U-Pb Isotopic Ages of Intrusive Rocks Related to Mineralization North of Terrace, British Columbia

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KEYWORDS: U-Pb zircon isotopic age, intrusive-related gold mineralization, Bowser Lake Group, molybdenum porphyry, copper porphyry

INTRODUCTION

In 2004, the BC Ministry of Energy, Mines and Petroleum Resources and Bootleg Exploration Inc. entered into a partnership agreement aimed at the evaluation of the regional potential for intrusive-related gold mineralization near Terrace, British Columbia. Bootleg Exploration Inc. is a wholly owned subsidiary of Eagle Plains Resources Ltd., and their area of interest is around Kitsum – Kalum Lake, centred approximately 35 km north of Terrace (Fig. 1). Preliminary results from that partnership were published in Mihalynuk and Friedman (2005). Geochronological data that have come available since then are reported here.

Six samples were collected for U-Pb geochronological work from widely separated localities (Fig. 2). Results from analyses of one sample were presented in Mihalynuk and Friedman (2005), four other samples are presented here, and one sample did not yield sufficient material to permit generation of an interpretable dataset. Readers interested in the geological setting of the intrusions and mineral deposits described herein are referred to Downie and Stephens (2003) or Mihalynuk and Friedman (2005).

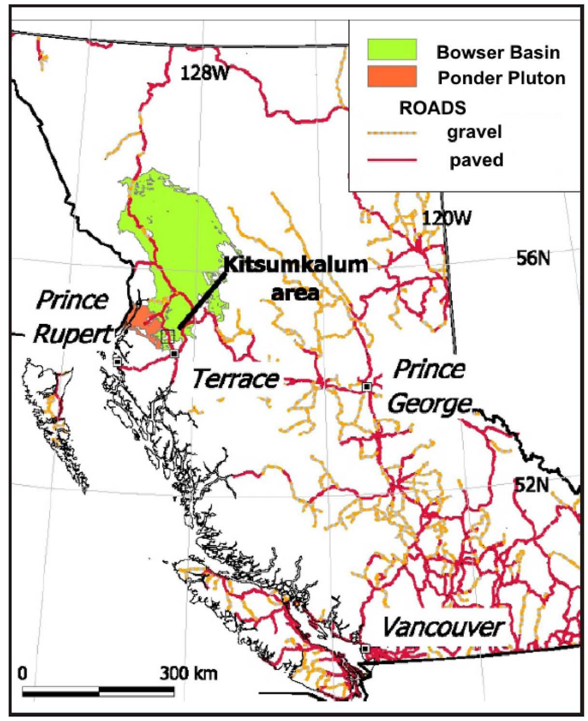

Figure 1. Location of the Kalum project area, approximately 35 km north of Terrace. Geology from Massey *et al.* (2003).

METHODS

Approximately 30 kg of unweathered intrusion was collected from each sample site to determine its crystallization age employing the isotope dilution – thermal ionization mass spectroscopy U-Pb method (ID-TIMS). All work was carried out at the Pacific Centre for Isotopic and Geochemical Research at the Department of Earth and Ocean Sciences, University of British Columbia.

Zircon was separated from rock samples using conventional crushing, grinding and Wilfley table techniques, followed by final concentration using heavy liquids and magnetic separations. Mineral fractions for analysis were selected based on grain morphology, quality, size and magnetic susceptibility. Except where noted, all zircon fractions were abraded prior to dissolution to minimize the effects of post-crystallization Pb-loss, using Krogh's (1982) technique. Samples were dissolved in concentrated hydrofluoric acid (HF) and nitric acid (HNO_3) in the presence of a mixed $^{233\text{-}235}$U-^{205}Pb tracer. Separation and purification of Pb and U employed ion exchange column techniques modified slightly from those described by Parrish *et al*. (1987). Pb and U were eluted separately and loaded together on a single Re filament using a phosphoric acid - silica gel emitter. Isotopic ratios were measured using a modified single collector VG-54R thermal ionization mass spectrometer equipped with a Daly photomultiplier. Measurements were done in peak-switching mode on the Daly detector. U and Pb total procedural blanks were in the range of 1 pg and 3 to 5 pg, respectively, during the course of this study. U fractionation was determined directly on individual runs using the $^{233\text{-}235}$U tracer, and Pb isotopic ratios were corrected for a fractionation of 0.37%/amu for Faraday and Daly runs, respectively, based on replicate analyses of the NBS-981 Pb standard and the values recommended by Thirlwall *et al*. (2000). All analytical errors were numerically propagated through the entire age calculation using the technique of Roddick (1987). Concordia intercept ages and associated errors were calculated using a modified version of the York-II regression model (wherein the York-II errors are multiplied by the mean square of weighted deviates [MSWD]) and the algorithm of Ludwig (1980). All errors

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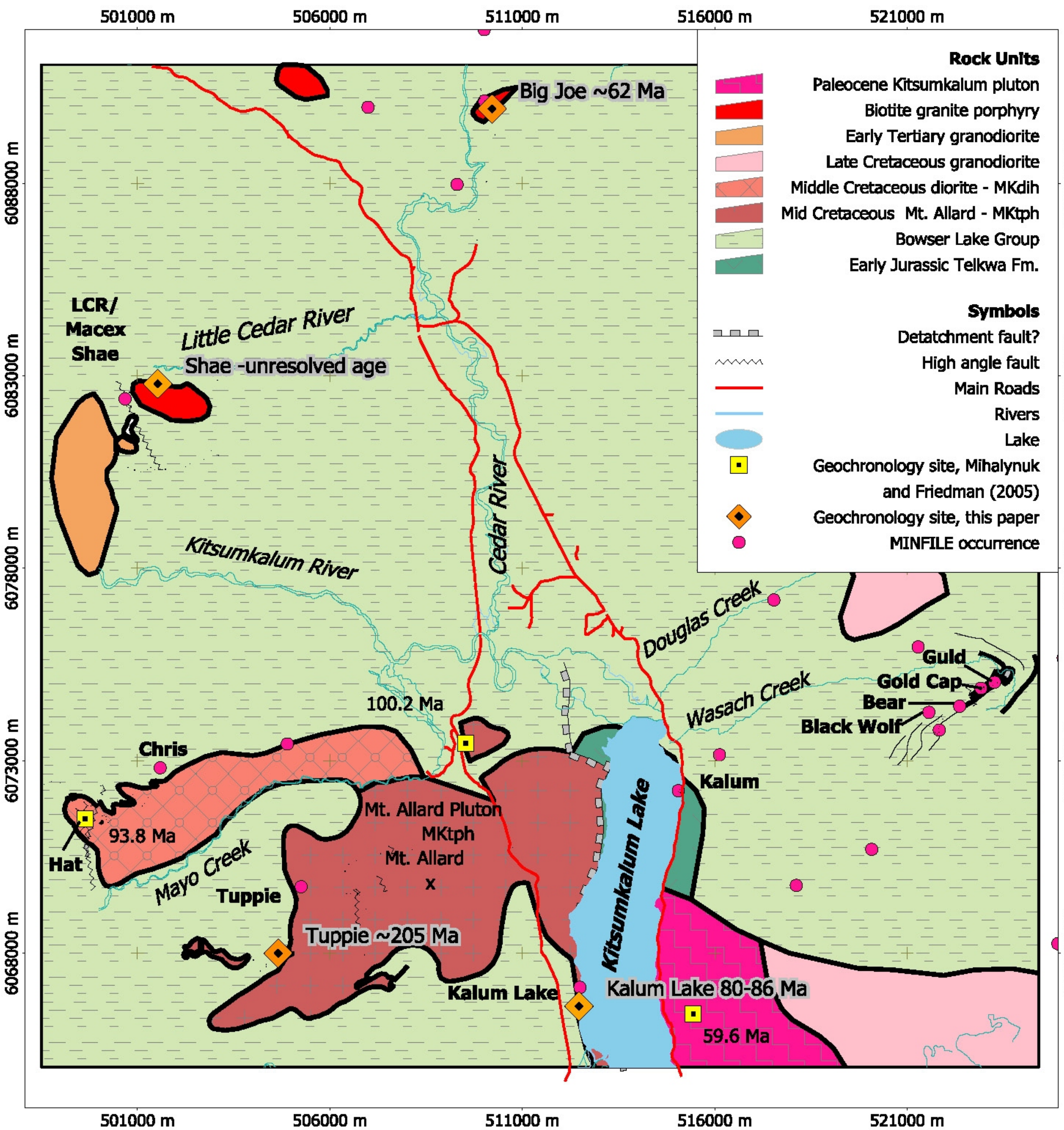

Figure 2. Generalized geology of the Kitsumkalum area. Sources of information: this project, Woodsworth *et al.* (1985), Downie and Stephens (2003) and Massey *et al.* (2003).

are quoted at the two sigma level. Results are plotted on a standard concordia diagram (Fig. 3) and listed in Table 1.

RESULTS OF GEOCHRONOLOGICAL ANALYSES

The locations of samples collected for geochronological study are shown in geological context on Figure 2. Analytical results are enumerated in Table 1, and concordia plots are shown on Figure 3.

Big Joe Biotite Granite

Molybdenite mineralization at the Big Joe occurrence is hosted by a biotite granite stock located within a kilometre of the east bank of the Cedar River, about 5 km upstream of its confluence with the Little Cedar River.

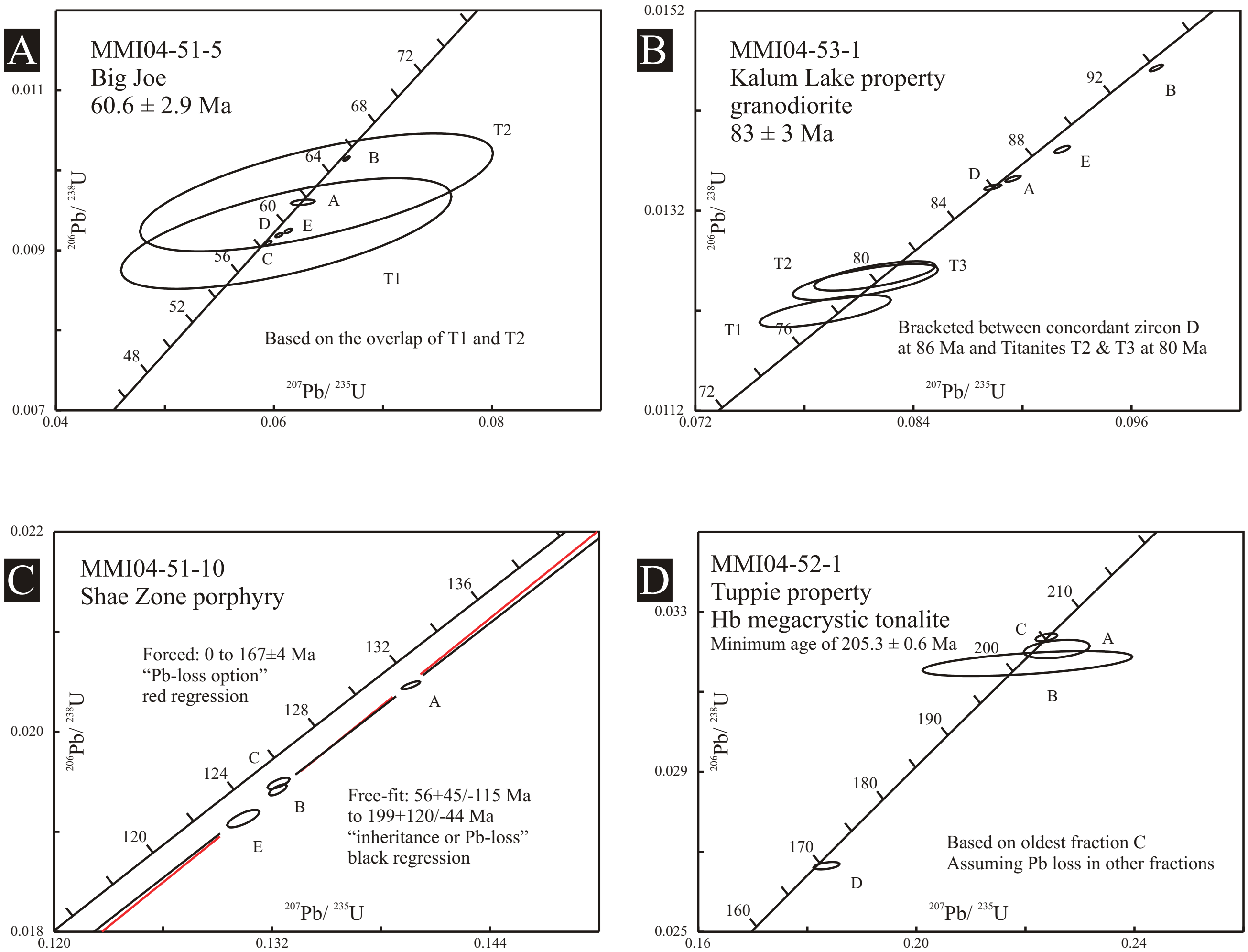

Figure 3. Concordia plots of isotopic data and interpreted ages. Data were obtained from analysis of samples from four intrusive bodies in the Kitsumkalum Lake area. See Figure 2 for locations and Table 1 for analytical data.

Medium-grained biotite granite comprises the poorly defined wedge-shaped intrusion, which has a long dimension of about 1 km. It is extensively affected by moderately intense phyllic alteration that has resulted in bleaching and yellow or rust weathering. Secondary white mica+/-pyrite is ubiquitous (Fig. 4). North-trending, centimetre-thick sheeted quartz veins are common. Some veins attain thicknesses of 35 cm. A west-trending subset of veins is locally well developed. Molybdenite occurs as fine rosettes and vein coatings, but it is not abundant in surface exposures. Fist-sized clots of molybdenite occur sporadically (Fig. 5).

A sample of the pluton was collected to date the molybdenite mineralization, assuming that the molybdenite is syngenetic. Both zircon and titanite were recovered and analyzed from this sample. Zircon results are scattered, reflecting the presence of minor inheritance and Pb loss, although fraction A is concordant at about 62 Ma (Fig. 3A). The overlap of two relatively imprecise titanite analyses at 60.6 ±2.9 Ma, which includes concordant zircon fraction A, provides the best estimate for the age of the rock.

Biotite Granodiorite at Kalum Lake Property

Medium-grained biotite granodiorite at the Kalum Lake property crops out near the east shore of southern Kalum Lake. Exposures show extensive carbonate alteration and weathered rock is orange in colour. The least altered parts of the exposures contain chloritized biotite and accessory magnetite, with average magnetic susceptibility values of 25 (versus 0.3 where altered). Mineralization displayed by excavated parts of the intrusion consists of quartz veins and tabular quartz stockworks, with a minimum 65 cm thickness, that carry pyrite, tetrahedrite and chalcopyrite as the principal sulphides. Mihalynuk and Friedman's (2005) analyses of these veins revealed approximately 1200 to 2300 ppb gold and 112 ppm silver; however,

TABLE 1. U-Pb ID-TIMS ANALYTICAL DATA FOR INTRUSIONS IN THE KITSUMKALUM LAKE AREA.

Fraction[1]	Wt (mg)	U^2 (ppm)	Pb^{*3} (ppm)	$^{206}Pb^4/^{204}Pb$	Pb^5 (pg)	$^{208}Pb^6$	Isotopic ratios (1σ, %)[7] $^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$	Apparent ages (2σ, Ma)[7] $^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$
Big Joe granite MMI04-51-5: 60.6 +/-2.9 Ma												
A, 1	18	276	2.6	870	3	8.7	0.00960 (0.18)	0.0627 (0.87)	0.04733 (0.81)	61.6 (0.2)	61.7 (1.0)	65.8 (38/39)
B, 6	50	760	7.6	4772	5	8.0	0.01015 (0.13)	0.0667 (0.22)	0.04764 (0.15)	65.1 (0.2)	65.5 (0.3)	81.5 (7.1)
C, 5	37	958	8.4	3294	6	6.4	0.00909 (0.16)	0.0595 (0.24)	0.04746 (0.18)	58.4 (0.2)	58.7 (0.3)	72.3 (8.7)
D, 15	49	731	6.6	4739	4	7.7	0.00919 (0.14)	0.0605 (0.28)	0.04771 (0.21)	59.0 (0.2)	59.6 (0.3)	85 (10)
E, 20	37	540	4.8	2576	4	7.0	0.00924 (0.15)	0.0613 (0.28)	0.04812 (0.22)	59.3 (0.2)	60.4 (0.30	105 (10)
T1	343	155	1.5	33	2030	13.3	0.00921 (3.8)	0.0611 (12.4)	0.04813 (10.3)	59.1 (4.4)	60 (15)	106 (425/575)
T2	333	150	1.5	33	2030	14.6	0.00973 (3.8)	0.0639 (12.7)	0.04767 (10.5)	62.4 (4.7)	63 (15)	83 (436/595)
Kalum Lake prospect MMI04-53-1: 83 +/-3 Ma												
A 3	44	503	6.5	2548	7	5.4	0.01352 (0.11)	0.0895 (0.24)	0.04800 (0.16)	86.6 (0.2)	87.0 (0.4)	99.2 (7.6)
B, 7	64	636	8.9	5625	6	5.6	0.01463 (0.11)	0.0974 (0.19)	0.04828 (0.12)	93.6 (0.2)	94.3 (0.3)	112.8 (5.5)
D, 9	28	515	6.6	2616	5	6.0	0.01344 (0.10)	0.0884 (0.26)	0.04770 (0.20)	86.0 (0.2)	86.0 (0.4)	84.4 (9.7)
E, 4	24	815	10.9	4676	4	7.2	0.01381 (0.13)	0.0922 (0.23)	0.04840 (0.16)	88.4 (0.2)	89.5 (0.4)	118.9 (7.5)
T1	400	230	3.7	105	795	30.8	0.01220 (0.66)	0.0791 (2.3)	0.04707 (1.9)	78.1 (1.0)	77.3 (3.4)	52.7 (88/93)
T2	434	261	4.3	96	1110	31.4	0.01249 (0.72)	0.0813 (2.5)	0.04725 (2.0)	80.0 (1.2)	79.4 (3.8)	61.8 (94/100)
T3	396	252	4.3	115	793	33.6	0.01255 (0.59)	0.0819 (2.0)	0.04732 (1.7)	80.4 (0.9)	79.9 (3.1)	66 (79/83)
Shae Zone porphyry MMI04-51-10: minimum age of 167 +/–4 Ma												
A, 2	54	374	7.5	7696	3	7.8	0.02047 (0.10)	0.1396 (0.19)	0.04948 (0.12)	130.6 (0.3)	132.7 (0.5)	170.8 (5.6)
B, 3	69	475	8.9	7125	5	6.0	0.01942 (0.14)	0.1323 (0.19)	0.04942 (0.13)	124.0 (0.4)	126.2 (0.4)	167.6 (6.1)
C, 7	41	655	12.1	2552	13	4.7	0.01949 (0.14)	0.1324 (0.23)	0.04926 (0.16)	124.4 (0.4)	126.2 (0.6)	160.4 (7.5)
E, 7	31	510	9.2	2317	8	4.6	0.01913 (0.23)	0.1304 (0.34)	0.04801 (1.5)	122.2 (0.6)	124.5 (0.8)	169 (11)
Tuppie MMI04-52-1: minimum age of 205.3 +/-0.6 Ma												
A, 2	18	82	2.7	1321	2	12.7	0.03207 (0.36)	0.2257 (1.3)	0.05105 (1.3)	203.5 (1.4)	206.7 (5.0)	243 (58/60)
B, 9	14	35	1.1	120	9	12.4	0.03171 (0.49)	0.2204 (4.4)	0.05041 (4.1)	201.2 (2.00	202 (16)	214 (181/203)
C, 9	27	141	4.5	1242	6	8.2	0.03236 (0.15)	0.2239 (0.45)	0.05017 (0.39)	205.3 (0.6)	205.1 (1.7)	203 (18)
D, 12	16	140	3.8	962	4	11.8	0.02665 (0.6)	0.1835 (0.65)	0.04994 (0.60)	169.7 (0.6)	171.1 (2.1)	192 (27/28)

[1] Upper case letter is zircon fraction identifier, followed by the number of grains; titanite: T1, T2, etc. All zircon fractions were air abraded.

[2] U blank correction of 1 pg +/-20%; U fractionation corrections were measured for each run with a double ^{233}U-^{235}U spike (about 0.004/amu).

[3] Radiogenic Pb.

[4] Measured ratio corrected for spike and Pb fractionation of 0.0037/amu +/-20% (Daly collector), which was determined by repeated analysis of NBS Pb 981 standard throughout the course of this study.

[5] Total common Pb in analysis based on blank isotopic composition.

[6] Radiogenic Pb.

[7] Blank Pb was 3 to 5 pg throughout the course of this study; U <1 pg; common Pb composition for corrections based on Stacey and Kramers (1975) model Pb at the age of the rock or the $^{207}Pb/^{206}Pb$ age of the rock.

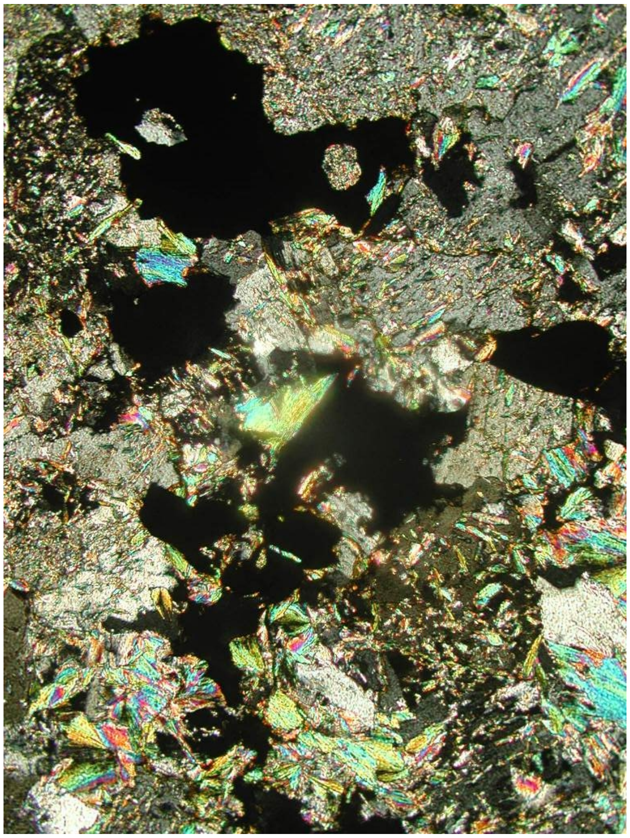

Figure 4. Photomicrograph of typical alteration assemblage in granite stock hosting molybdenite mineralization at the Big Joe. The long dimension of the photo represents approximately 4 mm and the photo was taken using cross-polarized light. Brightly coloured (high birefringence) mineral grains are white mica; opaques are mainly pyrite and minor molybdenite.

Figure 5. Blue-grey molybdenite occurs in irregular clots up to fist size at the Big Joe occurrence. Highly reflective mineral grains are pyrite and white mica.

spectacular assays were reported by Cavey and Howe (1984), 251 g/t gold and 226 g/t silver.

A sample of the least altered, intact intrusion was collected for determination of a magmatic crystallization that would provide a maximum age limit on the mineralization. This sample yielded abundant zircon and titanite. Of four analyzed multigrain zircon fractions, three are discordant due to the presence of minor inheritance (Fig. 3B; Table 1). The youngest fraction (D) is concordant and thus appears to be free of inheritance or may contain a trace of slightly older (Cretaceous) inheritance. Results for the three analyzed multigrain titanite fractions plot between 77 to 81 Ma. The two nearly identical older results (T2 and T3) represent the minimum age for the rock.

Shae Quartz-Biotite Porphyry

Quartz-biotite porphyry is exposed at low elevations in the Little Cedar River valley (Fig. 2). Porphyry-style copper-molybdenum mineralization is locally developed, and in several places the immediately adjacent country rocks are replaced by pyrrhotite, pyrite and chalcopyrite. Chilled phases are quartz-eye porphyry with quartz up to 8 mm in diameter, comprising up to 5% of the rock. Oxidation of finely disseminated pyrite produces rusty outcrops, which may be cut by sheeted or stockwork quartz veins (Fig. 6). Mihalynuk and Friedman (2005) interpreted this intrusion as coeval with pyritic quartz-biotite-feldspar porphyry dikes that intrude parallel to fold hinges in the Bowser Lake Group strata on the ridge to the south. If correct, the dikes post-date folding in the Bowser Lake Group strata.

Four multigrain zircon fractions were analyzed. All are discordant with early Cretaceous Pb-U dates; they define a quasi-linear array nearly parallel to this segment of the concordia curve. Both free-fit (black) and forced 0 Ma (red) regression lines are plotted on Figure 3C and the intercepts are listed in Table 1. The forced 0 Ma option implies Pb-loss, no inheritance and a Jurassic magmatic minimum age (167 ±4 Ma). The free-fit regression allows for either Pb-loss or inheritance interpretations. The former yields an Early Mesozoic to Late Palaeozoic age and the latter a Cenozoic to Cretaceous age with Jurassic to Palaeozoic inheritance. This sample requires more U-Pb work. Ar-Ar dating currently in progress may also provide verification of one of the interpretations.

Hornblende Megacrystic Tonalite

Dikes and sills of hornblende tonalite cut and thermally metamorphose siltstone and argillite at the Tuppie property (Downie and Stephens, 2003), about 7 km west of Kitsumkalum Lake (approximately 4 km southwest of Mount Allard). Contacts of these sills are commonly foliated, and some of the foliated zones are carbonate altered (Fig. 7), locally with quartz veining and base metal sulphide mineralization. One of the thickest sills, with a

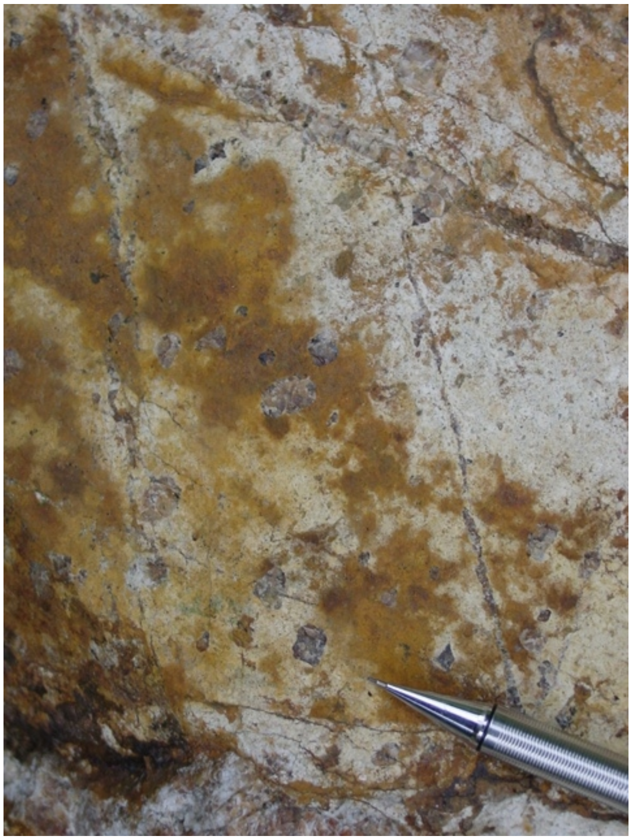

Figure 6. Quartz veining in altered biotite-quartz porphyry at the Shae occurrence. Coarse quartz eyes are well developed in chilled phases, as shown here.

Figure 7. Relatively fine-grained border of hornblende megacrystic tonalite at the Tuppie occurrence showing foliated and carbonate-altered equivalent.

foliated lower margin (270/22), was sampled for geochronological age determination. A date would place a maximum age constraint on this mineralization.

A conspicuous feature of these dikes and sills is a high proportion (~25%) of euhedral hornblende phenocrysts up to 5 cm long. Microscopic examination of these phenocrysts shows that they enclose biotite grains that may display a well-developed alignment (Fig. 8) and comprise up to a third of the phenocrysts. Whether or not this high biotite content is typical of the megacrystic tonalite is uncertain. If so, this helps to distinguish it from the tonalitic Mount Allard pluton, which also contains a high proportion of euhedral hornblende phenocrysts, but the Mount Allard phenocrysts contain abundant inclusions of quartz and feldspar as opposed to biotite.

Only a very small quantity of zircon could be extracted from the Tuppie sample, which was subdivided into four multigrain fractions on the basis of grain size. Fractions A and B consisted of euhedral prisms that were abraded prior to dissolution, while C and D were unabraded blocky anhedral to subhedral grains (Fig. 3D; Table 1). Results for the three coarser fractions overlap concordia between about 199 and 206 Ma. The finest unabraded grains comprise fraction D, which give significantly younger and discordant results suggesting strong Pb loss. If the dispersion of data can be attributed entirely to Pb loss, fraction C with Pb-U dates of about 205 Ma provides a minimum age for the rock.

Figure 8. Photomicrograph of an approximately 3.5 mm long hornblende phenocryst displaying a typical poikilitic enclosure of biotite.

If the Pb-loss interpretation is correct, the latest Triassic age determination leads to a geological impossibility. Regional mapping (Duffell and Souther, 1964; Woodsworth *et al*., 1985; Downie and Stephens, 2003) indicates that the sedimentary strata around the Tuppie are part of the Upper Jurassic Bowser Lake Group, the oldest parts of which are about 166 Ma (Evenchick and McNicoll, 2002). One possible explanation for this inconsistency is that the dated fractions are zircon xenocrysts. Until this problem can be resolved, the possibility of Late Triassic strata should be acknowledged because of the significant implications for mineral exploration. In particular, the limits of stratigraphy which bracket the age of the mineralized horizon at Eskay Creek, interpreted as a shallow submarine hydrothermal deposit (Alldrick, 1995), could be extended to the Kitsumkalum Lake area.

SUMMARY

Four new U-Pb age determinations are available for intrusive rocks in the Kitsumkalum area. Interpreted best ages for magmatic crystallization and constraint on the age of associated mineralization, from youngest to oldest, are

1) 60 ±2.9 Ma; Big Joe granite and ?syngenetic molybdenum mineralization;
2) 83 ±3 Ma; Kalum Lake granodiorite, which predates the mineralized quartz veins that cut it;
3) a tenuous and highly interpretive, low reliability minimum age of 167 ±4 Ma is suggested for the Shae biotite-quartz porphyry and disseminated plus replacement copper+/-molybdenum mineralization;
4) a provisional minimum age of 205.3 ±0.6 Ma is suggested for the hornblende megacrystic tonalite on the Tuppie property, which predates mineralized quartz veins that cut its foliated margin.

None of the samples analyzed yielded a straightforward geochronological dataset. All are subject to interpretation and more analytical work is needed to confirm the best ages suggested. Both of the older samples are particularly speculative. Nevertheless, the suggestion of Late Triassic to Middle Jurassic magmatic ages provided by these samples is important because it allows for the possibility of stratigraphy that is age equivalent to strata hosting the rich Eskay Creek deposit.

ACKNOWLEDGMENTS

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