U-Pb GEOCHRONOLOGY OF THE MOUNT STAPLER QUARTZ MONZONITE: EVIDENCE FOR EARLY JURASSIC MAGMATISM IN THE TULSEQUAH GLACIER AREA, NORTHWEST BRITISH COLUMBIA (104K/13)

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INTRODUCTION

The Tulsequah Glacier area is within the rugged Coast Mountains of northwestern British Columbia (Figure 1) at the westernmost edge of northern Stikine Terrane. Fieldwork in 1993 consisted of property-scale sampling and relogging of core from the Tulsequah Chief and Big Bull volcanogenic massive sulphide deposits by F.C. (Sherlock *et al.*, 1994) and 1:50 000-scale mapping of NTS map sheets 104K/12 and 13 by M.M. (Mihalynuk *et al.*, 1994a, b). Mapping on Mount Stapler revealed a tabular quartz monzonite stock with associated dissected dikes and (?)apophyses. The intrusive body dated in this study is truncated by splays of the Llewellyn fault, a long-lived crustal-scale north-northwest-trending fault with both sinistral and dextral motion.

GEOLOGICAL SETTING

Four tectonic elements constitute the gross geology between the Tulsequah Glacier area and the Yukon border. Two basement elements have been recognized: a regionally metamorphosed suite (here included with the Yukon-Tanana Terrane, *sensu* Mortensen, 1992) to the west, and late Paleozoic arc strata of the Stikine assemblage (Monger, 1977) to the east. They are overlapped by a succession of Jurassic and perhaps Upper Triassic rocks of mainly arc-derived marine sediment. All are cut by the Llewellyn fault. In northwestern British Columbia, these geologic elements have been mapped for 180 kilometres within the eastern Coast Ranges (Mihalynuk and Rouse, 1988b; Doherty and Hart, 1988; Mihalynuk *et al.*, 1989, 1990, 1994b, 1995, this volume; Currie, 1990). To the north, in southern Yukon Territory, the Llewellyn fault has been interpreted to converge with the Tally-Ho shear zone (Doherty and Hart, 1988).

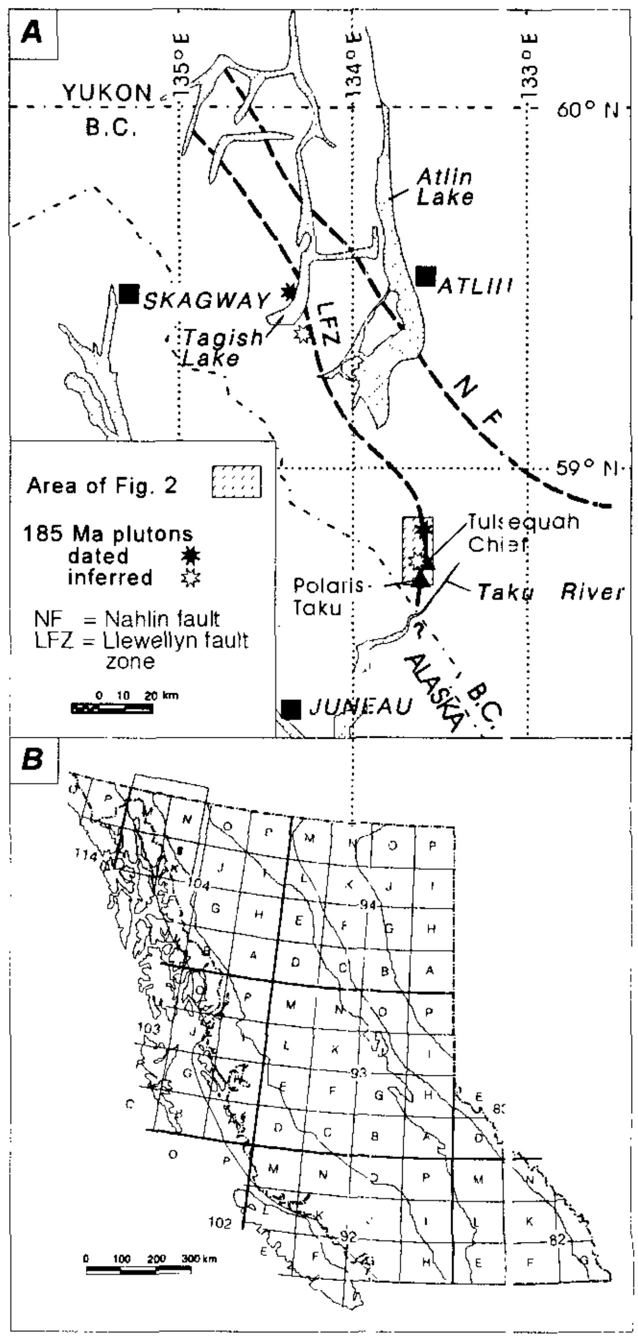

Figure 1. General location of the study area with respect to (a) geographic and cultural features and (b) the National Topographic System.

Original mapping in the Tulsequah area by Souther (1971) correlated most of the unmetamorphosed volcanic arc rocks with the Upper Triassic Stuhini Group. Recent biochronology (Nelson and Payne, 1984; Mihalynuk *et al.*, 1994b, 1995) and U-Pb geochronology (Sherlock *et al.*, 1994) have shown these rocks to be at least Early Permian to early Mississippian in age.

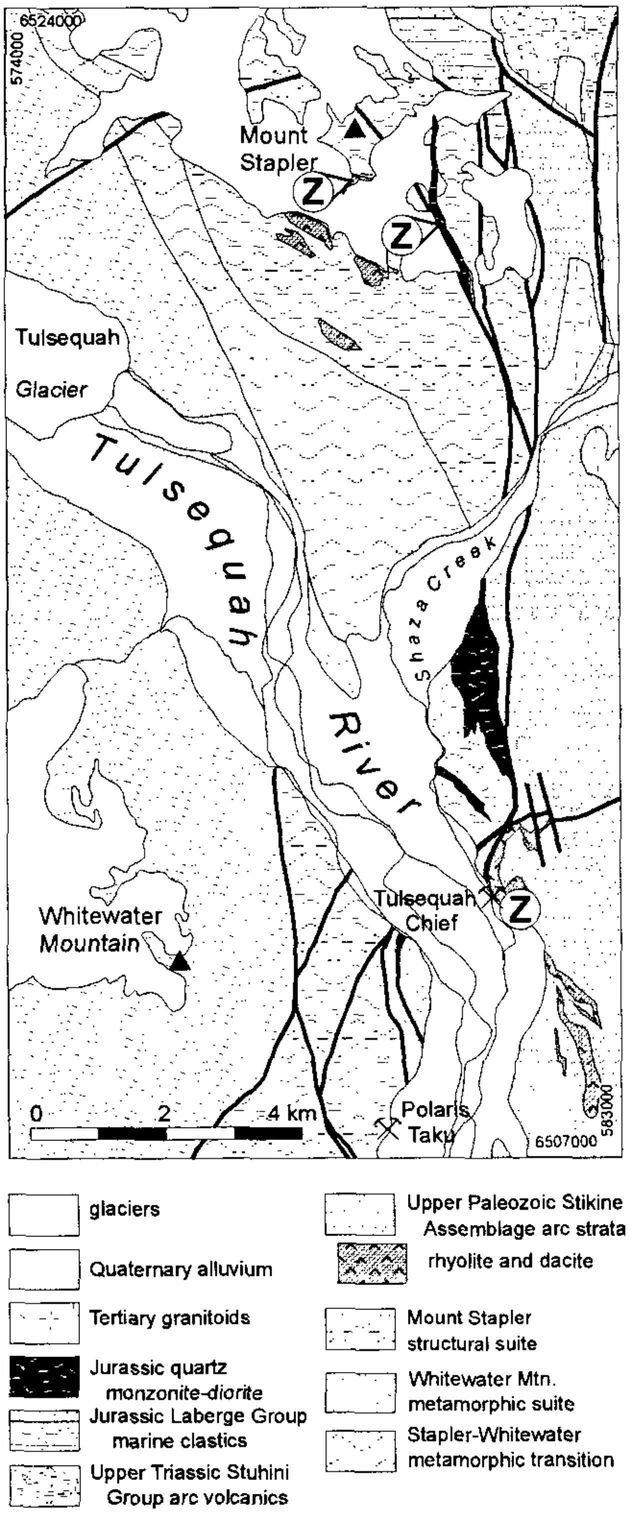

Figure 2. Distribution of metamorphic and structural suites, and Early Jurassic intrusive rocks near Tulsequah (simplified from Mihalynuk *et al.*, 1994b). 'Z' indicates sites of U-Pb zircon age date samples discussed.

Regionally metamorphosed rocks form a narrow (5 to 50 km), southward-broadening belt. For most of its northern length the metamorphic belt is composed of deformed volcanic rocks of arc derivation. These have been metamorphosed to transitional greenschist-amphibolite grade and are known as the Boundary Ranges Metamorphic Suite (Mihalynuk and Rouse, 1988a). Currie (1992) suggested that the Boundary Ranges suite is partially coeval with the Stikine assemblage; a contention which is supported by the data presented here.

Metamorphic grade in the belt culminates near the south end of Atlin Lake where sillimanite overprints kyanite. Protoliths there are thick carbonates, semipelites and quartzites of probable continental margin derivation. This package is known as the Florence Ranges Metamorphic Suite (Currie, 1990). Between Atlin Lake and the Tulsequah River area, several abrupt changes in structural style and/or protolith are recognized as separate metamorphic or structural suites. These include the Whitewater Metamorphic Suite that consists of quartz-rich graphitic schist, lesser metabasite and quartzite, and sparse carbonate and ultramafic rocks, and the Mount Stapler structural suite that consists of volcanic arc derived strata with relict protolith textures (Mihalynuk *et al.*, 1994a, b). The Mount Stapler suite is divided into upper and lower divisions, dominated by volcanic and sedimentary rocks, respectively. Rocks of the volcanic-dominated succession include pyroxene-phyric basaltic breccia and tuff (Photo 1), rhyolite tuff (Photo 2), tuffaceous sediment, and carbonate (Photo 3). Rocks of the lower division are primarily clastic sediments that change, structurally down-section, with decreasing tuffaceous component and increasing quartz content. At lowest structural levels, isoclinally refolded graphitic quartz siltstone gives way to graphitic schist of the Whitewater suite. The contact is interpreted to have originally been stratigraphic.

MOUNT STAPLER QUARTZ MONZONITE

The Mount Stapler suite is cut by one or more irregular, dissected intrusions of pink quartz monzonite cut by the Llewellyn fault (Figure 2). Quartz monzonitic rocks are most common near the contact between basaltic breccia dominated strata and siltstone-limestone dominated strata, and clearly intrude both.

The intrusion ranges in composition from leucogabbro to quartz monzonite. Foliation is variably developed; moderately strong foliation is typical but original igneous fabrics are locally preserved. The original texture is sparsely potassium feldspar porphyritic (<5%, up to 2 cm, pink) in a hypidomorphic matrix of plagioclase, quartz, altered hornblende and biotite. The monzonite is cut by aplite and pegmatitic dikelets that, in turn, are cut by minor brittle faults with apparent dextral

Photo 1a. Deformed basaltic tuff of the Mount Stapler suite. Note preservation of original breccia fragments, now flattened in the foliation. (1b) More intensely deformed, finer grained and less competent mafic ash tuff.

Photo 2. Deformed early Mississippian rhyolite of the Mount Stapler suite. Wavy white streaks are flattened and deformed lapilli.

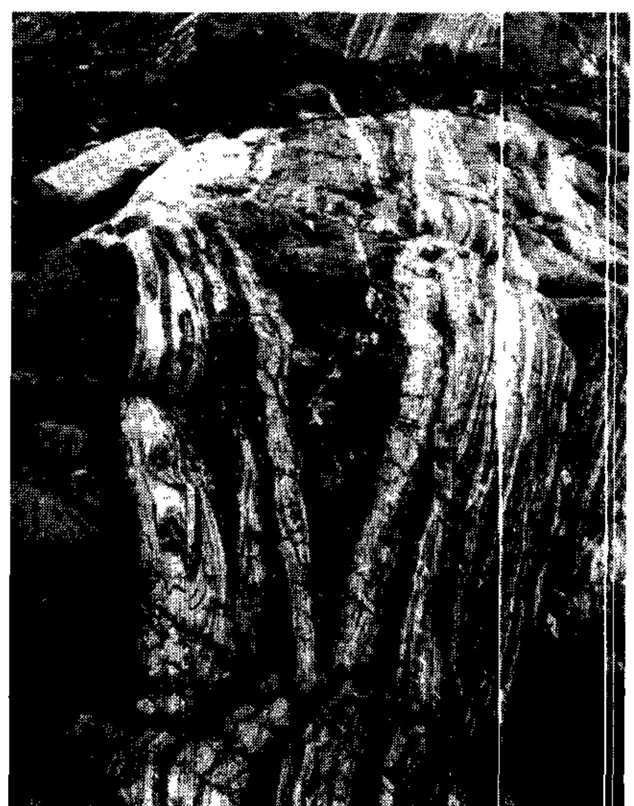

Photo 3. Intensely folded, foliated, rusty carbonate of the Mount Stapler suite.

offset (Photo 4). No clear indication of shear sense is apparent within the ductile fabric; however, rotation of monzonite blocks is consistent with an overall sinistral shear sense (Photo 5). In places, brittle shears offset and isolate segments of monzonite dike (Photo 6).

GEOCHRONOLOGY

A sample was collected for U-Pb geochronology from the largest pink quartz monzonite body, a tabular stock 1.75 kilometres southeast of Mount Stapler (Figure 2). An effort was made to select the freshest, coarsest and most quartz-rich portion of the body. Approximately 40 kilograms, devoid of crosscutting dikelets, was collected. The results are presented below.

ANALYTICAL TECHNIQUES

The sample was processed and zircon was separated using conventional crushing, grinding, Wilfley table and heavy liquid techniques. All fractions were air abraded prior to analysis, to reduce the effects of surface-correlated lead loss (Krogh, 1982).

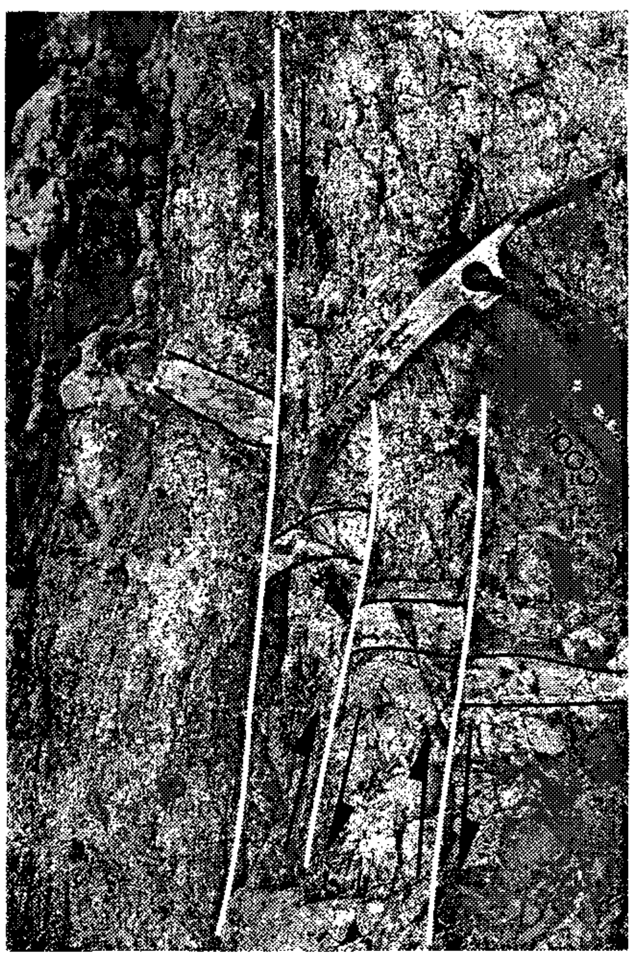

Photo 4. Pink quartz monzonite displays a weak to moderately developed foliation that is cut by late-phase(?) aplite and pegmatitic dikes. Dikes are cut by brittle faults with apparent dextral offset.

Photo 5. An apophysis of light-weathering pink quartz monzonite intrudes coarse basaltic tuff. It has been subjected to cataclasis, but the original eastern (left) contact is preserved (striking 170°, view to the north). Discrete shears offset the eastern contact in a consistently dextral sense, but do not offset the western contact, which is a ductile shear zone within chlorite schist. Counterclockwise rotation of the blocks is consistent with an overall sinistral shear sense.

Photo 6. A light-weathering quartz monzonite dike near the Llewellyn fault zone is dissected by late brittle shears. In this photo, structurally isolated blocks float in matrix of chlorite schist with relict basaltic breccia fragments.

Sample preparation and U-Pb analyses were carried out at the Geochronology Laboratory of the University of British Columbia. Zircon grains were selected based on criteria such as magnetic susceptibility, clarity, morphology and size. Procedures for dissolution of zircon and extraction and purification of uranium and lead follow those of Parrish *et al.* (1987). Uranium and lead were loaded onto single, degassed refined rhenium filaments using the silica gel and phosphoric acid emitter technique. Procedural blanks were 9 and 6 picograms for lead and uranium, respectively. Errors assigned to individual analyses were calculated using the numerical error propagation method of Roddick (1987) and all errors are quoted at the 2σ level. Ages were calculated using the decay constants recommended by Steiger and Jäger (1977). Common lead corrections were made using the two-stage growth model of Stacey and Kramers (1975). Discordia lines were regressed using a modified York-II model (York, 1969; Parrish *et al.*, 1987). Uranium-lead analytical results are presented in Table 1.

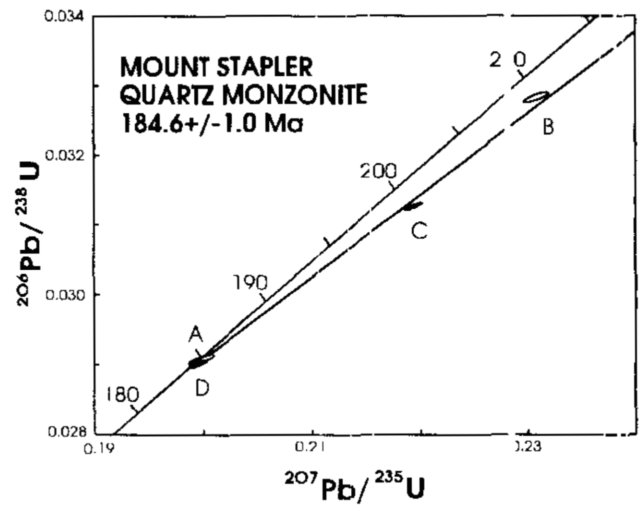

Figure 3. $^{206}Pb/^{238}U$ versus $^{207}Pb/^{238}U$ concordia diagram for the Mount Stapler quartz monzonite.

ANALYTICAL RESULTS

Zircons from this rock were high-quality prisms, with a length:width ratio of ~3:1. The grains had good clarity and contained minor colourless rod and bubble-shaped inclusions. Minimal material was found in the nonmagnetic separate therefore all fractions were picked from the 2°M separate. Initially three multi-grain fractions (A to C) of euhedral prisms, none with visible cores, were picked and separated on the basis of size. These three fractions yield $^{207}Pb/^{206}Pb$ ages which range from 185.2±10.4 to 240.2±7.8 Ma, for one concordant and two discordant analyses (Figure 3; Table 1). These results indicate an Early Jurassic crystallization age and the presence of an older, inherited zircon component, either as "cryptic" cores or xenocrysts. To confirm the age of the concordant fraction A, a fourth fraction was analyzed. Fraction D consisted of a single grain, broken in half and abraded to physically remove material which may have been present as an inherited component in the core of the grain. Fraction D is also concordant and is in good agreement with fraction A. Regression of the four fractions yields a loosely constrained lower Paleozoic upper intercept of 482 $^{+161}/_{-145}$ Ma. This is consistent with the region being underlain by the Paleozoic Stikine assemblage. The best estimate of the age of crystallization of the quartz monzonite is given by the overlapping $^{206}Pb/^{238}U$ ages of fractions A and D, at 184.6 ±1.0 Ma.

CORRELATION AND IMPLICATIONS

Pink quartz monzonite within the Mount Stapler suite shares many lithological characteristics with coeval pink quartz monzonite of the Long Lakes Plutonic Suite in the Yukon (*sensu* Hart, 1994; Mortensen *et al.*, 1994). In southwest Yukon, these upper crustal level plutons intrude strongly foliated mid-crustal level quartz diorite bodies of the Aishihik Plutonic Suite (Hart, 1994; Johnston and Erdmer, in press), but both yield

TABLE 1. U-Pb ZIRCON ANALYTICAL DATA MOUNT STAPLER QUARTZ MONZONITE

Fraction[1]	Wt.	U	Pb[2]	$^{206}Pb^{3}/^{204}Pb$	Pb[4]	$^{208}Pb^{5}$	Isotopic ratios(±1σ,%)[6]			Isotopic dates(Ma, 2σ)[6]		
	mg	ppm	ppm		pg	%	$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$	$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$
A,m,M2,p(13)	0.072	241	7.2	1005	31	8.1	0.02909±0.11	0.1997±0.31	0.04979±0.23	184.8±0.4	184.8±1.0	185.2±10.4
B,f,M2,p(20)	0.072	263	8.7	1881	20	8.9	0.03284±0.12	0.2309±0.25	0.05099±0.17	208.3±0.5	210.9±0.9	240.2±7.8
C,f,M2,p(100)	0.144	508	15.8	4145	34	8.4	0.03126±0.10	0.2193±0.20	0.05088±0.11	198.5±0.4	201.3±0.7	235.3±5.1
D,c,M2,p(1)	0.012	2685	71.4	3562	16	8.6	0.02902±0.11	0.1993±0.23	0.04981±0.14	184.4±0.4	184.5±0.8	186.1±6.6

[1] All fractions are air abraded. Grain size, smallest dimension: c = +134μm, m = -134 μm + 74 μm, f = -74 μm;
Magnetic codes: Franz magnetic separator sideslope at which grains are magnetic; e.g., M2=magnetic at 1°; Field strength for all fractions =1.8A; Front slope for all fractions=20°; Grain character codes: p=prismatic; number in brackets refers to number of grains in analysis.
[2] Radiogenic Pb
[3] Measured ratio corrected for spike and Pb fractionation of 0.0043/amu ±20% (Daly collector)
[4] Total common Pb in analysis based on blank isotopic composition
[5] Radiogenic Pb
[6] Corrected for blank Pb, U and common Pb (Stacey-Kramers model Pb composition at the $^{207}Pb/^{206}Pb$ date of fraction, or age of sample)

crystallization ages that are the same within error. Near the south end of Tagish Lake, hornblende granodiorite orthogneiss is interleaved with metamorphosed volcanic arc rocks of the Boundary Ranges suite (Mihalynuk *et al.*, 1990; Currie, 1990). This unit yielded a U-Pb age of 185±1 Ma (Currie, 1992), similar to the lithologically identical Aishihik batholith ($187^{+9.7}/_{-1.0}$ Ma; Johnston, 1993).

Plutons of identical age and similar composition are also present within the Stikine Terrane to the south, in the Iskut River area. These include 186±1 Ma plagioclase porphyry in the Brucejack Lake area (Davies *et al.*, 1994) and the 185±5 Ma Eskay porphyry (Macdonald *et al.*, 1992).

The Mount Stapler suite is interpreted to be metamorphosed Stikine assemblage. This correlation is supported by similarities between the Stikine assemblage and Mount Stapler lithologies (where relict protolith textures are preserved) and the proportion of similar lithologies within Stikine assemblage in the Tulsequah area. The correlation is further supported by a preliminary early Mississippian U-Pb age from a metarhyolite from Mount Stapler (F. Childe, preliminary data, not presented in this paper). Zircons from this unit have similar morphology and degree of inheritance to zircon from the early Mississippian Stikine assemblage rhyolite that hosts massive sulphide mineralization at the Tulsequah Chief mine (Sherlock *et al.*, 1994).

DISCUSSION

The Early Jurassic U-Pb age of 184.6±1.0 Ma from pink quartz monzonite intruding the Mount Stapler suite is significant as it strengthens correlations between upper units of the northern Stikine Terrane with those in the Yukon-Tanana Terrane to the north. If correlations between the Mount Stapler structural suite and the Stikine assemblage are correct, then many of the metavolcanic rocks to the north may be prospective for volcanogenic massive sulphide accumulations, similar to those at the Tulsequah Chief deposit.

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REFERENCES

Currie, L.D. (1990): Metamorphic Rocks in the Florence Range, Coast Mountains, Northwestern British Columbia (104M/8); *in* Geological Fieldwork 1989, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1990-1, pages 197-203.

Currie, L.D. (1992): Metamorphic Rocks in the Tagish Lake Area, Northern Coast Mountains, British Columbia: A Possible Link Between Stikinia and parts of the Yukon-Tanana Terrane; *in* Current Research, Part A, *Geological Survey of Canada*, Paper 92-1A, pages 199-208.

Davies, A. G. S., Lewis, P. D. and Macdonald, A. J. (1994): Stratigraphic and Structural Setting of Mineral Deposits in the Brucejack Lake Area, Northwestern British Columbia; *Geological Association of Canada*, Program with Abstracts, page A26.

Doherty, R. A. and Hart, C. R. J. (1988): Preliminary Geology of the Fenwick Creek (105D/3) and Alligator Lake (105D/6) Map Areas; *Indian and Northern Affairs Canada*, Open File 1988-2, 87 pages.

Hart, C.J.R. (1994): Magmatic and Tectonic Evolution of the Intermontane Superterrane and Coast Plutonic Complex in Southern Yukon Territory; unpublished M.Sc. thesis, *University of British Columbia*.

Johnston, S.T. (1993): The Geologic Evolution of Nisling Assemblage and Stikine Terrane in the Aishihik Lake Area, Southwest Yukon; unpublished Ph.D. thesis, *University of Alberta*, Edmonton, 270 pages.

Johnston, S.T. and Erdmer, P. (in press): Magmatic Flow and Emplacement Foliations in the Early Jurassic Aishihik Batholith, Southwest Yukon: Implications for Northern Stikinia; *in* Jurassic Magmatism and Tectonics of the North American Cordillera, Miller, D. and Ruby, C., Editors, *Geological Society of America*, Special Paper 299.

Krogh, T. (1982): Improved Accuracy of U-Pb Zircon Ages by the Creation of More Concordant Systems Using Air Abrasion Technique; *Geochemica et Cosmochemica Acta*, Volume 46, pages 637-649.

Macdonald, A. J., van der Heyden, P., Lefebure, D. V. and Alldrick, D. J. (1992): Geochronometry of the Iskut River Area - An Update (104A and B); *in* Geological Fieldwork 1991, Grant, B. and Newell, J. M., Editors, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1992-1, pages 495-502.

Mihalynuk, M.G. and Rouse, J.N. (1988a): Preliminary Geology of the Tutshi Lake Area, Northwestern British Columbia (104M/15); *in* Geological Fieldwork 1987, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1988-1, pages 217-231.

Mihalynuk, M.G. and Rouse, J.N. (1988b): Geology of the Tutshi Lake Area (104M/15); *B.C. Ministry of Energy, Mines and Petroleum Resources*, Open File 1988-5.

Mihalynuk, M.G., Currie, L.D., Mountjoy, K. and Wallace, C. (1989): Geology of the Fantail Lake (West) and Warm Creek (East) Map Area (NTS 104M/9W and 10E); *B.C. Ministry of Energy, Mines and Petroleum Resources*, Open File 1989-13.

Mihalynuk, M.G., Mountjoy, K.J., Currie, L.D., Lofthouse, D.L. and Winder, N. (1990): Geology and Geochemistry of the Edgar Lake and Fantail Lake Map Area, (NTS 104M/8, 9E); *B.C. Ministry of Energy, Mines and Petroleum Resources*, Open File 1990-4.

Mihalynuk, M.G., Smith, M.T. Hancock, K.D. and Dudka, S. (1994a): Regional and Economic Geology of the Tulsequah River and Glacier Areas (104K/12 & 13); *in* Geological Fieldwork 1993, Grant, B. and Newell, J.M., Editors, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1994-1, pages 171-197.

Mihalynuk, M.G., Smith, M.T. Hancock, K.D., Dudka, S. and Payne, J. (1994b): Tulsequah River and Glacier Areas (104K/12 & 13); *B.C. Ministry of Energy, Mines and Petroleum Resources*, Open File 1994-3.

Mihalynuk, M.G., Meldrum, D., Sears, S. and Johannson, G. (1995): Geology and Mineralization of the Stuhini Creek Area (104K/11); *in* Geological Fieldwork 1994, Grant, B. and Newell, J.M., Editors, *B.C. Ministry of Energy,*

Mines and Petroleum Resources, Paper 1995-1, this volume.
Monger, J.W.H. (1977): Upper Paleozoic Rocks of the Western Canadian Cordillera and their Bearing on Cordilleran Evolution; *Canadian Journal of Earth Sciences*, Volume 14, pages 1832-1859.
Mortensen, J.K. (1992): Pre-mid-Mesozoic Evolution of the Yukon-Tanana Terrane, Yukon and Alaska; *Tectonics*, Volume 11, pages 836-854.
Mortensen, J.K., Johnston, S.T., Murphy, D.C. and Bremner, T.J. (1994): Age and Metallogeny of Mesozoic and Tertiary Plutonic Suites in the Yukon; Abstract, *Canadian Institute of Mining, Metallurgy and Petroleum*, 16th District 6 Annual General Meeting, Vancouver.
Nelson , J. and Payne, J. G. (1984): Paleozoic Volcanic Assemblages and Volcanogenic Massive Sulphide Deposits near Tulsequah, British Columbia; *Canadian Journal of Earth Sciences*, Volume 21, pages 379-381.
Parrish, R. R., Roddick, J. C., Loveridge, W. D. and Sullivan, R. W. (1987): Uranium-Lead Analytical Techniques at the Geochronological Laboratory, Geological Survey of Canada; *in* Radiogenic Age and Isotopic Studies, Report 1, *Geological Survey of Canada*, Paper 87-2, pages 3-7.
Roddick, J, C. (1987): Generalized Numerical Error Analysis with Applications to Geochronology and Thermodynamics; *Geochimica et Cosmochimica Acta*, Volume 51, pages 2129-2135.
Sherlock, R., Childe, F., Barrett, T.J., Mortensen, J.K., Chandler, T., Lewis, P., McGuigan, P., Dawson, G.L. and Allen, R. (1994): Geological Investigations of the Tulsequah Chief Massive Sulphide Deposit, Northwestern British Columbia; *in* Geological Fieldwork 1993, Grant, B. and Newell, J.M., Editors, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1994-1, pages 373-379.
Souther, J. G. (1971): Geology and Mineral Deposits of the Tulsequah Map-area, British Columbia; *Geological Survey of Canada*, Memoir 362, 84 pages.
Stacey, S. J. and Kramers, J. D. (1975): Approximation of Terrestrial Lead Isotope Evolution by a Two-stage Model; *Earth and Planetary Science Letters*, Volume 26, pages 207-221.
Steiger, R. H. and Jäger, E. (1977): Subcommission on Geochronology: Convention on the Use of Decay Constants in Geo- and Cosmochronology; *Earth and Planetary Science Letters*, Volume 36, pages 359-362.
York, D. (1969): Least-squares Fitting of a Straight Line with Correlated Errors; *Earth and Planetary Science Letters*, Volume 5, pages 320-324.

NOTES