trends at a larger angle to the axis of the shear belt than does S_1; its orientation indicates a left-lateral component of movement during D_2.

The overall movement pictures for D_0, D_1, and D_2 were determined from strain indicators, fold styles and geometries, and the geometries of metamorphic foliations and lineations. All three deformations were produced by a northeast trending compressional stress couple oriented perpendicular to the axis of the shear belt. Movement during D_1 was mainly subvertical along S_1, while movement during D_2 was mainly subhorizontal along S_2. A horizontal compressional stress couple of the magnitude required to produce the deformation in the shear belt could have been caused by collision of two crustal plates.

EARLY DEFORMATION OF ORE BODIES AND DESCRIPTION OF ORE BODIES

Whether ore bodies were deformed during D_1 (and D_2) or were introduced later and controlled in their emplacement by the structure of the deformed rocks is critical to the hypotheses of origin of the ore bodies. Until recently, ore bodies were thought to have been hydrothermally introduced into a deformed shear belt. Supporting evidence included:

1) ore veins cut and heal S_1,

2) metasomatic minerals (quartz, chlorite, muscovite, anhydrite) appeared to be superimposed on metamorphic minerals formed during D_1,

3) all ore bodies occur in the shear belt, suggesting a structural control of emplacement.

Recent work indicates that ore bodies were deformed during D_1. Evidence proving such deformation is difficult to document because of the ease of recrystallization of quartz and sulfides under stress even at low temperatures. The following features indicate deformation of ore bodies.

1) quartz and quartz-sulfide veins, especially those at large angles to S_1 were tightly folded and strongly attenuated along their limbs; the geometry of these folds is similar to that of F_1. Extreme deformation locally completely squeezed out the veins along the limbs of the folds, and left only irregular patches at the noses of folds. Similar deformation of bedded pyrite is well displayed in the Jane Basin.

2) quartz in ore-stage veins is strained and partly recrystallized to a fine grained mosaic of unstrained quartz, generally along the borders of strained grains. In contrast, quartz in late, vuggy quartz-carbonate-sulfide veins is undeformed.

3) Pyrite grains surrounded by chalcopyrite commonly are cut by a series of subparallel fractures, some of which have been filled by chalcopyrite and lesser quartz. This indicates that pyrite was fractured during deformation while chalcopyrite and quartz flowed and recrystallized. The intensity of fracturing of pyrite is greatest in rocks in which S_1 is best developed, indicating that deformation of pyrite occurred during D_1.

4) Pyrite grains in chalcopyrite are more rounded in rocks with strong S_1 than in rocks with weak S_1. This could be caused by abrasion of pyrite during deformation. In contrast to deformed pyrite, pyrite in late-stage veins is sub- to euhedral, with some crystals deeply embayed by sphalerite. Late pyrite grains are not fractured as are pyrite grains in ore bodies.

5) In the No. 10 ore body, intimate intergrowths of chalcopyrite and chlorite are strongly flattened parallel to S_1.

6) Pyrrhotite exsolution(?)lenses in chalcopyrite are bent and folded.

Other macroscopic evidence is compatible with deformation of sulfides; this includes the following:

1) Some massive sulfides appear to have flowed around rock fragments and quartz patches; some bedded fragments in massive sulfides have been rotated up to 90° relative to similar bedded rocks adjacent to the sulfide veins.

2) some massive sulfide veins appear to be boudinaged along S_1.

Because of the mobility of sulfides during deformation, they probably continued to be mobile after the surrounding rocks had become rigid. These sulfides formed veins in the rock, generally subparallel to S_1, but some cutting S_1 at low angles. The fact that most veins are subparallel to S_1, even though ore bodies may cut across S_1 at moderate angles suggests that original ore bodies have been deformed and sulfides and quartz have flowed out to new positions subparallel to S_1.

Based on the above evidence of deformation of sulfides, a hypothesis was developed that the ore bodies are late-stage products of the dacitic volcanism; the model is similar to that for the Kuroko deposits in Japan.

Major sulfide concentrations occur in pyroclastic dacite units and in immediately overlying andesitic tuffs and sediments. Most ore bodies are near the upper contact of the lower dacitic tuff unit (see Jane Basin stratigraphic section), but the No. 10 body is near the upper contact of the upper dacitic tuff unit.

The ore bodies can be classified according to the Kuroko model (see Fig. 1a and 1b for the spatial distribution of the ore bodies).

type	examples
1. sphalerite-barite-(chalcopyrite-galena) (black ore)	Jane, Fairview Zinc
2. pyrite-chalcopyrite-(quartz-chlorite) (yellow ore)	No. 10, Victoria, Empress
2a. sphalerite-pyrite-chalcopyrite-(quartz-chlorite) (mixed black and yellow ?)	No. 8
3. quartz-pyrite-chalcopyrite (siliceous ore)	Bluff, No. 5, No. 10, Fairview veins
4. anhydrite (gypsum); barite (sulfate "ore")	widespread zones near sulfide ore bodies

Deformation has strongly disturbed the original ore bodies so that their present disposition may not give an accurate picture of their original distribution. Each type of ore appears to have a particular mode of occurrence in the dacitic center. Black ore occurs in fine andesitic sediments, tuffs, and sericite schists above the contact with the coarse dacitic tuff, and generally spatially removed from the other types of sulfide ore. Yellow and mixed black and yellow ore occur along and near the contact of the coarse dacitic tuff and overlying andesitic sediments, fine tuffs, and cherty sediments. The highest grade ore is generally just above the contact. Cherty sediments are particularly abundant in the No. 8 ore bodies. Siliceous ore occurs mainly in coarse dacitic tuff as a series of quartz-sulfide veins and vein stockworks in a strongly silicified rock. Most occurrences are near the stratigraphic top of the coarse dacitic tuff, and commonly the grade of ore increases towards the top. However the Fairview veins are spread through the entire unit. Sulfates, especially anhydrite, are widespread in the shear belt, especially in andesitic sediments and sericite schists near ore bodies. Fine andesitic sediments above the coarse dacitic tuffs locally contain up to 50% very fine grained pyrite in tiny lenses elongated parallel to bedding. They may be a poorly developed equivalent to the pyritic cap of some Kuroko deposits. Some coarse tuffs contain local zones with abundant fragments rich in very fine grained pyrite. These may represent an original massive sulfide body near the volcanic vent which was fragmented and carried off during formation of the coarse tuff.

DACITE INTRUSIONS

During a period of dilatency following the major compressional deformation, abundant dacite magma was intruded. In foliated rocks dikes were formed subparallel to S_1, while in rocks with little or no foliation sills and irregular bodies were formed. Near the axis of the Britannia anticline, sills appear as "hoods" capping some of the ore bodies, and at one time were considered to be a structural trap for the ore solutions. The source of the dacitic magma might be similar to that of the earlier pyroclastic dacites, suggesting a possible short interval between original volcanism, ore formation, deformation, and later dacite intrusion.

Most dikes are cut and bleached by a series of northeast trending vuggy quartz-carbonate-chlorite gash veins. Locally these contain scattered sulfides - sphalerite, galena, chalcopyrite, pyrite, pyrrhotite, and rarely realgar. Where dacite dikes cut ore bodies, chalcopyrite has migrated from the ore bodies to form massive brassy blobs in the late veins; such chalcopyrite is not found in late veins more than a few feet from an ore body.

Several texturally distinct types of dacite are mapped in the shear zone, but age relations between types are uncertain.

LATE DEFORMATION

A third metamorphic foliation, S_3, is formed locally. It is parallel to the northeast trending gash fractures in dacites, and to a series of late northeast trending faults. These faults typically have a left lateral displacement of a few inches and rarely up to a few feet. Commonly they contain vuggy quartz-carbonate veins, and have weak to strong sideritic alteration halos, which are best developed in late andesitic dikes (see below).

A fourth metamorphic foliation, S_4, is a widespread strain-slip cleavage which cuts all other foliations and dacite dikes. It is very prominent locally, being best developed in rocks with relatively strong S_1. It strikes roughly subparallel to the shear zone and dips moderately south; it forms a subhorizontal to gently dipping lineation on S_1. Movement is with the top side to the south.

A major series of late faults cut the rocks in the shear belt subparallel to its margins. Faults are braided and larger ones contain up to a few feet of gouge. Most faults contain very little gouge, and movements of several feet have been observed on faults with practically no gouge. Displacement along these faults is both pre-dacite intrusion and post-dacite intrusion. Detailed work in several areas and large scale correlations suggest a right lateral displacement with a plunge of 20 to 30° to the east, with the south side moving upwards and to the west. The amount of displacement on major faults is unknown, but could be hundreds to thousands of feet. The major faults converge upwards and to the west to form one major fault on surface, and have the effect of constricting the shear belt to the west.

All ore bodies are cut by many small faults, and most ore bodies are bounded by major faults on at least one side. The smaller faults have broken up continuous sulfide bodies into a large number of irregularly shaped blocks, causing severe problems in ore control. The major faults may have caused large displacement of segments of ore bodies, and some of the bodies which now are distinct probably originally were parts of larger bodies. Thus, the No. 8, 8A, and 8B bodies are probably faulted segments of an original larger body, and the Jane and Fairview Zinc may be parts of another.

The Gambier group rocks to the south are reported to unconformably overlie plutonic rocks of the Coast Range batholith, and some dacite intrusions contain inclusions up to 30 feet across of strongly altered granodiorite. Plutonic rocks of the batholith intrude the Gambier group rocks on the north and east. No plutonic basement has been seen below the Britannia pendant, nor have any inclusions of plutonic rocks been found in the pendant rocks. Several major plutons and numerous minor bodies intrude the Britannia pendant.

On the northeast are several bodies of massive acidic plutonic rocks which may be connected at depth (Squamish, Mountain Lake, and Seymour River plutons). The main rock type is coarse grained quartz-rich granodiorite. Less abundant phases include older, medium grained quartz diorite to diorite, and younger, fine grained, porphyritic granodiorite to quartz monzonite with abundant coarse quartz phenocrysts and less abundant feldspar phenocrysts. The rocks intrude massive andesite and argillite of the Goat Ridge section. Dacite dikes, probably similar to post-deformation dikes in the shear belt are contact metamorphosed along the Squamish pluton border. The coarse grained granodiorite of the Squamish pluton has been dated at 94 m.y. (K/A method).

On the southwest is the Furry pluton, composed mainly of foliated quartz diorite. Foliation is most intense along the border of the pendant, and there it is parallel to S_1 in the pendant rocks.Further from the pendant the foliation swings clockwise until a few miles south it is almost perpendicular to S_1 in the pendant. The pluton contains abundant inclusions of mafic gneiss; in foliated rocks these are flattened parallel to the foliation. On the southwest contact of the pendant is a small body of mainly foliated, fine grained leucogranodiorite with abundant quartz eyes flattened parallel to the foliation (parallel to S_1 of the pendant rocks). Less foliated varieties are similar to the fine grained late phase of the Squamish pluton. Dikes of this rock cut the foliated quartz diorite.

Other intrusions within the pendant are mainly small bodies of massive, fine grained quartz diorite, diorite, leucogranodiorite, and several types of dacite. Age relations among these intrusions are unclear because of lack of contact relations. Some intrusions are probably fine grained relatives of coarse rocks outside the pendant.

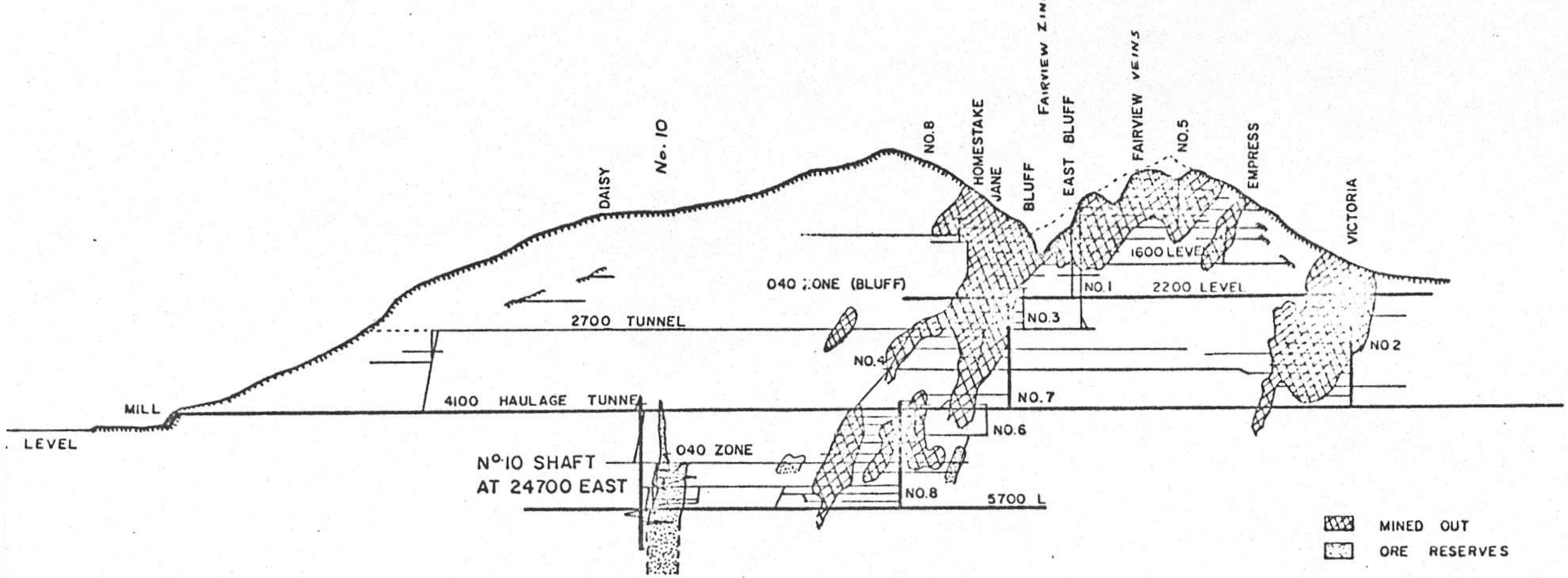
LATE DIKES

Unaltered andesite and lamprophyre dikes cut all rocks and form very continuous thin sheets subparallel to S_1, and less commonly cutting S_1. The age of andesite dikes is uncertain. One dike occurs in the gouge of a late major fault, but is itself fresh and undeformed. Most andesite dikes show strong sideritic alteration along northeast trending faults, which generally are older than the major late faults. Some dikes show a faint foliation parallel to their contacts and to S_1, while others appear boudinaged.

Lamprophyre dikes probably are related to the Pleistocene Garibaldi group of volcanic and hypabyssal rocks which outcrop extensively a few miles to the north.

BRITANNIA MINE 1971

SCALE — 1" = 2700'

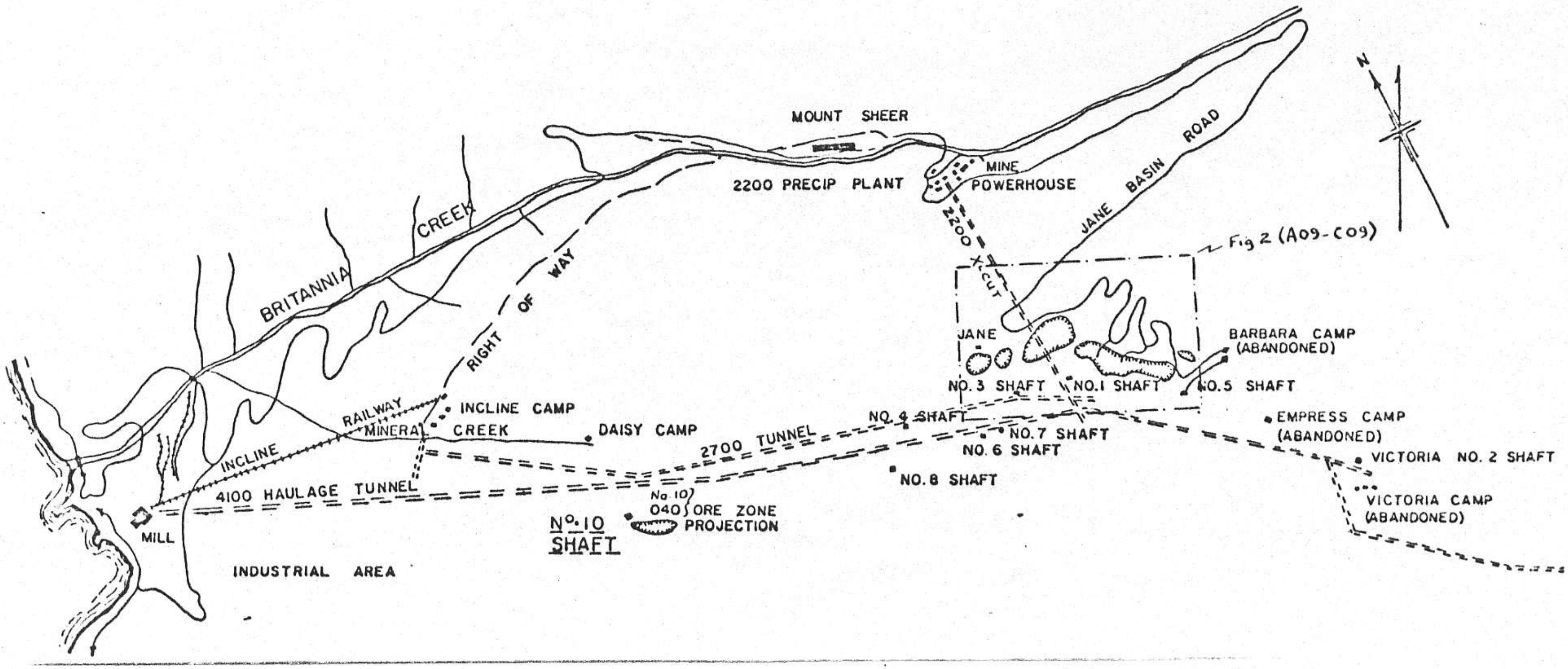


VERTICAL WEST – EAST SECTION

Figure 1a
DB – RCMP

BRITANNIA MINE 1971

SCALE —— 1" = 2700'



PLAN

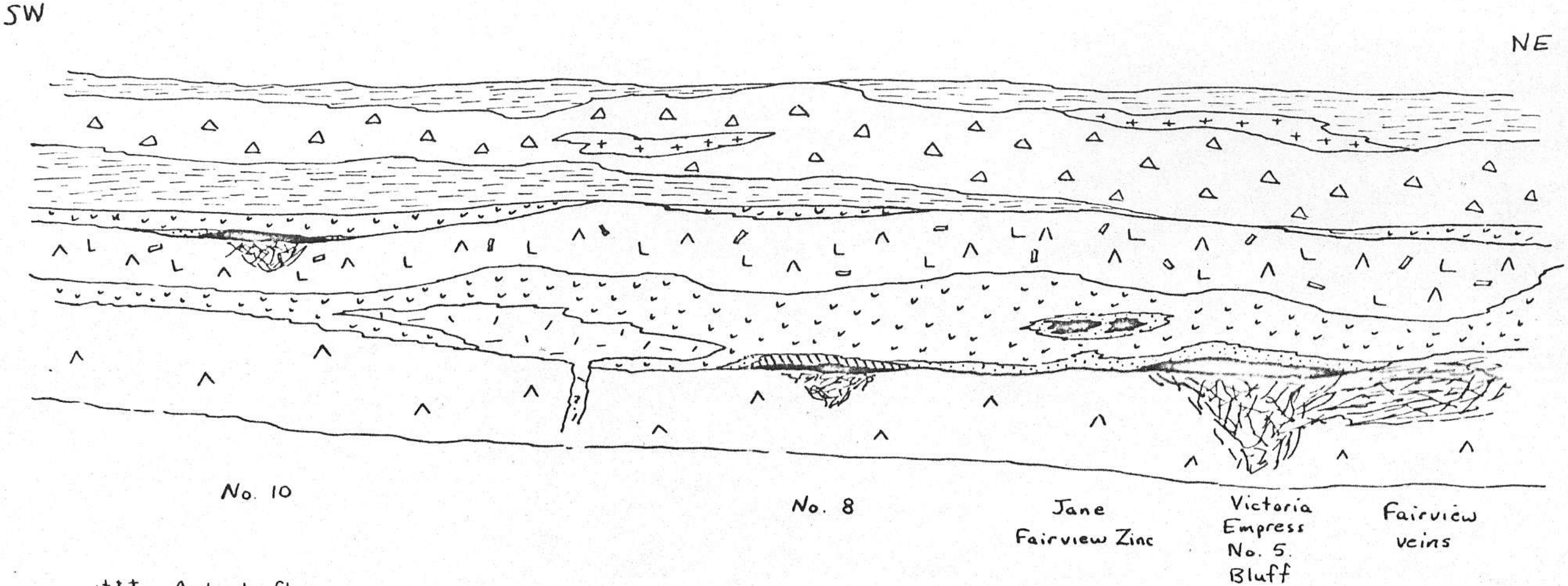
Figure 1b

DB-RCMP

HYPOTHETICAL STRATIGRAPHIC SECTION

(Pre - deformation)

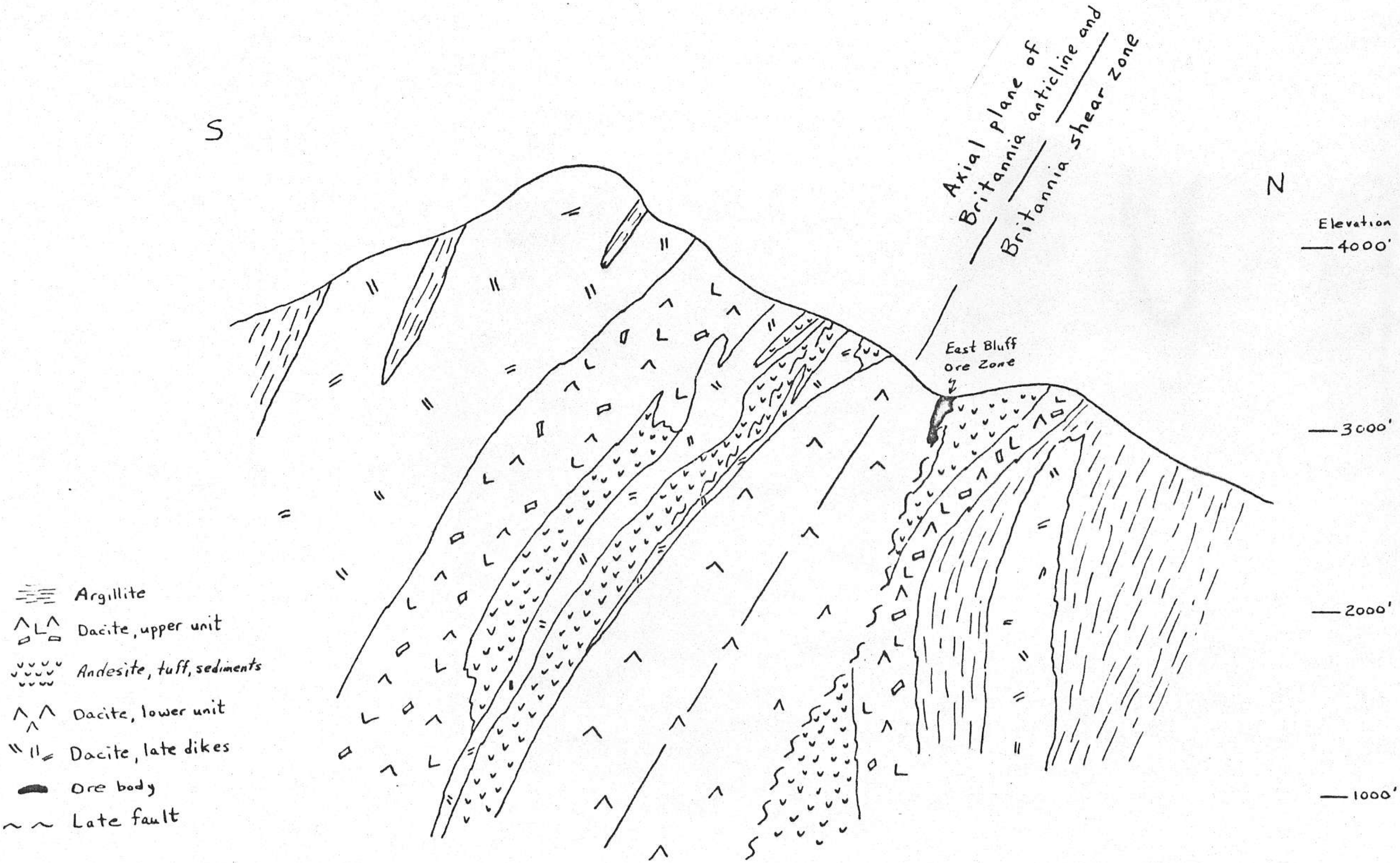
BRITANNIA



- Andesite flow
- Coarse pyroclastic andesite
- Argillite
- Dacite - coarse tuff ; upper unit
- Andesite - fine tuffs, sediments
- Dacite - coarse tuff, lower unit
- Dacite - intrusion
- massive sulfides
- quartz - sulfide vein stockworks
- sulfate zones
- cherty sediments

Approximate Scale: horizontal 1" = 1000'
vertical 1" = 1000'

Figure 2



BRITANNIA (Present)
2200 X-CUT
Scale: 1" = 1000'

Figure 3