LITHOSTRATIGRAPHY AND GEOCHRONOMETRY, BRUCEJACK LAKE, NORTHWESTERN BRITISH COLUMBIA (104B/8E)

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KEYWORDS:: Economic geology, Hazelton Group, Stikine assemblage, geochronometry, metallogeny, silver, gold, Brucejack Lake, stratigraphy, flow-dome complex.

INTRODUCTION

This paper describes lithostratigraphy and two new U-Pb dates from the Brucejack Lake area, located in the southeast portion of the Bruceside property (Newhawk Gold Mines Ltd. 60%; Granduc Mines Ltd. 40%), part of the Sulphurets copper-gold-silver district (Figure 2-11-1). The study is part of the Mineral Deposit Research Unit's Project "Metallogeny of the Iskut River Area, Northwestern British Columbia". The Sulphurets area is important to the project due to the occurrence of mineral deposit types ranging from porphyry deposits (Cu, Cu-Au, and possibly Au-only), "mesothermal" veins to "epithermal" veins (*N.B.* usage of "mesothermal" and "epithermal" is based upon textural features) within a restricted area. It is not known whether this spectrum of mineral deposits is co-ten poral. Britton and Alldrick (1988) suggest that some miner dization in the Sulphurets area is coeval with intrusive acti ity, and intrusive activity is both syn and post-volcanic. Therefore, one part of this project is designed to understand the geological environment(s) prevailing during volcanic activity, intrusion of plutonic and hypabyssal rocks, base and precious metal mineralization, and finally, whether any or all of these events are related. Here, volcanic and subvolcanic igneous rocks and associated sediments in the Brucejack Lake area are described, with an emphasis on the volcanic environment.

The exploration history of the Sulphurets property to late 1991 is given by Roach and Macdonald (1992). Significant mineral deposits with published reserves in the immediate area include the Kerr porphyry copper-gold deposit (Placer Dome Inc., 125.7 million tonnes, 0.27 g/t Au, 0.62% Cu), and the West zone (Newhawk Gold Mines Ltd., 750 000 tonnes, 15.4 g/t Au, 644 g/t Ag).

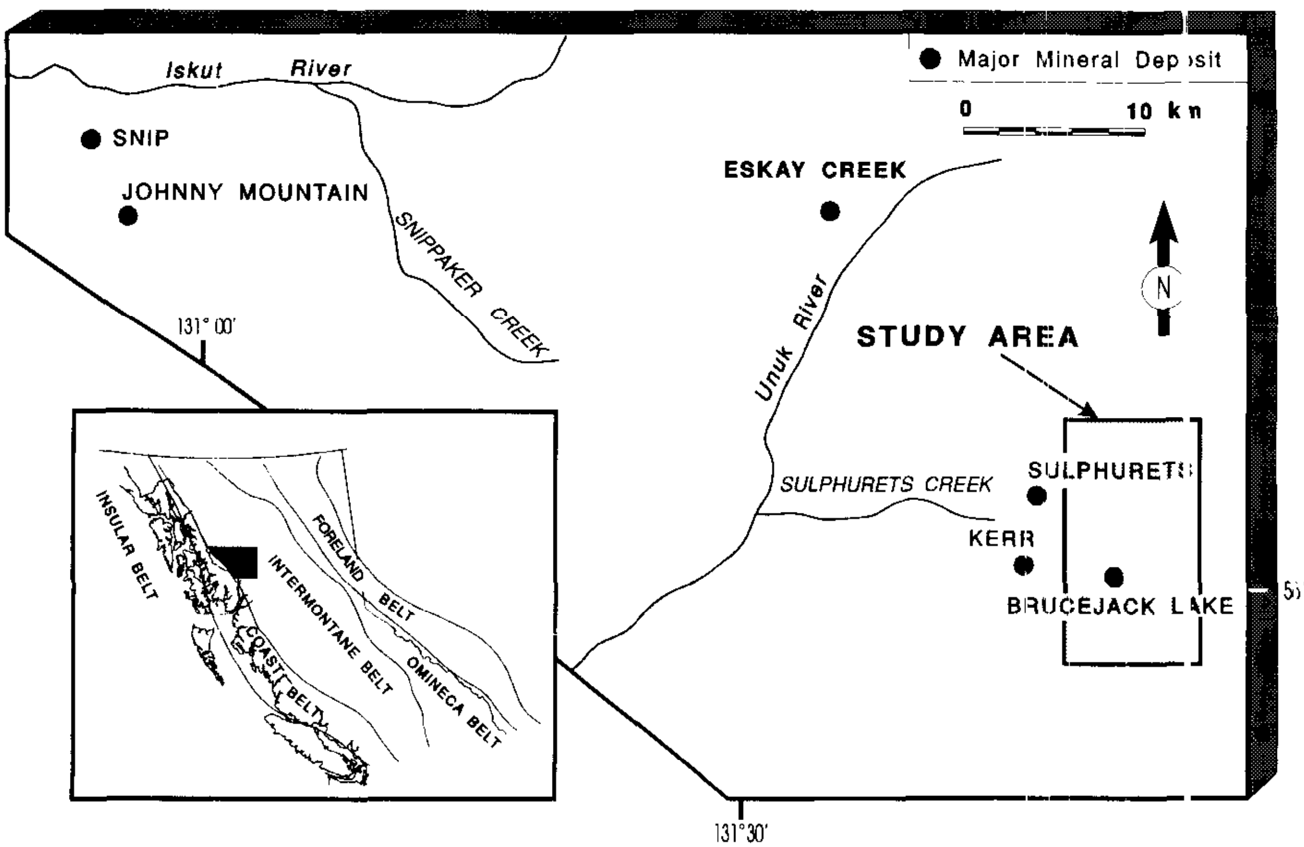

Figure 2-11-1. Location map, Brucejack Lake, Northwestern British Columbia

REGIONAL GEOLOGY

The results of recent studies (Aldrick and Britton, 1988; Henderson *et al.*, 1992; Kirkham, 1991, 1992; Lewis, 1992) collectively suggest that Upper Triassic Stuhini Group in the Sulphurets area is overlain unconformably by the Lower to Middle Jurassic Hazelton Group, at the base of which is a heterogeneous clastic sedimentary unit, comprising locally fossiliferous limy sandstone, siltstone and heterolithic conglomerate; the unit has been termed the Jack formation (named informally after the Jack Glacier) by Henderson *et al. (ibid)*. Overlying the Jack formation is the bulk of the Hazelton Group, comprising at lower levels a succession of dominantly intermediate volcanic and volcaniclastic rocks, with minor sediments, overlain by an intermediate to felsic extrusive unit (Mount Dilworth formation) and capped by a mixed sedimentary/mafic volcanic assemblage (Salmon River Formation). Overlying the Hazelton Group is an onlap sedimentary unit, the Middle to Upper Jurassic Bowser Lake Group, comprising rhythmically bedded sandstone and argillite, and laterally discontinuous conglomerate; the assemblage is interpreted to be a turbidite succession by Henderson *et al.* (1992).

In this paper facies relationships are described from exposures within a small interval of the Sulphurets stratigraphy, comprising Hazelton volcanic, volcaniclastic and sedimentary rocks associated with a flow dome.

ECONOMIC GEOLOGY

In the vicinity of Brucejack Lake, precious metal mineralization occurs in two modes: semi-brittle, shear vein systems (*e.g.*, West zone), and brittle extension and breccia veins (*e.g.*, Quartz Hill, 367 zones). There are no data available to suggest that the two styles reflect two discrete, unrelated hydrothermal events. Galena lead-lead isotopes from both styles of mineralization are essentially identical; data fall within the Jurassic cluster defined by Godwin *et al.* (1990). The West zone crops out approximately 200 metres south of Brucejack Creek (draining the west end of Brucejack Lake) and plunges to the north under the creek. The geology and structure of the syntectonic, shear zone hosted West zone has been described by Lefebure (1987), Britton and Alldrick (1988), Roach and Macdonald (1992) and Macdonald and Roach (1992). Other shear-related vein structures are exposed to the north and northeast, for example, Gossan Hill and Shore zones.

Along strike to the northwest of the West zone and extending for in excess of 2 kilometres in its footwall (to the south-southwest), stockworks, extension veins and breccia veins are locally developed; for example, Galena Hill, 367, North Spine, Napoleon, Electrum, Mammoth, Quartz Hill, Bridge, Agatha, Jessica, and Fletcher veins and zones (Kirkham, 1992). The veins and their hostrocks are characterized by a lack of penetrative fabric, in contrast with intense schistosity developed in spatially restricted, quartz-sericite-pyrite hostrock near the West zone. Gangue mineralogy is dominated by quartz (locally microcrystalline) and locally by carbonate, and very locally, barite; in places, bladed carbonate is replaced by quartz, a feature that has been recognized in epithermal environments such as Mount Skukum in the Yukon Territory (McDonald and Godwin, 1986) and Pajingo in Queensland, Australia (Dowling and Morrison, 1989). Lefebure (1987) first pointed out that quartz-carbonate veins are developed peripherally to the intense quartz-sericite-pyrite alteration around the ductily deformed West zone vein mineralization. This spatial relationship suggests that the two styles may be related.

LITHOSTRATIGRAPHY – BRUCEJACK LAKE

The Hazelton Group in the Brucejack Lake area consists of a thick (>2 km) sequence of interbedded sedimentary and volcanic rocks including both flows and pyroclastic deposits (Britton and Alldrick, 1988). The sedimentary rocks vary from fine-grained argillaceous rocks (*e.g.*, in the footwall of the West zone; Roach and Macdonald, 1992) to conglomerate with fine-grained muddy matrix, to epiclastic rocks (Britton and Alldrick, 1988). Conglomerate matrix is locally a hematitic, finely banded siltstone (*see* below).

Crystal tuffs, lapilli tuffs and blocky tuff breccias of intermediate composition are volumetrically the most significant volcanic rock type in the Brucejack Lake area; they are commonly well layered (Plate 2-11-1), exhibit graded bedding, locally reverse grading (coarsening upwards), with local development of tractional bed forms such as ripples (Plate 2-11-2), small troughs associated with low-angle cross-stratification and erosional contacts formed during the emplacement of overlying deposits (Plate 2-11-3). The volcaniclastic deposits are interlayered with marine sedimentary units; in addition, Britton and Alldrick (1988) note the presence of air-fall tuffs, although these have not been observed during this study. Accretionary lapilli are preserved locally, and are concentrated in the upper part of bedded, intermediate volcaniclastic deposits (location marked in Plate 2-11-1). The lapilli are "rim-type" under the classification of Schumacher and Schminke (1991), in which a fine to medium-grained core of each ash lapillus is surrounded by an extremely fine grained rim of ash (Plate 2-11-4). Multiple banding is not seen in the fine ash rims; rare lapilli have no obvious core, composed only of fine ash.

In the lithic and breccia tuffs, both clasts and matrix may contain plagioclase, potassium feldspar and/or hornblende phenocrysts. Flow rocks may also contain similar phenocryst assemblages and, as described below, show local interdigitations with volcaniclastic rocks, suggesting that the two are closely related. Mafic pillow lavas are present (Britton and Alldrick, 1988), but are volumetrically insignificant. Clast size in blocky tuff breccias reaches in excess of 3 metres to the south of Brucejack Lake.

Superficially similar to pyroclastic lithic tuffs and tuff breccias, although genetically quite different, complex polylithic units are interpreted to form from the juxtaposition and admixture of more than one pyroclastic deposit, either as an intrusion breccia, in which a younger flow brecciates an older flow or pyroclastic deposit (Plate 2-11-5), or by the disaggregation of an unconsolidated deposit during introduction of subsequent flow(s) (Plate 2-11-6). Complex breccias resulting from the process of interaction of volcanic or volcaniclastic rocks with unconsolidated precursor volcanic, volcaniclastic or sedimentary rocks, have been

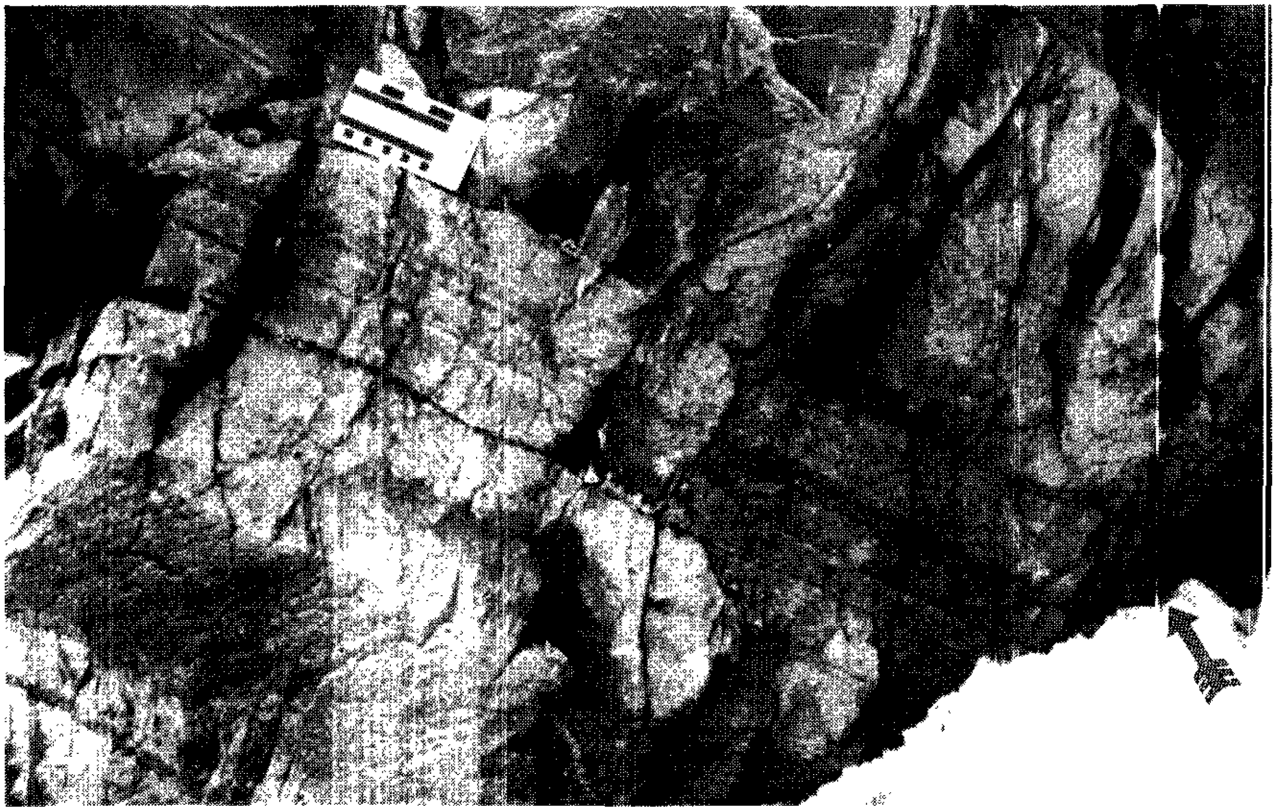

Plate 2-11-1. Layered intermediate pyroclastic rocks, south of Brucejack Lake. Arrow notes stratigraphic level of accretionary lapilli (refer to Plate 2-11-6).

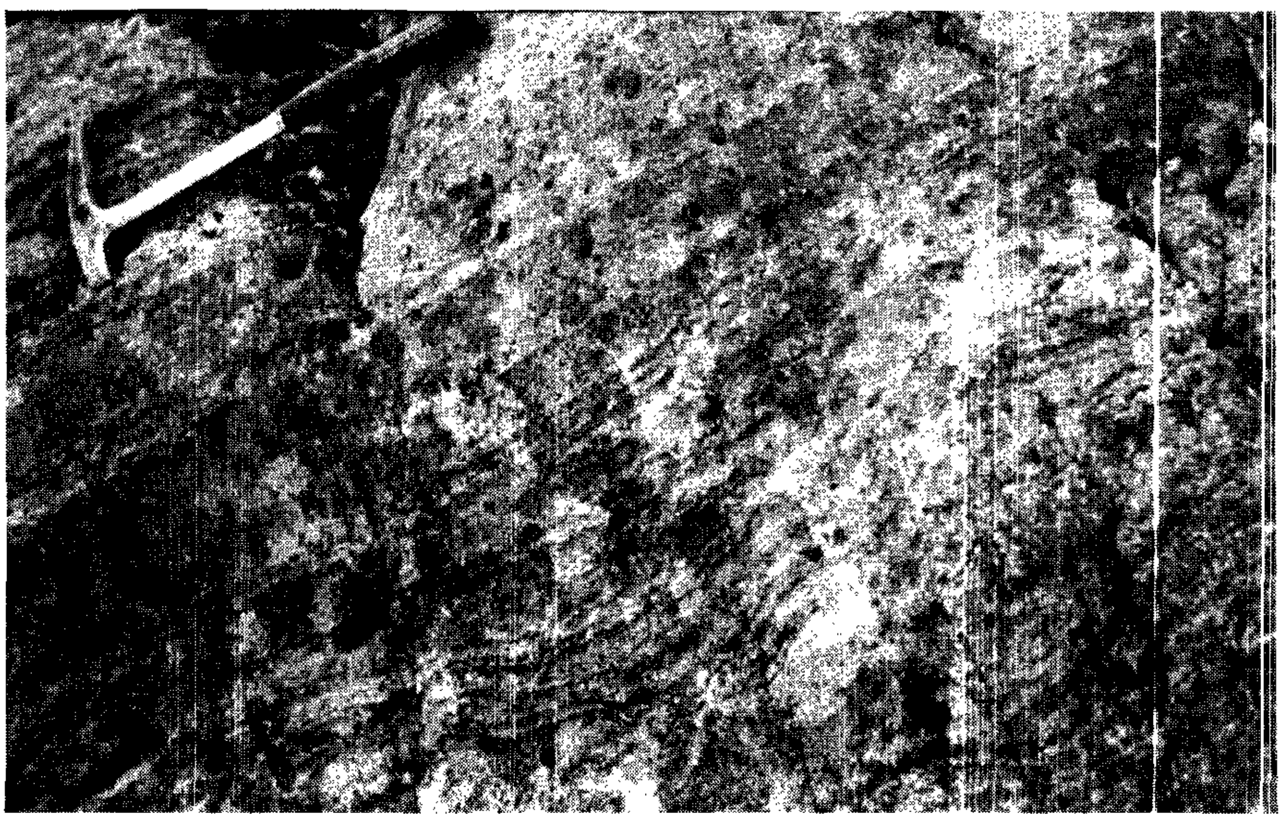

Plate 2-11-2. Ripple bed-forms in intermediate pyroclastic rocks, southeast of Brucejack Lake.

Plate 2-11-3. Erosional relationships exhibited by pyroclastic deposits, south wall of Hanging Glacier valley.

described elsewhere in the Iskut River map area, such as the Eskay Creek mining lease (Macdonald, 1990), and the Treaty nunatak (Lewis *et al.*, 1993).

A felsic flow-dome complex within the Hazelton rocks outcrops near Brucejack Lake (Roach and Macdonald, 1992); both intrusive and extrusive components of the complex are well exposed. The intrusive component is flow banded and locally flow folded (Plate 2-11-7); the attitude of flow banding is highly variable in the body of the intrusive phase, but becomes aligned subparallel to intrusive contacts with enclosing, heterogenous, bedded to massive pyroclastic rocks; faulted contacts with enclosing volcaniclastic rocks are also common. The appearance of flow banding is enhanced in hand specimen by reddish, hematitic alteration spatially related to millimetre to centimetre-scale, sygmoidal fractures developed preferentially in the fine-grained flow bands and not in intervening feldspar-phyric material.

The flow-banded unit has gradational, diffuse, irregular and interfingering contacts with a voluminous breccia unit (Plate 2-11-8) comprising clasts and boulders of massive and flow-banded felsic material identical in hand specimen to the intrusive phase, in a hematitic, muddy and locally finely laminated matrix. Higher in the section to the south of Brucejack Lake, the flow-banded felsic unit rests in apparent stratigraphic contact upon marooon, blocky tuff and the above-mentioned breccia unit; flow banding in this extrusive component of the unit is generally subparallel to both the contact with underlying breccias and tuffs, and bedding in other pyroclastic and sedimentary units south of Brucejack Lake (Alldrick and Britton, 1991). The thickness of the breccia unit is variable, but is best developed, in excess of 30 metres, on the south and southwest flank of Mount John

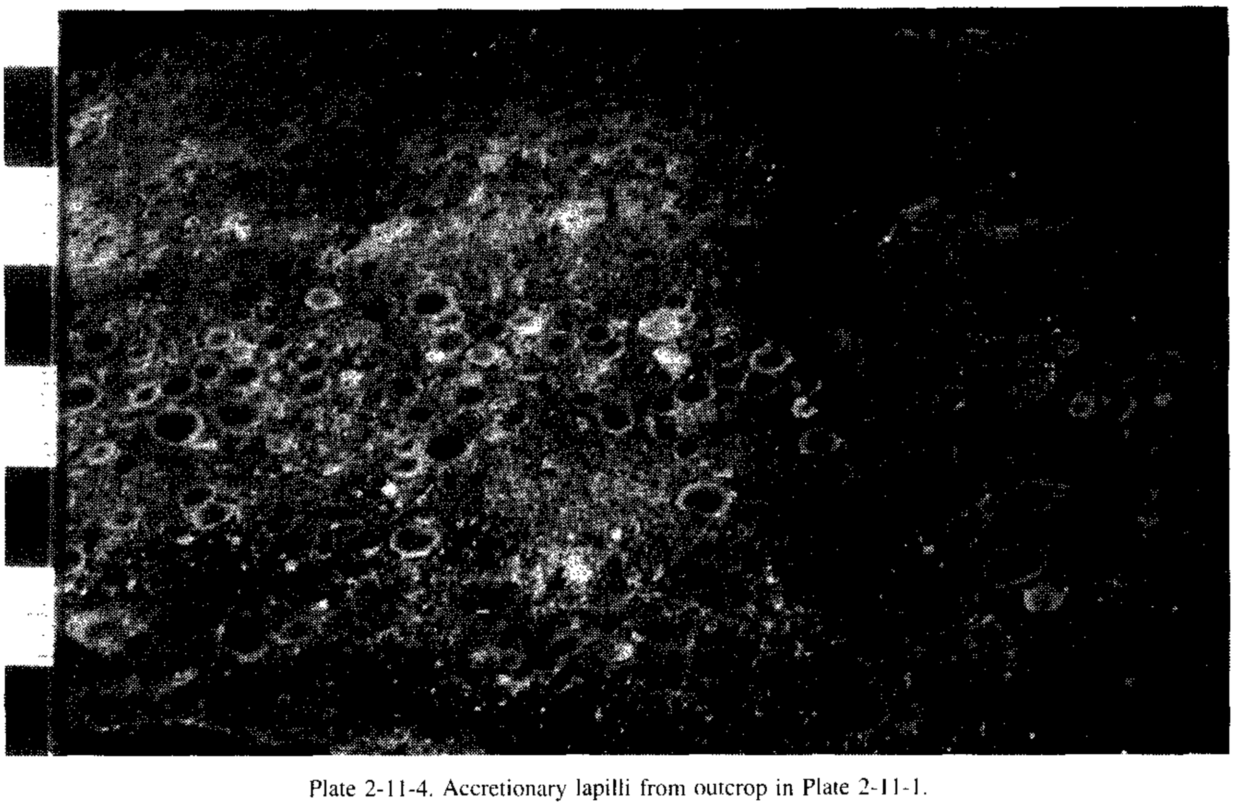

Plate 2-11-4. Accretionary lapilli from outcrop in Plate 2-11-1.

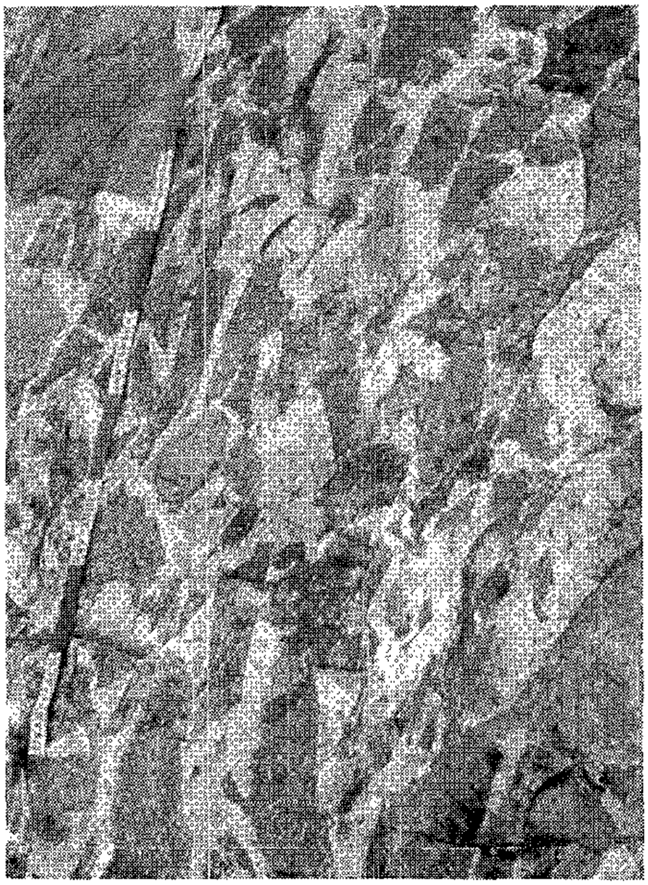

Plate 2-11-5. Breccia of light grey intermediate volcanic rock intruding dark intermediate pyroclastic rock, south of Brucejack Lake. Scale: measuring tape (decimetre scale on outcrop).

Walker, north of Brucejack Lake, from where the unit can be traced intermittently around the east end of Brucejack Lake to the intrusive and extrusive components of the flow dome described above, and northwest to the south wall of Hanging Glacier (referred to as Freegold Glacier in some pre-1990 publications) a strike length of approximately 4 kilometres.

In thin section, the flow banded rock is seen to contain (a) 35 to 40 per cent plagioclase phenocrysts to 4 millimetres exhibiting minor sericite alteration along fractures, and local epidote and hematite alteration; the hematite is manifest as a curious "peppering" of altered feldspar (?plagioclase), the significance of which is not yet clear; (b) conspicuous, trace apatite (<0.2%) needles to 400 microns; (c) approximately 60 per cent groundmass of quartz±feldspar±clay±sericite±carbonate; the rock is cut by sericite-carbonate veinlets, locally up to 5 millimetres wide.

The flow dome is intruded by felsic dikes, striking north-northwesterly, dipping steeply, and generally less than 50 centimetres wide (visible under the measuring tape in Plate 2-11-7). Locally the dikes disaggregate into bulbous, ovoid bodies, less than a metre in long dimension (Plate 2-11-9). Although these bodies exhibit some geometric similarities to boudins, the hostrock (flow-banded felsic unit) shows no visible strain.

In thin section, the felsic dike rock exhibits pervasive alteration of plagioclase (approximately 30%, to 3 mm in long dimension) by epidote. This rock, like the flow-banded rock it intrudes, contains strongly altered grains of feldspar (?plagioclase), partially replaced by hematite; the groundmass comprises 65 to 70 per cent of the rock, similar to the flow-banded unit; the dike rock (including epidote after plagioclase) is cut by quartz veinlets.

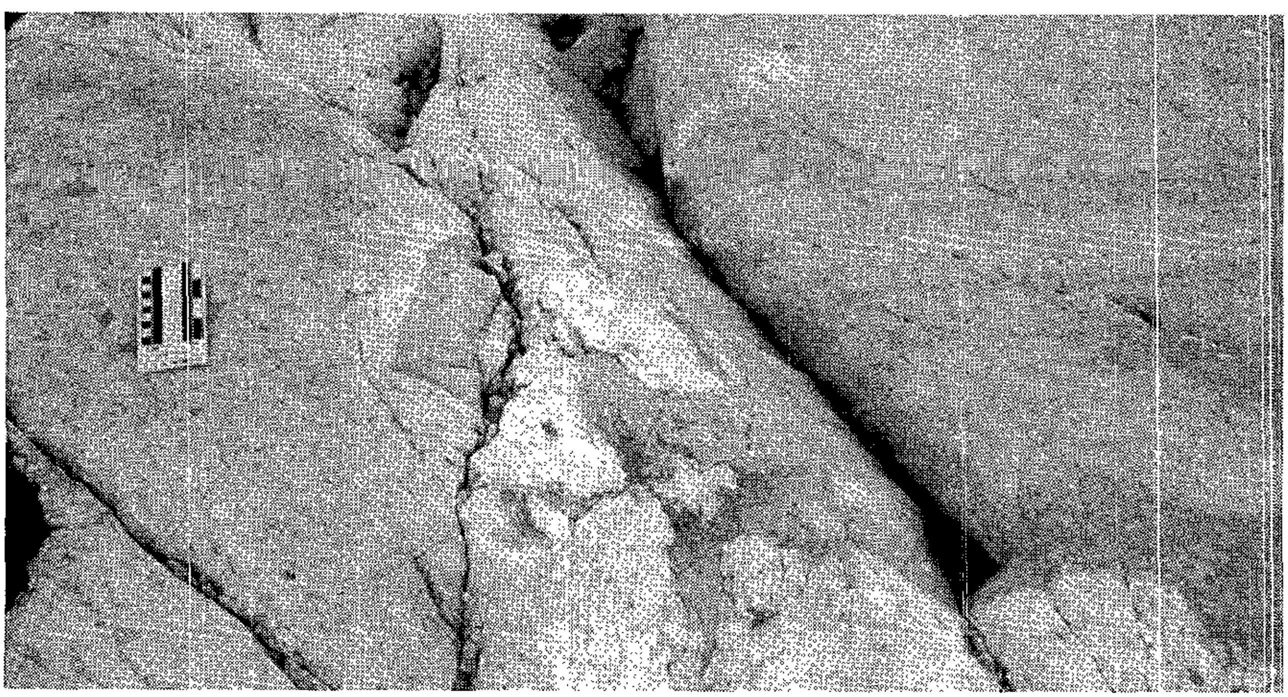

Plate 2-11-6. Disaggregation of unconsolidated pyroclastic deposit during influx of subsequent pyroclastic deposit, south wall of Hanging Glacier valley.

Plate 2-11-7. Flow-folded, intrusive component of flow-dome complex, south of Brucejack Lake. Microgranite dike visible beneath tape measure. Scale:measuring tape (decimetre scale on outcrop).

Plate 2-11-8. Boulder breccia marginal to flow-dome complex; boulders of flow-dome granodiorite in a hematitic, finely laminated, muddy matrix.

Lithogeochemical analyses of the flow dome and dike are described elsewhere (Macdonald, 1992); in brief, both the flow dome and dike have similar modal proportions, and may be classified as granodiorite and microgranite, respectively (after the method of LeMaitre, 1989).

GEOCHRONOMETRY

Two samples from the flow-dome complex were selected for U-Pb zircon geochronometry: AJM-ISK91-388 (intrusive component of flow dome) and AJM-ISK91-399 (disaggregated felsic dike from within intrusive component of flow dome). Analytical procedures are those described by Macdonald *et al.* (1991); the only modification pertains to the total procedural blanks, which are approximately 30 picograms for lead and 6 picograms for uranium. The analyses were performed by Dr. D. Ghosh in the Geochronometry Laboratory, Department of Geological Sciences at The University of British Columbia; results are reported in Table 2-11-1.

The flow-dome sample is interpreted to be 185.6$\pm$1.0 Ma (2σ) based on the lower intercept of the well-defined discordia with a mean squared weighted deviation (MSWD) of 0.16 (Figure 2-11-2). The upper intercept of about 1013+261/-241 Ma suggests incorporation of a lead component from an older source.

The dike sample is interpreted to be 185$\pm$1.0 Ma (2s) based also on the lower intercept of the well-defined discordia with an MWSD of 0.03 (Figure 2-11-3). For this sample also, incorporation of an old lead component is suggested by the upper intercept of the discordia at about 1058+386/-342 Ma.

Interpreted ages of these two samples from the Sulphurets area are similar within errors and suggest plutonic activity during the late Early Jurassic (Toarcian; Harland *et al.*, 1989) in the Stikine Terrane. Inheritance of an old (about 1000 Ma) lead component in the zircon fractions from both the samples suggests presence of a basement on which Toarcian magmatic arc developed (Ghosh, 1992). This basement might be part of the Nisling Terrane or its equivalent.

Plate 12-11-9. Disaggregated microgranite dike within intrusive component of flow-dome complex.

This terrane has been recently defined as a metamorphosed Proterozoic to lower Paleozoic(?) passive continental-margin assemblage in the western part of the Cordillera (Wheeler *et al.*, 1991).

These ages are similar to 186±2 Ma obtained from the Eskay porphyry (Eskay Creek area) by Macdonald *et al.* (1991) suggesting that Toarcian magmatism was widespread. It is interesting to note that even though the samples from the Sulphurets area show lead inheritance, dated samples from the Eskay Creek, Inel and Iskut River (Macdonald *et al.*, *ibid*) rather show lead loss.

INTERPRETATION

Henderson *et al.* (1992) infer the presence of considerable topographic relief during Hazelton Group volcanism in the Sulphurets area, with ensuing rapid facies changes over small distances along strike; these relationships suggest that the Sulphurets area was a probable volcanic centre during deposition of Hazelton rocks, a suggestion made earlier by Alldrick (1989). The presence of rim-type accretionary lapilli in the upper parts of individual pyroclastic units indicates deposition by a pyroclastic flow or surge (as opposed to co-ignimbrite ashfall), and deposition within less than 4 kilometres from the volcanic source (based on Schumacher and Schminke, 1991), again consistent with the hypothesis of proximity to a volcanic centre.

Both crosscutting and conformable relationships exhibited by the flow-banded unit indicate a progression from intrusive at depth, to complex interdigitations with related ejecta at intermediate levels, to extrusive at the highest observed level. Microgranite dikes intrude the flow-dome complex, but become disaggregated within the body of the feldspar-phyric, flow-banded rock. These field relationships suggest that the two (flow dome and dike) are coeval, an hypothesis confirmed by U-Pb geochronometry. The presence of both intrusive and extrusive components of a flow-dome complex is additional evidence for a local magmatic centre in the vicinity of Brucejack Lake during the Toarcian. Mud-cemented breccias are the lateral equivalent of the flow dome, with which they interfinger; the breccias are also overlain by the extrusive component of the flow-dome complex. The breccias are interpreted to be talus material formed by erosion of the emergent dome. In turn, the morphology and geometry of the breccias suggests conformity with enclosing flow rocks, including potassium feldspar, plagioclase and hornblende-phyric flows.

Available geological evidence, when considered collectively, is consistent with deposition of volcanic and volcaniclastic rocks in a submarine environment, and includes the rythmic interbeds of sediment containing marine fossils, the finely laminated nature of muddy matrix to breccias peripheral to the flow-dome complex, tractional bed forms, such as ripples. Oxidation of units that imparted a prominent reddish colouration to the rocks, resulting from hematite alteration, occurred at some period subsequent to original deposition; it is not known when this event occurred, although it is speculated that the Jurassic volcanic edifice in the Sulphurets area may have been wholly or

TABLE 2-11-1

U-Pb ANALYTICAL DATA

Sample/ Fraction[2]	Wt (mg)	U (ppm)	Pb[3] (ppm)	Isotopic abundance[4] $^{206}Pb=100$: 208	207	204	206/204[5]	Isotopic ratios[6] ±2 sigma errors / Dates (Ma)[7] ±2 sigma errors: $^{206}Pb^*/^{238}U$	$^{207}Pb^*/^{235}U$	$^{207}Pb^*/^{206}Pb$
AJM-ISK91-388[8]										
a. M2/1	0.6	354	10.9	16.11	5.80	0.0559	1563	0.02920±14	0 20053±106	0.04981±10
ABR, +74m								**185.5±0.8**	**185.6±0.8**	**186.3±5.0**
b. NM2/1	0.7	309	9.4	16.24	5.30	0.0229	3250	0.02906±14	0.19886±104	0.04963±12
ABR, -74+44m								**184.7±0.8**	**184.2±0.8**	**177.7±5.4**
c. M2/1, NM1.5/3	0.3	445	14.1	18.21	5.25	0.0161	3534	0.02967±14	0.20546±108	0.05022±14
ABR, -74m								**188.5±0.8**	**189.7±1.0**	**205.3±6.4**
AJM-ISK91-389[9]										
a, NM2/1	0.4	389	11.7	14.85	5.16	0.0131	4196	0.02910±12	0.19967±104	0.04976±16
ABR, 149+74m								**184.9±0.8**	**184.8±0.8**	**183.7±7.2**
b. M2/1 NM1.5/3	0.4	413	13.0	17.91	5.61	0.0404	1980	0.02950±14	0.20403±102	0.05017±12
ABR, -74+44m								**187.4±0.8**	**188.5±0.8**	**202.9±5.4**
c. NM1.5/3 M1.0/5	0.3	586	18.1	17.36	5.19	0.0146	4147	0.02917±14	0.20036±106	0.04982±10
ABR, -74+44m								**185.3±0.8**	**185.4±0.8**	**186.5±4.8**

NOTES:

1 Complete analytical data, including the measured $^{206}Pb/^{204}Pb$ errors, the mole % blank Pb and the $Pb^*/(Pb^* + Pb_{common})$ ratios in the analyses, the assumed Stacey-Kramers common Pb ages and their errors, and the correlation coefficients for the Pb/U ratios, are recorded on UBC Geochronometry Laboratory data sheets.

2 NM= non magnetic, M=magnetic, -74+44m = size range in microns; ABR=abraded: all fractions were abraded for 2 hours to remove the outer rims

3 radiogenic+common Pb

4 radiogenic+common Pb, corrected for 0.43%/amu (atomic mass units) fractionation and for 30 pg Pb blank with composition 208:207:206:204=37.67:15.30:18.12:1

5 $^{206}Pb/^{204}Pb$ measured, corrected for 0.43%/amu fractionation.

6 corrected for fractionation (0.44%/amu for U and 0.43%/amu for Pb), blank Pb (see note above), and for common Pb using Stacey and Kramers (1975) growth curves; errors are 2 sigma, only last digits shown.

7 decay constants used in age calculation : $\lambda^{238}U=1.55125 \times 10^{-10}$; $\lambda^{235}U=9.8485 \times 10^{-10}$; $^{238}U/^{235}U=137.88$ (Steiger and Jager, 1977). Errors are 2 σ.

8 collected by AJM, Longitude: 130° 09' 21"; Latitude: 56° 27' 52".

9 collected by AJM, Longitude and Latitude: same as above.

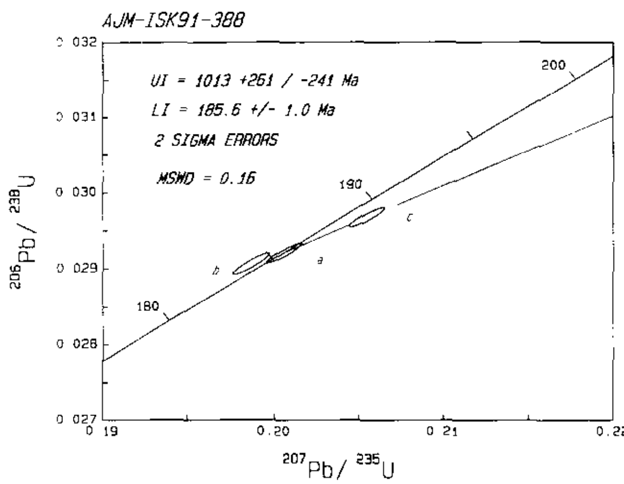

Figure 2-11-2. $^{206}Pb/^{238}U$ vs. $^{207}Pb/^{235}U$ concordia diagram for AJM-ISK91-388. LI = lower intercept, UI = upper intercept.

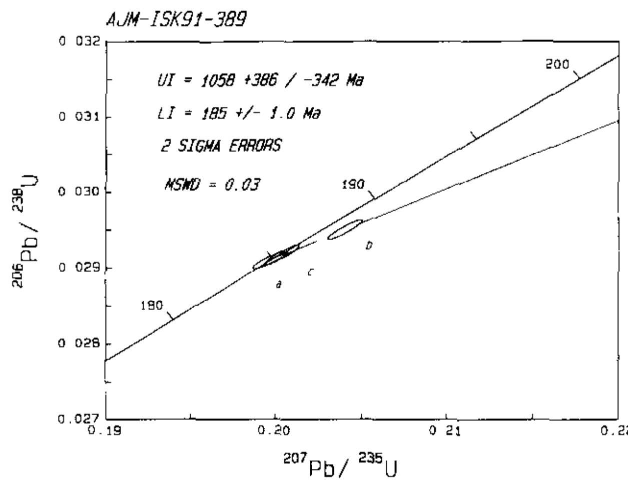

Figure 2-11-3. $^{206}Pb/^{238}U$ vs. $^{207}Pb/^{235}U$ concordia diagram for AJM-ISK91-389. LI = lower intercept, UI = upper intercept.

partially exposed to the atmosphere prior to burial by younger rocks.

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