U-Pb and K-Ar Isotopic Dates from the Beece Creek – Tatlayoko Lake Area (NTS 92N/9, 92O/5, 6), Southwestern British Columbia

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INTRODUCTION

The geology of the eastern Coast Belt in parts of the Mount Waddington (92N) and Taseko Lakes (92O) map areas was updated during the Tatlayoko bedrock mapping project, carried out by the British Columbia Geological Survey Branch in the early to mid-1990s. The results of this program are summarized in a geological report by Schiarizza and Riddell (1997) and a 1:100 000-scale geoscience map by Schiarizza *et al*. (2002). The geological mapping was supported by isotopic dating carried out at the University of British Columbia. In this paper we present previously unpublished data and age interpretations on four samples that were collected during fieldwork associated with the Tatlayoko project.

GEOLOGICAL SETTING

The geology of the central part of the Tatlayoko project area, simplified from Schiarizza *et al*. (2002), is shown in Figure 1. The area encompasses the boundary between the Coast and Intermontane morphogeological belts, which corresponds approximately with the trace of the Yalakom fault, a major linear feature that extends for about 300 km and was the locus of more than 100 km of Late Cretaceous (?) to early Tertiary dextral strike-slip displacement (Umhoefer and Schiarizza, 1996). The oldest rocks in the map area are assigned to three separate terranes: Cadwallader-Methow, Bridge River and Stikine. Younger rocks comprise the Jura-Cretaceous Tyaughton-Methow basin and overlying Upper Cretaceous subaerial volcanic rocks of the Powell Creek formation. Late Cretaceous and Eocene intrusive rocks are common in the Beece Creek and Fish Lake areas.

The Cadwallader-Methow Terrane comprises Middle Triassic to Middle Jurassic arc-related volcanic, plutonic and sedimentary rocks that are exposed southwest of the Yalakom fault in a belt that extends from west of Tatlayoko Lake southeastward to the Nemaia valley. These rocks are stratigraphically overlain by sedimentary rocks of the Tyaughton-Methow basin, including the Jura-Cretaceous Relay Mountain Group and the mid-Cretaceous Jackass Mountain Group. This belt is truncated south of the Nemaia valley by the Taseko fault. The bedrock geology south of the Taseko fault is dominated by exposures of mid-Cretaceous sedimentary rocks of the Taylor Creek Group (equivalent in age but lithologically distinct from the Jackass Mountain Group) and overlying Upper Cretaceous volcanic rocks of the Powell Creek formation. The basement to these exposures is inferred to be the oceanic Bridge River Terrane (Schiarizza *et al*., 1997), a Mesozoic accretion-subduction complex that is locally represented by a thin belt of chert and greenstone along the south side of the Taseko fault.

Outcrop is poor, and geological relationships are consequently less well understood, in the area of subdued topography northeast of the Yalakom fault. Pre-Neogene strata along the Chilko River comprise volcanic and volcaniclastic rocks that have been correlated with the Lower to Middle Jurassic Hazelton Group of the Stikine Terrane (Tipper, 1969a,b). To the southeast, in the Chaunigan Lake – Fish Lake area, pre-Neogene bedrock consists of mainly Lower Cretaceous sedimentary and volcanic rocks that are correlated with the upper part of the Relay Mountain Group and the overlying Jackass Mountain Group (Schiarizza *et al*., 2002).

GEOCHRONOLOGY

Conventional isotope-dilution thermal-ionization mass spectrometry (ID-TIMS) U-Pb data are reported and interpreted for zircons from three rock samples from the Anvil Mountain and Fish Lake areas, and K-Ar data are reported from a single sample collected near Tatlayoko Lake. All sample preparation and analyses were carried out at the Department of Earth and Ocean Sciences, University of British Columbia. Sample preparation and U-Pb analytical techniques are given in Friedman *et al*. (2001). The U-Pb data are listed in Table 1 and plotted on concordia diagrams in Figure 2. The K-Ar data are listed in Table 2.

Fish Lake Dacite

Sedimentary and volcanic rocks that crop out along and near the lower reaches of the creek that drains Fish Lake include pebbly sandstone and pebble conglomerate containing volcanic and granitoid clasts, tuffaceous sand-

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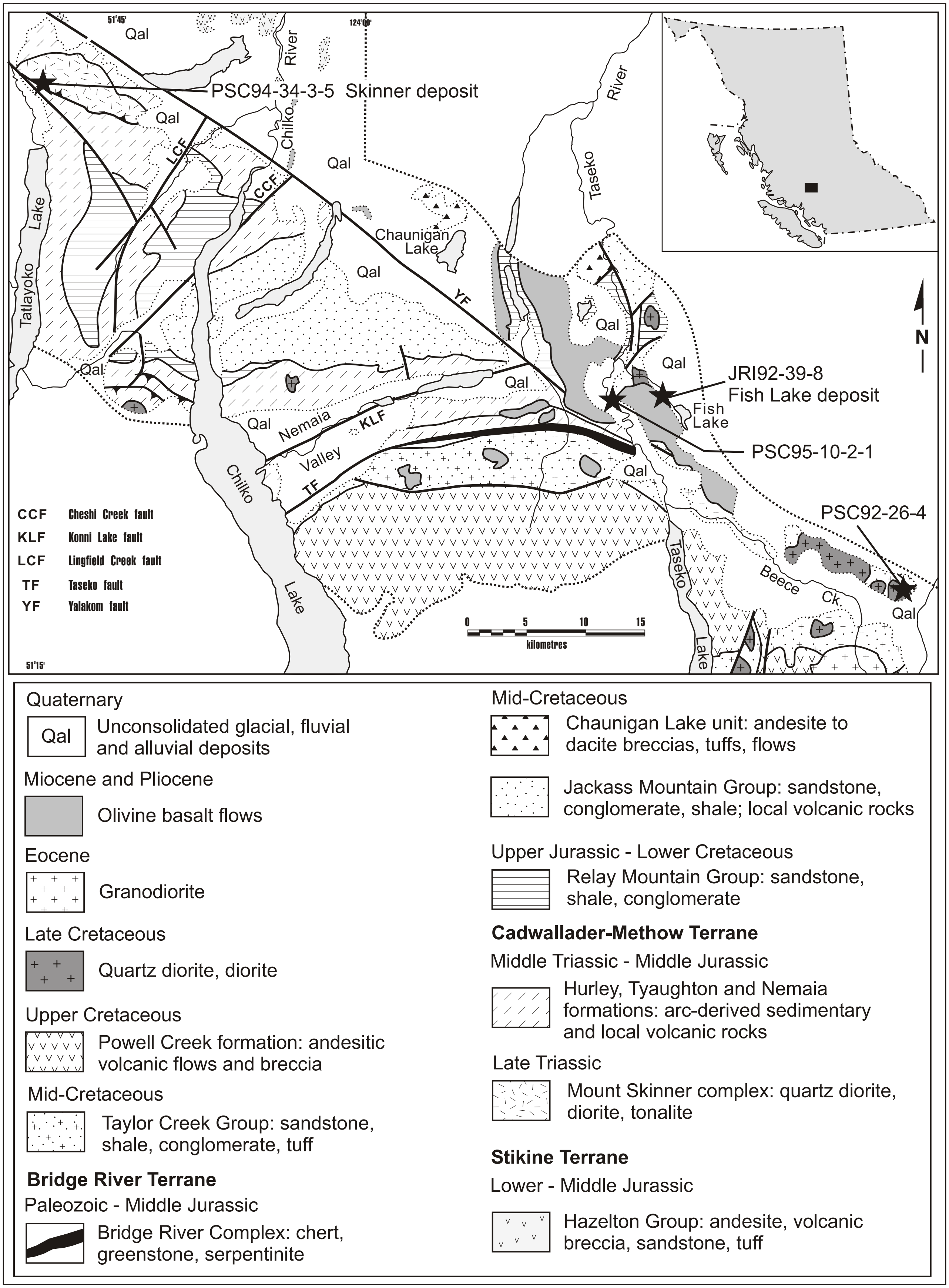

Figure 1. Simplified geological map of the Beece Creek – Tatlayoko Lake area, showing locations of samples discussed in this report.

TABLE 1. URANIUM-LEAD ANALYTICAL DATA.

Fraction[1]	Wt	U^2	Pb^{*3}	$^{206}Pb^4$	Pb^5	$^{208}Pb^6$	Isotopic ratios (1 ,%) [7]			Apparent ages (2 ,Ma) [7]		
	(mg)	(ppm)	(ppm)	^{204}Pb	(pg)		$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$	$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$
PSC95-10-2-1 Fish Lake dacite: 100.5 +7.2/-0.6 Ma; weighted $^{207}Pb/^{206}Pb$ and one concordant analysis												
A	0.080	230	3.7	1185	15	11.4	0.01571 (0.10)	0.1040 (0.34)	0.04803 (0.27)	100.5 (0.2)	100.5 (0.6)	101 (13)
B	0.113	336	5.1	2465	23	12.8	0.01451 (0.17)	0.09608 (0.29)	0.04802 (0.22)	92.9 (0.3)	93.2 (0.5)	100 (11)
C	0.069	441	6.1	1052	24	14.1	0.013169 (0.18)	0.0872 (0.43)	0.04803 (0.37)	84.3 (0.3)	84.9 (0.7)	101 (17/18)
PSC92-26-4 Anvil Mountain pluton: ca. 93 Ma; one concordant analysis												
A	0.161	105	1.4	448	35	6.7	0.01432 (0.18)	0.0955 (0.69)	0.04839 (0.61)	91.6 (0.3)	92.6 (1.2)	119 (29)
B	0.156	106	1.5	1101	14	7.1	0.01460 (.06)	0.0964 (0.24)	0.04789 (0.22)	93.4 (0.1)	93.4 (0.4)	94 (11)
JRI92-39-8: Fish Lake quartz diorite: 91.5 +1.1/-5.6 Ma; lower intercept age												
A	0.779	265	3.9	2214	85	9.8	0.01460 (0.11)	0.0974 (0.18)	0.04837 (0.11)	93.5 (0.2)	94.4 (0.3)	117 (5)
G	0.043	285	4.1	1003	11	10.8	0.01571 (0.09)	0.0954 (0.35)	0.04803 (0.31)	92.2 (0.2)	92.5 (0.6)	101 (15)
H	0.046	286	4.1	1103	11	10.8	0.01571 (0.12)	0.0969 (0.32)	0.04796 (0.24)	93.8 (0.2)	93.9 (0.5)	97 (11)

[1] Upper case letter = zircon fraction identifier. All zircon fractions were air abraded to remove grain facets; PSC95-10-2-1: zircon nonmagnetic at 20 degrees sideslope and 1.8 amperes field strength on Franz™ magnetic separator; (front slope 15 degrees for all samples). Fraction A +134 m, B -134+74 m, C-74 m. PSC92-26-4: zircon nonmagnetic at ~2 degrees sideslope and 1.8 amperes field strength on Franz™ magnetic separator; All grains >134 m picked and strongly abraded. JRI92-39-8: zircon nonmagnetic at 1 degree sideslope and 2.0 amperes field strength on Franz™ magnetic separator; >134 m, H comprises tips broken off of these grains.

[2] U blank correction of 1pg ± 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 0.0043/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] Corrected for blank Pb (1-4 pg, throughout the course of this study), U (1 pg) and common Pb concentrations based on Stacey Kramers (1975) model Pb at the age of the rock or the $^{207}Pb/^{206}Pb$ age of the rock.

stone, hornblende-feldspar–phyric andesite, and dacite containing quartz and feldspar phenocrysts. These rocks may correlate with the volcanic and sedimentary package (observed only in drillcore) that hosts the Fish Lake porphyry copper-gold deposit a few kilometres to the east. They were assigned to the informal Fish Creek succession (unit lKsv) by Schiarizza and Riddell (1997), but Schiarizza *et al*. (2002) separated them into a lower shale-sandstone unit, assigned to the lower Cretaceous Relay Mountain Group, and an upper unit of sandstone, conglomerate and volcanic rocks that was included in a volcanic-bearing facies of the mid-Cretaceous Jackass Mountain Group. Columnar-jointed quartz-feldspar–phyric dacite that crops out along the Taseko Lakes road is part of the sedimentary-volcanic succession that is included in the Jackass Mountain Group. Sample PSC95-10-2-1 was collected from this dacite exposure to determine the age of the volcanic rocks in this succession.

Sample PSC95-10-2-1 yielded a modest quantity of good-quality, clear, pale pink, stubby prismatic and equant multifaceted zircon grains. Zircons with diameters of about 150 to 60 m were selected and air abraded to remove all facets. The grains were then subdivided into three fractions on the basis of size. Results for these three fractions, plotted in Figure 2, define a linear array, with the coarsest grains concordant at ca. 100 Ma and finer grains discordant with younger Pb/U and Pb/Pb dates. This array is interpreted to result from Pb loss with no evidence of older inherited zircon. An interpreted age of 100.5 +7.2/-0.6 Ma is based on the weighted mean of $^{207}Pb/^{206}Pb$ dates for the three fractions; the $^{206}Pb/^{238}U$ date for concordant fraction A provides a minimum age for the sample.

The sedimentary-volcanic succession along Fish Creek is assigned to the Jackass Mountain Group on the basis of characteristic rock types, including granitoid-bearing conglomerates and pebbly sandstones. The occurrence of volcanic rocks is unusual for the Jackass Mountain Group, but the mid-Cretaceous age obtained from the dacite sample supports the inclusion of these volcanic rocks in the group. Volcanic rocks exposed to the north and northwest, assigned to the Chaunigan Lake unit by Schiarizza and Riddell (1997) and Schiarizza *et al*. (2002), may be correlative, although these rocks are assigned to the age-equivalent Spences Bridge Group by Hickson and Higman (1993).

Anvil Mountain Pluton

Hornblende diorite, quartz diorite and hornblende-feldspar porphyry occur as stocks, plugs and dikes that are common within the Taylor Creek Group east of Taseko Lake (Fig. 1). These intrusive rocks are associated with porphyry copper-molybdenum mineralization at the Chita showing (MINFILE 092O 049) east of Taseko Lake, and with epithermal-style mineralization at the Knight showing (MINFILE 092O 002) near the headwaters of Nadila Creek (Schiarizza *et al*., 2002). The largest pluton in this area comprises diorite to quartz diorite that underlies the Anvil Mountain ridge system, northeast of Beece Creek. Sample

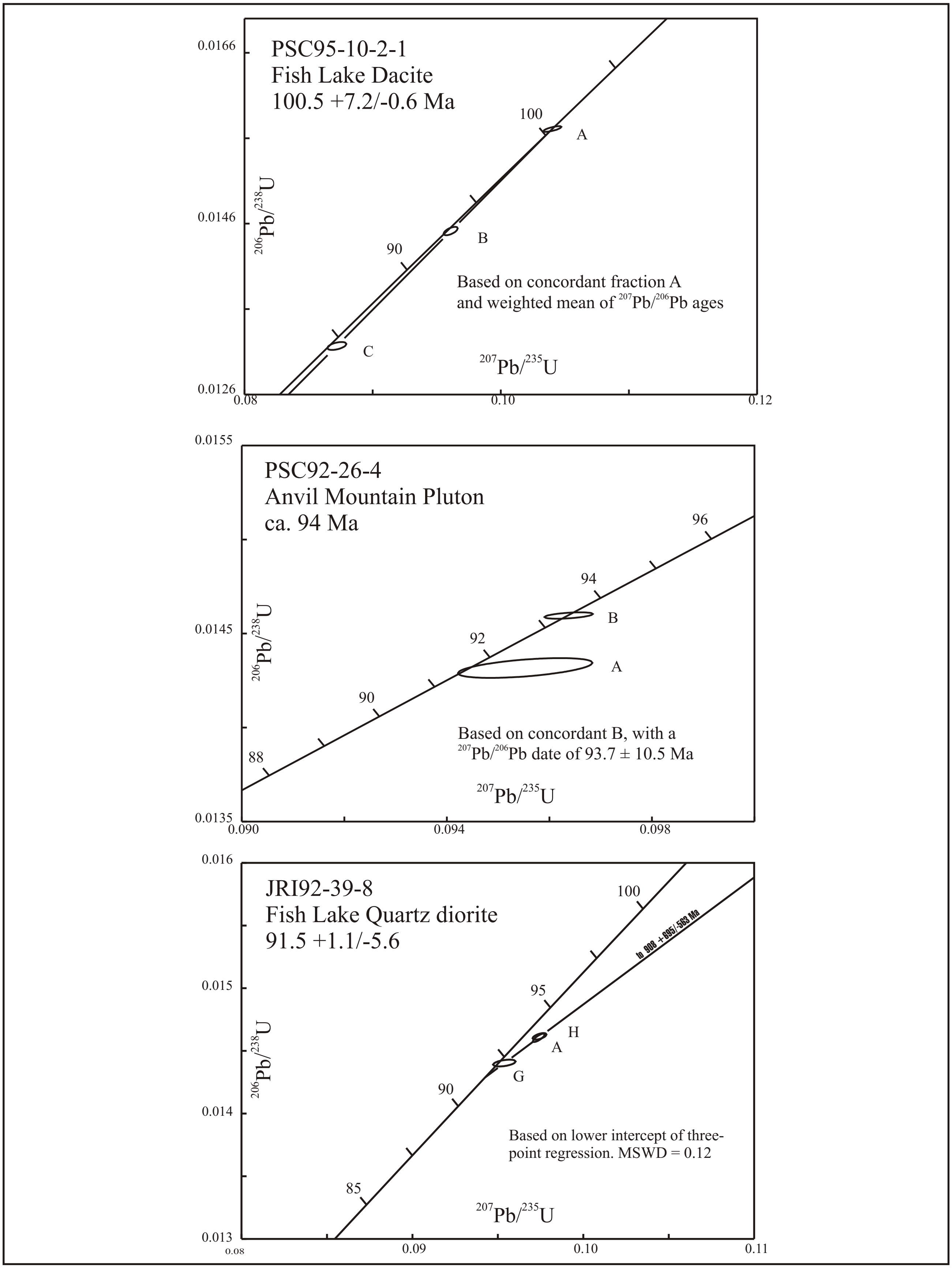

Figure 2. Concordia plots with results displayed at the 2 level of uncertainty.

PSC92-26-4, comprising hornblende quartz diorite, was collected from the eastern part of this ridge system in order to determine the crystallization age of this pluton.

Clear, colourless, equant rounded to stubby prismatic multifaceted zircons were recovered from sample PSC92-26-4. The modest amount of material present was only sufficient for two fractions. An age of ca. 94 Ma is suggested on the basis of concordant fraction B, with a $^{206}Pb/^{238}U$ date of 93.4 ± 0.1 Ma. Fraction A is discordant, just below the concordia curve at ca. 92 Ma, due to Pb loss and/or the presence of minor inherited zircon. It is difficult to suggest an age with associated precision on the basis of one concordant result. However, a conservative estimate would be 93.7 ± 10.5 Ma, based on the $^{207}Pb/^{206}Pb$ date for concordant fraction B.

The date obtained from the Anvil Mountain pluton compares closely with an Ar-Ar date of 92 ± 1.3 Ma obtained from volcanic rocks near the base of the Powell Creek formation by J.A. Maxson (reported in Wynne *et al*., 1995) in the Mount Tatlow area. It suggests that the intrusive rocks cutting the Taylor Creek Group in this area may be comagmatic with the overlying Powell Creek formation.

Fish Lake Quartz Diorite

The Fish Lake porphyry copper-gold deposit is located in an area of virtually no bedrock exposure about 5 km east of the Taseko River (Fig. 1). Based on 143 945 m of drilling in 326 holes, Independent Mining Consultants calculated a mineable reserve of 633 million tonnes at an average grade of 0.253% Cu, 0.466 g/t Au and 0.5 g/t Ag (Taseko Mines Limited, press release, March 16, 1998). The deposit is described by Wolfhard (1976) and Caira *et al*. (1995). According to Caira *et al*., the Fish Lake deposit is spatially and genetically related to a steeply dipping lenticular body of porphyritic quartz diorite that is surrounded by an east-west elongate complex of steep, southerly-dipping, subparallel quartz-feldspar porphyry dikes. These rocks, referred to as the Fish Lake Intrusive Complex, cut volcanic and volcaniclastic rocks, as well as an older intrusive body of porphyritic diorite that may be coeval with the volcanics. Mineralization occurs within both the intrusive complex and adjacent volcanic, volcaniclastic and plutonic country rocks. Core sample JRI92-39-8, of hornblende-quartz-feldspar porphyry from the Fish Lake Intrusive Complex, was collected in order to determine a crystallization age for the synmineralization intrusions.

Zircons recovered from sample JRI92-39-8 are primarily clear, colourless, euhedral prisms with length-width ratios of ~2.5–3.5. Results for three analyzed fractions are discordant to marginally concordant and define a linear array. Although cores were not observed during grain selection, all fractions are interpreted to contain minor inheritance, even fraction H, which comprised tips broken from more elongate prisms. The interpreted age of 91.5 +1.1/-5.6 Ma is based on the lower intercept of a three-point regression (MSWD = 0.12). A very poorly constrained upper intercept of 908 +695/-563 Ma provides an estimate for the average age of inheritance in analyzed grains.

The 91.5 +1.1/-5.6 Ma date presented here for the Fish Lake Intrusive Complex is about 10 million years older than the preliminary 80 Ma estimate from the same sample presented by Schiarizza and Riddell (1997). It is also older than a previous whole-rock K-Ar date of 77.2 ± 2.8 Ma obtained from a hornfels containing 40% secondary biotite, which was interpreted as the date of mineralization (Wolfhard, 1976). It is very similar to the date obtained from the compositionally similar Anvil Mountain pluton, suggesting that the two intrusive suites are related.

Skinner Gold-Quartz Vein

The Skinner mineral occurrence (MINFILE 092N 039), located 5 km north of the north end of Tatlayoko Lake (Fig. 1), comprises a system of gold-bearing quartz veins within Late Triassic quartz diorite and diorite of the Mount Skinner Igneous Complex. Individual veins are arranged en echelon within a structurally controlled lineament that trends 070 (Berniolles, 1991). Development has focused on the Victoria vein, at the southwest end of the system, which has been traced for more than 130 m and ranges up to 1.4 m thick. It strikes between 050 and 060 and dips steeply to the northwest. The vein walls are defined by slickensided faults, and the veins themselves are cut by parallel faults, at least some of which accommodated sinistral movement. The vein consists almost entirely of quartz, with minor amounts of pyrite, chalcopyrite, malachite and rare visible gold. Gold values are variable, and concentrations as high as 136 g/t across 0.65 m have been recorded (Berniolles, 1991). A 172 t bulk sample extracted from the vein by Ottarasko Mines Limited in 1992 and 1993 produced 11 351 g of gold (Northern Miner, June 6, 1994).

White mica locally lines vugs and open fractures in quartz of the Victoria vein. Sample PSC94-34-3-5, of muscovite-bearing vein material, was collected for K-Ar dating of the mica. The mica separate yielded an Early Eocene date of 51.9 ± 2.6 Ma (Table 2). This provides a minimum age for the vein and most likely dates the late stages of the hydrothermal system responsible for the veining. If this interpretation is correct, then the veining was probably coincident with dextral movement along the Yalakom fault, which is just 5 km northeast of the Skinner occurrence (Fig. 1). This suggests that the Skinner vein system formed along an antithetic sinistral fault system related to dextral movement along the Yalakom fault. The Lingfield Creek and Cheshi Creek faults to the southeast may have had a

TABLE 2. K-AR ANALYTICAL DATA.

Sample	Size fraction (mesh)	K (%)	^{40}Ar rad (mole/g x 10^{-10})	^{40}Ar rad (% of total)	Age (Ma; 2 error)
PSC94-34-3-5					
Muscovite	-40+80	7.98	16.3	72.4	51.9 ± 2.6

Notes: Samples analysed in the Geochronology Laboratory, Department of Earth and Ocean Sciences, U.B.C., by Janet Gabites (potassium) and Joe Harakal (argon).
Decay constants l_e=0l581 x 10^{-10} yr^{-1}, l_b = 4.962 x 10^{-10} yr^{-1},
$^{40}K/K$ = 1.167 x 10^{-4} mole/mole.

similar origin, although these structures and the Skinner vein system are oriented slightly more easterly than would be expected for antithetic riedel shears in an ideal simple shear model (e.g. Wilcox *et al*., 1973). These departures may reflect varying degrees of clockwise rotation in the structural blocks southwest of the Yalakom fault, as is suggested by the structural analysis of Umhoefer and Kleinspehn (1995), who relate this block rotation to the area's position between the Tchaikazan and Yalakom faults.

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REFERENCES

Berniolles, L. (1991): Prospecting report - Skinner Group; *BC Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 22007.

Caira, N.M., Findlay, A., DeLong, C. and Rebagliati, C.M. (1995): Fish Lake porphyry copper-gold deposit, central British Columbia; *in* Porphyry Deposits of the Northwestern Cordillera of North America, Schroeter, T.G., Editor, *Canadian Institute of Mining, Metallurgy and Petroleum*, Special Volume 46, pages 327–342.

Friedman, R.M., Diakow, L.J., Lane, R.A. and Mortensen, J.K. (2001): New U-Pb age constraints on latest Cretaceous magmatism and associated mineralization in the Fawnie Range, Nechako Plateau, central British Columbia; *Canadian Journal of Earth Sciences*, Volume 38, pages 619–637.

Hickson, C.J. and Higman, S. (1993): Geology of the northwest quadrant, Taseko Lakes map area, west-central British Columbia; *in* Current Research, Part A, *Geological Survey of Canada*, Paper 93-1A, pages 63–67.

Schiarizza, P. and Riddell, J. (1997): Geology of the Tatlayoko Lake – Beece Creek area (92N/8, 9, 10; 92O/5, 6, 12); *in* Interior Plateau Geoscience Project: Summary of Geological, Geochemical and Geophysical Studies, Diakow, L.J. and Newell, J.M., Editors, *BC Ministry of Employment and Investment*, Paper 1997-2, pages 63–101.

Schiarizza, P., Gaba, R.G., Glover, J.K., Garver, J.I. and Umhoefer, P.J. (1997): Geology and mineral occurrences of the Taseko – Bridge River area; *BC Ministry of Employment and Investment*, Bulletin 100, 291 pages.

Schiarizza, P., Riddell, J., Gaba, R.G., Melville, D.M., Umhoefer, P.J., Robinson, M.J., Jennings, B.K. and Hick, D. (2002): Geology of the Beece Creek – Niut Mountain area, British Columbia (NTS 92N/8, 9, 10; 92O/5, 6, 12); *BC Ministry of Energy and Mines*, Geoscience Map 2002-3, 1:100 000 scale.

Stacey, J.S. and Kramer, J.D. (1975): Approximation of terrestrial lead isotope evolution by a two-stage model; *Earth and Planetary Science Letters,* Volume 26, pages 207–221.

Tipper, H.W. (1969a): Mesozoic and Cenozoic geology of the northeastern part of Mount Waddington map area (92N), Coast District, British Columbia; *Geological Survey of Canada*, Paper 68-33.

Tipper, H.W. (1969b): Geology, Anahim Lake; *Geological Survey of Canada*, Map 1202A, 1:253 440 scale.

Umhoefer, P.J. and Kleinspehn, K.L. (1995): Mesoscale and regional kinematics of the northwestern Yalakom Fault System: major Paleogene dextral faulting in British Columbia, Canada; *Tectonics*, Volume 14, pages 78–94.

Umhoefer, P.J. and Schiarizza, P. (1996): Latest Cretaceous to Early Tertiary dextral strike-slip faulting on the southeastern Yalakom fault system, southeastern Coast Belt, British Columbia; *Geological Society of America Bulletin*, Volume 108, pages 768–785.

Wilcox, R.E., Harding, T.P. and Seely, D.R. (1973): Basic wrench tectonics; *American Association of Petroleum Geologists Bulletin*, Volume 57, pages 74–96.

Wolfhard, M.R. (1976): Fish Lake; *in* Porphyry Deposits of the Canadian Cordillera, Sutherland Brown, A., Editor, *Canadian Institute of Mining and Metallurgy*, Special Volume 15, pages 317–322.

Wynne, P.J., Irving, E., Maxson, J.A. and Kleinspehn, K.L. (1995): Paleomagnetism of the Upper Cretaceous strata of Mount Tatlow: evidence for 3000 km of northward displacement of the eastern Coast Belt, British Columbia; *Journal of Geophysical Research*, Volume 100, pages 6073–6091.