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Late Cretaceous ages for the Chelaslie River and Tetachuck-north plutons, northern Tetachuck Lake map area, central British Columbia[1]

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Abstract: New U-Pb isotopic data indicate Late Cretaceous crystallization and cooling ages for zircon and titanite from two plutons in the northern Tetachuck Lake map area (NTS 93 F/05). The Chelaslie River biotite-hornblende diorite and monzodiorite intruded Middle Jurassic Naglico and Entiako formations of the Hazelton Group and are nonconformably overlain by Tertiary volcanic rocks. Zircon in the pluton has a crystallization age of 80.3 ± 0.2 Ma and an equivalent but less precise titanite age indicates rapid postcrystallization cooling. Hornblende-biotite quartz monzodiorite of the Tetachuck-north pluton is inferred to intrude the Middle Jurassic Naglico formation. Uranium-lead ages for titanite indicate a minimum crystallization and cooling age of 76.6 ± 0.9 Ma; a maximum crystallization age of 79.3 ± 0.2 Ma derives from a single concordant zircon analysis. The newly recognized Late Cretaceous intrusions are correlated with and extend eastward the distribution of the metallogenically important Bulkley plutonic suite.

Résumé : De nouvelles données radiométriques (U-Pb) indiquent des âges de cristallisation et de refroidissement du Crétacé tardif pour des zircons et des titanites de deux plutons situés dans la partie nord de la région cartographique de Tetachuck Lake (SNRC 93F/05). Le pluton de Chelaslie River, une intrusion de diorite à hornblende-biotite et de monzodiorite, recoupe des unités du Jurassique moyen, rapportées aux formations de Naglico et d'Entiako du Groupe de Hazelton, et est recouvert en discordance par des roches volcaniques datant du Tertiaire. L'analyse du zircon de ce pluton a révélé un âge de cristallisation de 80,3 ± 0,2 Ma, alors qu'un âge équivalent, mais moins précis, obtenu par analyse de la titanite témoigne d'un refroidissement rapide après la cristallisation. On présume que la monzodiorite à hornblende-biotite du pluton de Tatachuck Nord recoupe la Formation de Naglico du Jurassique moyen. La datation U-Pb sur titanite de ce pluton a révélé un âge minimal de cristallisation et de refroidissement de 76,6 ± 0,9 Ma, alors que l' âge maximal de cristallisation a pu être établi à 79,3 ± 0,2 Ma d'après un seul résultat concordant d'analyse sur zircon. Ces plutons nouvellement rapportés au Crétacé tardif ont été mis en corrélation avec la suite plutonique de Bulkley qui revêt une grande importance métallogénique. Ils constitueraient le prolongement vers l'est ce cette suite.

[1] Contribution to the Nechako NATMAP Project

INTRODUCTION

Uranium-lead dating of zircon and titanite from two representative samples of the Chelaslie River and Tetachuck-north plutons represents one component of a detailed study of four mafic to felsic plutons (Billesberger et al., 1999). The plutons were examined during regional-scale bedrock mapping of the Tetachuck Lake map area (NTS 93 F/05) in 1998 as a part of the Nechako NATMAP Project (Fig. 1, inset; Struik and MacIntyre (1999) and references therein; Quat and Struik (1999)). The project contributes to the ongoing revision of the Nechako River 1:250 000 scale geological map (Tipper, 1963). The plutons dated were considered to be Late Jurassic–Cretaceous (Tipper, 1963), Cretaceous–Tertiary (Williams, 1997), or Middle Jurassic and Tertiary (Billesberger et al., 1999) based on previous mapping, compilation, and/or geochemical comparisons.

The sampled plutons are located north of Tetachuck Lake and intruded volcanic rocks of the Hazelton Group (Fig. 1). One underlies a portion of the Chelaslie River in the northwestern portion of the map area and is informally named the Chelaslie River pluton. The Tetachuck-north pluton is the more northerly of two plutons located farther to the southeast, north of Tetachuck Lake, and best exposed along Tetachuck road.

Field relationships and geochemical and petrographical studies helped distinguish the plutons and phases in the northern Tetachuck Lake map area (Billesberger et al., 1999). Geological contacts are inferred and extrapolated beyond the outcrop distributions across the extensive Quaternary cover (Fig. 1).

NATURE AND SETTING OF THE SAMPLED PLUTONS

In the Tetachuck Lake map area, various plutons of Cretaceous to Tertiary age intruded volcanic rocks of the Middle Jurassic Entiako and Naglico formations of the Lower to Middle Jurassic Hazelton Group (Diakow et al., 1997; Quat and Struik, 1999), and are nonconformably overlain by Neogene (?)Chilcotin Group volcanic rocks (e.g. Resnick et al., 1999). Sampled plutons include the Chelaslie River (unit lKCRd) and Tetachuck-north (unit lKTNqm) intrusions, which are briefly described below (Fig. 1).

Chelaslie River pluton

The Chelaslie River pluton underlies an area of about 6.5 km^2 in the northwestern Tetachuck Lake map area (Fig. 1; Billesberger et al., 1999). It is mainly medium-grey, fine- to medium-grained, hypidiomorphic-granular biotite-hornblende or actinolite (clinopyroxene) diorite. The pluton intruded andesitic tuff, plagioclase-phyric andesitic agglomerate, and fossiliferous limestone of Naglico formation and andesite breccia and tuff, and volcaniclastic sedimentary rocks of the Entiako formation of the Hazelton Group. The intrusive contact with the surrounding Naglico formation is covered and inferred along its southern margin.

Along the Chelaslie River, the pluton is cut by rhyolite, basalt, and andesite dykes which are interpreted as hypabyssal equivalents of the Eocene Ootsa Lake and Endako groups. Neogene (?)Chilcotin Group basalt locally nonconformably overlies the pluton. A zone of highly altered, fractured, and pyrite-bearing rocks is located along the northeastern contact of the pluton with the Naglico formation. In this zone exposed diorite is rusty, appears leached, and contains pyrite disseminations and fracture coatings.

The primary mineralogy of the Chelaslie River pluton is (in early to late order of crystallization; Billesberger et al. (1999)) apatite, opaque minerals, (titanite), (clinopyroxene), (orthopyroxene), plagioclase, amphibole, biotite, and quartz (parenthesized minerals do not occur in all thin sections). Plagioclase (andesine) crystals are euhedral and elongate to stubby in nature, and have been subject to sausseritization along the edges, in cracks, and within their characteristic labradorite cores. Many amphibole crystals cored by clinopyroxene were either partially altered to sericite or replaced by biotite which has in turn been altered to chlorite. Biotite has locally been altered to hematite.

Tetachuck-north pluton

The Tetachuck-north pluton underlies about 3.5 km^2 in the east-central portion of the Tetachuck Lake map area. It is best exposed in a series of discontinuous outcrops which occur over a 1.5 km interval along the Tetachuck road and at localities 300 m to the east of the road (Fig. 1). The pluton mainly comprises white, medium-grained, hypidiomorphic-granular hornblende-biotite quartz monzodiorite. The U-Pb sample (SCBF98-4707) is distinguished by its quartz monzonite composition. The pluton is surrounded by and is inferred to have intruded rocks of the Naglico formation of the Hazelton Group. Pluton-country rock contacts are covered; the location of its western and southern contacts of the intrusion is inferred from the nearest exposures of Hazelton Group volcanic rocks.

The primary mineralogy of the pluton included the following (in early to late order of crystallization): apatite, zircon, opaque minerals, titanite, corroded plagioclase cores, hornblende, biotite, later plagioclase, alkali feldspar, and quartz. Plagioclase crystals exhibit textures indicating two distinct phases of crystallization with the dominant, later phase crystals containing crystals of the earlier phase. The earlier phase of plagioclase crystallization is distinguished by crystals with heavily corroded cores, subhedral crystal forms, and oscillatory zonation which is either normal or reverse in nature. Euhedral crystal forms, albite and Carlsbad twinning, and normal oscillatory zonation characterize the later phase plagioclase crystals.

Geochemical composition

The petrographic and geochemical character of the samples was used by Billesberger et al. (1999) to help correlate the undated Tetachuck Lake area plutons with better dated suites to the east (e.g. Anderson et al., 1998).

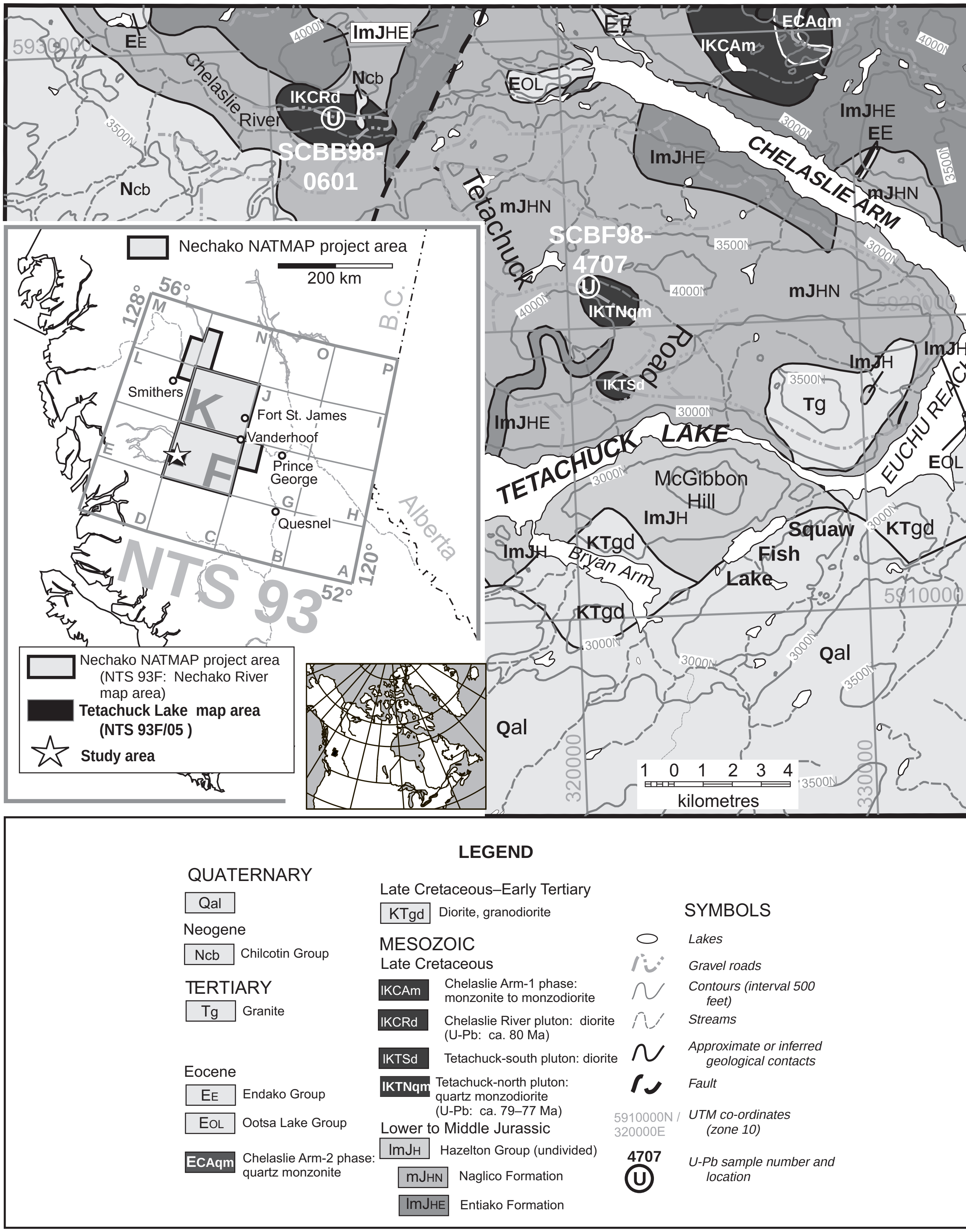

Figure 1. Geological map of the Tetachuck Lake map area showing locations of plutons studied. Country rock geology is from L.C. Struik and M.B. Quat (unpub. data, 1998). Inset map shows location of Tetachuck Lake map area within the Nechako NATMAP project area.

The plutons sampled in this study were shown by Billesberger et al. (1999) to be typical of the plutons in the Tetachuck Lake area; they are mostly subalkaline, calc-alkaline (orthopyroxene-normative), and medium- to high-potassium, metaluminous (clinopyroxene-normative), and exhibit volcanic-arc affinities. The more evolved character of the samples from the Tetachuck-north pluton help distinguish it from the other samples on most variation diagrams and resembles that for the felsic Middle Jurassic Stag Lake and Eocene Copley Lake plutonic suites (Anderson et al., 1998) although the Tetachuck area pluton samples are generally more alkaline but less potassium-rich than other Jurassic plutonic suites studied within the Nechako Plateau (Anderson et al., 1998). The Chelaslie River pluton was correlated with the Middle Jurassic Stag Lake suite based on petrographical and geochemical attributes (Billesberger et al., 1999).

U-Pb GEOCHRONOLOGY

Analytical procedures

Zircon and titanite concentrates were prepared from representative 1–3 kg samples from the Chelaslie River and Tetachuck-north plutons using conventional crushing, grinding, Wilfley table, heavy liquid, and magnetic separation techniques. The methodology for zircon grain selection, abrasion, geochemical preparation, and mass spectrometry are described by Mortensen et al. (1995). Uranium-lead analyses were done at the University of British Columbia (Table 1, Fig. 2). Errors attached to individual analyses were calculated using the numerical error propagation method of Roddick (1987). Decay constants used are those recommended by Steiger and Jäger (1977).

Table 1. U-Pb analytical data for the Chelaslie River and Tetachuck-north plutons.

Fraction[1]	Wt mg	U[2] ppm	Pb*[3] ppm	$^{206}Pb/^{204}Pb$ [4]	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] $^{206}Pb/^{238}U$	$^{207}Pb/^{206}Pb$
Cheslaslie River pluton: SCBB98-0601[8]											
A N2,c,p,s	0.045	320	4.2	956	12	13.3	0.01254 (0.12)	0.0824 (0.34)	0.04768 (0.27)	80.3 (0.2)	83 (13)
B N2,c,p	0.090	297	3.7	533	41	11.1	0.01238 (0.14)	0.0830 (0.41)	0.04862 (0.32)	79.3 (0.2)	130 (15)
C N2,m,p	0.070	281	3.7	824	19	12.7	0.01269 (0.10)	0.0837 (0.47)	0.04781 (0.41)	81.3 (0.2)	90 (20)
D N2,m,p	0.090	300	4.0	603	36	14.5	0.01253 (0.12)	0.0824 (0.52)	0.04766 (0.46)	80.3 (0.2)	83 (22)
E N2,f,p	0.080	286	3.7	605	31	12.8	0.01254 (0.13)	0.0824 (0.43)	0.04764 (0.36)	80.3 (0.2)	81 (17)
T1 M20,m,b	0.400	93	1.4	195	168	22.6	0.01252 (0.33)	0.0822 (1.24)	0.04765 (1.05)	80.2 (0.5)	82 (49/51)
T2 M20,m,b	0.110	144	2.0	246	53	19.6	0.01220 (0.20)	0.0807 (1.32)	0.04800 (1.24)	78.1 (0.3)	100 (58/60)
Tetachuk-North pluton: SCBF98-4707[9]											
A N2,cc,p,	0.14	405	5.1	2174	20	9.7	0.01223 (0.09)	0.0805 (0.20)	0.04774 (0.13)	78.4 (0.1)	86.4 (6.0)
B N2,cc,p	0.16	370	4.5	5276	8.5	9.3	0.01215 (0.10)	0.0805 (0.17)	0.04806 (0.10)	77.8 (0.2)	102.4 (4.7)
C N2,cc,p,e	0.14	429	5.3	5890	7.6	10.4	0.01238 (0.11)	0.0812 (0.18)	0.04758 (0.10)	79.3 (0.2)	78.4 (4.8)
D N2,cc,p,e	0.15	400	4.9	4821	9.3	10.1	0.01231 (0.11)	0.0810 (0.18)	0.04775 (0.10)	78.8 (0.2)	87.0 (4.7)
E N2,c,p,e	0.1	388	4.8	2954	7.1	10.6	0.01228 (0.09)	0.0809 (0.18)	0.04779 (0.12)	78.7 (0.1)	89.0 (5.6)
T1 M20,cc,b	0.57	109	1.9	109	525	37.4	0.01195 (0.61)	0.0785 (2.13)	0.04763 (1.77)	76.6 (0.9)	81 (82/86)
T2 M20,cc,b	0.45	130	2.2	121	437	35.3	0.01193 (0.55)	0.0783 (1.87)	0.04759 (1.54)	76.5 (0.8)	79 (72/75)

Notes: analytical techniques are listed in Mortensen et al. (1995).

1 Upper case letter = fraction identifier; all zircon fractions air abraded; titanites are unabraded; grain size, cc=>180 μm, c= <180 μm and >134 μm, m=<134 μm and >104 μm, f=<104 μm; Magnetic codes: Franz magnetic separator sideslope at which grains are nonmagnetic (N) or Magnetic (M); e.g. N1=nonmagnetic at 1°; field strength for all fractions =1.8A; front slope for all fractions=20°; grain character codes: b=broken fragments, e=elongate, p=prismatic, s=stubby.

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 0.0035/amu ± 20% (Daly collector) and 0.0012/amu ± 7% and laboratory blank Pb of 3–5pg ± 20%. Laboratory blank Pb concentrations and isotopic compositions based on total procedural blanks analyzed throughout the duration of this study.

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

6 Radiogenic Pb.

7 Corrected for blank Pb, U, and common Pb. Common Pb corrections based on Stacey Kramers model (Stacey and Kramers, 1975) at the age of the rock or the $^{207}Pb/^{206}Pb$ age of the fraction.

8 Pluton: Chelaslie River; sample: SCBB98-0601; geographic location: 0.5 km north of north bank of Chelaslie River, 8 km west of western end of Chelaslie Arm, Nechako Reservoir, NTS 93 F/05 (northwest). UTM zone: 10; UTM eastings: 312775; UTM northings: 5927464; elevation: 3300 feet (from plotted location on map); field rock name: diorite; petrographic rock name: biotite-hornblende (clinopyroxene) diorite; magnetic susceptibility: 55.6; stratigraphic relationship: sample site in pluton overlain by Miocene (?)Chilcotin Group lhzerolite xenolith-bearing basalt.

9 Pluton: Tetachuck-north; sample: SCBF98-4707; geographic location: on Tetachuck Road, 0.3 km south of unnamed creek, 12.5 km west of confluence of Chelaslie Arm and Euchu Reach, Nechako Reservoir, NTS 93 F/05 (central); UTM zone: 10; UTM eastings: 321173; UTM northings: 5921312; elevation: 1145 m (altimeter); about 3850 feet (from plotted location on map); field rock name: quartz monzonite; petrographic rock name: hornblende-biotite quartz monzonite; magnetic susceptibility: 43.8; stratigraphic relationship: contact covered.

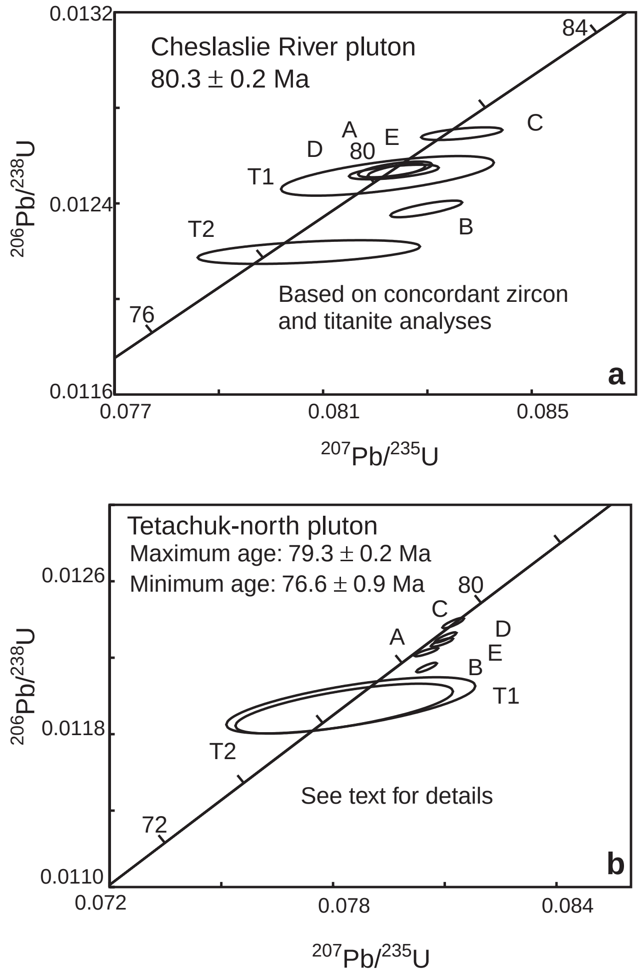

Figure 2. *Concordia plot of U-Pb data for* ***a)*** *Chelaslie River pluton sample SCBB98-0601, and* ***b)*** *Tetachuck-north pluton sample SCBF98-4707. Uppercase letters refer to analytical results for zircon fractions and T1 and T2 to analyses of titanite fractions in Table 1. Error ellipses are plotted at the 2 level of precision.*

Analytical results

Chelaslie River pluton (sample SCBB98-0601)

A diorite sample from the Chelaslie River pluton yielded abundant zircon and a modest quantity of titanite. Zircon is clear, pale pink, and commonly occurs as stubby euhedral grains (aspect ratios ≤ 2.0). Titanite is pale yellow with minor dark inclusions and occurs primarily as broken shards.

Five fractions of abraded zircon and two unabraded titanite fractions were analyzed and plot on or near concordia at ca. 80 Ma (Table 1, Fig. 2a). Three concordant and overlapping zircon analyses provide an age estimate of 80.3 ± 0.2 Ma (based on $^{206}Pb/^{238}U$ dates for fractions A, D, and E). The results from titanite T1 are in agreement with this age estimate, indicating that closure of the U-Pb system in this titanite occurred soon after zircon crystallization, probably due to rapid postcrystallization cooling. Zircon fractions B and C are likely to have contained minor inherited zircon components and zircon E and titanite T2 appear to have undergone minor Pb loss, probably at low temperature.

Tetachuck-north pluton (sample SCBF98-4707)

A sample of quartz monzonite from the Tetachuck-north pluton yielded both zircon and titanite. Zircon is clear, pale yellow, and occurs as euhedral, stubby to elongate prisms (aspect ratios = 1.5–4.0). Clear, rod-shaped and fine, dark inclusions are common and rare cores were observed in some of the coarsest grains. Titanite is clear, yellow, and commonly occurs as blocky broken fragments of coarse euhedral grains.

Five fractions of abraded zircon and two unabraded titanite fractions were analyzed from the Tetachuck-north pluton and all plot on or near concordia between about 76 Ma and 79 Ma (Table 1, Fig. 2b). Two concordant and overlapping titanite analyses give an average $^{206}Pb/^{238}U$ age of 76.6 ± 0.9 Ma, which provides a minimum estimate for closure of the U-Pb system in these grains, and for crystallization of the intrusion. A maximum crystallization age of 79.3 ± 0.2 Ma is given by the $^{206}Pb/^{238}U$ date for concordant fraction C. If this zircon age is correct, younger titanite ages can be accounted for by slow cooling or later reheating of the pluton, or by low-temperature Pb loss, none of which appear to be viable options. The low metamorphic grade of adjacent country rocks is inconsistent with deep-seated slow cooling or reheating of the pluton and it is unlikely that the titanite, whose sampled fractions gave overlapping and concordant results, underwent low-temperature Pb loss. The titanite ages are therefore more likely to record crystallization and rapid cooling of the Tetachuck-north pluton. In the context of this interpretation, the slightly older zircon fraction C can be accounted for if traces of young inherited zircon were present in some of the analyzed grains (from the Late Jurassic–Early Cretaceous Stag Lake and Francois Lake suites, for example).

DISCUSSION

Late Cretaceous U-Pb ages for the Chelaslie River and Tetachuck-north plutons permit confident correlation of these granitoid rocks with those of the well dated, compositionally similar Bulkley plutonic suite. Intrusions of the Bulkley suite are closely associated with important Cu and/or Mo porphyry deposits and occur to the west and north of the Tetachuck Lake area, in the Whitesail Lake, Smithers, and Hazelton map areas (Fig. 1, inset, NTS 93 E, L, and M; Carter, 1981; MacIntyre, 1985; Woodsworth et al., 1991). A composite age range of ca. 85–70 Ma for the Bulkley plutonic suite was originally established on the basis of K-Ar dating (Church, 1971; Christopher and Carter, 1976; Carter, 1976, 1981 and references therein). Well established U-Pb zircon crystallization ages of ca. 84–78 Ma have been determined for Bulkley suite intrusions in the Whitesail Lake map area (Friedman and Jordan, 1997; *see* Lepitre et al. (1998) for compilation). Statistically similar U-Pb and K-Ar ages for individual Bulkley suite intrusions dated with both techniques (n=3) suggest that these bodies underwent rapid cooling; in many instances K-Ar dates for Bulkley suite intrusions may give reliable crystallization ages.

In addition to the Chelaslie River and Tetachuck-north plutons, other dated and undated intrusions in the Nechako River map area (93 F, Fig. 1, inset) may belong to the Bulkley suite. The sparsely mineralized Cabin Lake pluton (the CABIN Ag-Pb-Zn-Cu showing, MINFILE number 93F038; Bailey et al., 1995) in the Knapp Lake area is tentatively correlated with the Bulkley suite on the basis of an unpublished K-Ar date of ca. 85 Ma reported by Kimura et al. (1980; *see also* Anderson et al., 1997, 1999). The undated Skins Lake pluton in the Marilla and Takysie Lake map areas (NTS 93 F/12, 13; Pint et al., 2000) is also possibly correlative. If correlation of the Chelaslie River and Tetachuck-north plutons with the metallogenically important Bulkley plutonic suite is correct, then these intrusions and other undated plutons in the area may represent more promising targets for mineral exploration than was previously recognized.

CONCLUSION

New U-Pb isotopic data for zircon and titanite from samples of the clinopyroxene-biotite-hornblende diorite of Chelaslie River and the quartz monzonite of Tetachuck-north plutons help refine or establish their correlation. The new ages and regional data extend the distribution of the metallogenetically important group of Late Cretaceous (ca. 85–70 Ma) Bulkley plutonic suite farther east than earlier known.

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REFERENCES

Anderson, R.G., L'Heureux, R., Wetherup, S., and Letwin, L.
1997: Geology of the Hallett Lake map area, central British Columbia: Triassic, Jurassic, Cretaceous, and Eocene? plutonic rocks; *in* Current Research 1997-A; Geological Survey of Canada, p. 107–116.

Anderson, R.G., Snyder, L.D., Resnick, J., Grainger, N., and Barnes, E.M.
1999: Bedrock geology of the Knapp Lake map area, central British Columbia; *in* Current Research 1999-A; Geological Survey of Canada, p. 109–118.

Anderson, R.G., Whalen, J.B., Struik, L.C., and Villeneuve, M.E.
1998: Mesozoic to Tertiary volcanism and plutonism in southern Nechako NATMAP area: Part 2. Triassic to Eocene composite intrusions and molybdenum metallogeny: the Endako Batholith redefined; *in* New Geological Constraints on Mesozoic to Tertiary Metallogenesis and on Mineral Exploration in central British Columbia: Nechako NATMAP Project, (ed.) L.C. Struik and D.G. MacIntyre; Geological Association of Canada, Cordilleran Section, March 27, 1998, Short Course Notes, 19 p.

Bailey, D.G., Jakobsen, D.E., and Lane, R.
1995: MINFILE 093F Nechako River mineral occurrence map; British Columbia Ministry of Energy, Mines and Petroleum Resources, MINFILE, revised March 1995.

Billesberger, S.M., Anderson, R.G., and Quat, M.
1999: Geology of four plutons in central and northern Tetachuck Lake map area, central British Columbia; *in* Current Research 1999-E; Geological Survey of Canada, p. 31–43.

Carter, N.C.
1976: Regional setting of porphyry deposits in west-central British Columbia; B.C.; *in* Porphyry Deposits of the Canadian Cordillera, (ed.) A. Sutherland Brown; The Canadian Institute of Mining and Metallurgy, Special Volume 15, p. 227–238.
1981: Porphyry copper and molybdenum deposits west-central British Columbia; British Columbia Ministry of Energy, Mines and Petroleum Resources, Bulletin 64, 150 p.

Christopher, P.A. and Carter, N.C.
1976: Metallogeny and metallogenic epochs for porphyry mineral deposits in the Canadian Cordillera; *in* Porphyry Deposits of the Canadian Cordillera, (ed.) A. Sutherland Brown; The Canadian Institute of Mining and Metallurgy, Special Volume 15, p. 64–71.

Church, B.N.
1971: Bergette; British Columbia Ministry of Energy, Mines and Petroleum Resources, Geology, Exploration and Mining in British Columbia 1970, p. 147–157.

Diakow, L.J., Webster, I.C.L., Richards, T.A., and Tipper, H.W.
1997: Geology of the Fawnie and Nechako Ranges, southern Nechako Plateau, central British Columbia (93 F/2, 3, 6, 7); *in* Interior Plateau Geoscience Project: Summary of Geological, Geochemical, and Geophysical Studies, (ed.) L.J. Diakow, J.M. Newell, and P. Metcalfe; British Columbia Geological Survey Branch, Open File 1996-2 and Geological Survey of Canada, Open File 3448, p. 7–30.

Friedman, R.M. and Jordan, S.J.
1997: U-Pb ages at the Huckleberry porphyry copper deposit, Tahtsa Lake District, Whitesail Lake map area, west-central British Columbia (93E/11); *in* Geological Fieldwork 1996; (ed.) D.V. Lefebure, W.J. McMillan, and J.G. McArthur; British Columbia Ministry of Employment and Investment, Paper 1997-1, p. 219–225.

Kimura, E.T., Bysouth, G.D., Cyr, J., Buckley, P., Peters, J., Boyce, R., and Nilsson, J.
1980: Geology of parts of southeast Fort Fraser and northern Nechako River map areas, central British Columbia; Placer Dome Incorporated, Internal Report and Maps, Vancouver, British Columbia.

Lepitre, M.E., Mortensen, J.K., Friedman, R.M., and Jordan, S.J.
1998: Geology and U-Pb geochronology of intrusive rocks associated with mineralization in the northern Tahtsa Lake district, west-central British Columbia; *in* Geological Fieldwork 1997; British Columbia Ministry of Employment and Investment, Paper 1998-1, p. 32-1–32-9.

MacIntyre, D.G.
1985: Geology and mineral deposits of the Tahtsa Lake District, west-central British Columbia; British Columbia Ministry of Energy, Mines and Petroleum Resources, Bulletin 75, 82 p.

Mortensen, J.K., Ghosh, D.K., and Ferri, F.
1995: U-Pb geochronology of intrusive rocks associated with copper-gold porphyry deposits in the Canadian Cordillera; *in* Porphyry Deposits of Northwestern Cordillera of North America, (ed.) T.G. Schroeter; Canadian Institute for Mining, Metallurgy, and Petroleum, Special Volume 46, p. 142-158.

Pint, C.D., Anderson, R.G., and Mahoney, J.B.
2000: Stratigraphy and structures within the Lower to Middle Jurassic Hazelton Group, Takysie Lake and Marilla map areas, central British Columbia; Geological Survey of Canada, Current Research 2000-A11, 9 p. (online; http://www.nrcan.gc.ca/gsc/bookstore)

Quat, M.B. and Struik, L.C.
1999: Stratigraphy of the Hazelton Group in southwestern Nechako River map area, central British Columbia; *in* Current Research 1999-E; Geological Survey of Canada, p. 21–29.

Resnick, J., Anderson, R.G., Russell, J.K., Edwards, B.R., and Grainger, N.
1999: Neogene basaltic flow rocks, xenoliths, and related diabase, northern Nechako River map area, central British Columbia; *in* Current Research 1999-A; Geological Survey of Canada, p. 157–167.

Roddick, J.C.
1987: Generalized numerical error analysis with application to geochronology and thermodynamics; Geochimica et Cosmochimica Acta, v. 51, p. 2129–2135.

Stacey, J.S. and Kramers, J.D.
1975: Approximation of terrestrial lead isotope evolution by a two stage model; Earth and Planetary Science Letters, v. 26, p. 207–221.

Steiger, R.H.J. and Jäger, E.
1977: Subcommission on geochronology: Convention on the use of decay constants in geo- and cosmochronology; Earth and Planetary Science Letters, v. 36, p. 359–362.

Struik, L.C. and MacIntyre, D.J.
1999: Nechako NATMAP Project overview, central British Columbia, year four; *in* Current Research 1999-A; Geological Survey of Canada, p. 79–87.

Tipper, H.W.
1963: Nechako River map-area, British Columbia; Geological Survey of Canada, Memoir 324, 59 p.

Williams, S.P.
1997: Geological compilation of the Nechako River (93F) map area, British Columbia; Geological Survey of Canada, Open File 3429, scale 1:250 000.

Woodsworth, G.J., Anderson, R.G., and Armstrong, R.L.
1991: Plutonic Regimes, Chapter 15; *in* Geology of the Cordilleran Orogen in Canada, (ed.) H. Gabrielse and C.J. Yorath; Geological Survey of Canada, Geology of Canada, no. 4, p. 491–531. (*also* Geological Society of America, The Geology of North America, no. G-2).

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