Geochemistry of Mesozoic Intrusions, Quesnel and Stikine Terranes (NTS 082, 092, 093), South-Central British Columbia: Preliminary Characterization of Sampled Suites[1]

by K. Breitsprecher[2], J.S. Scoates[2], R.G. Anderson[3] and D. Weis[2]

KEYWORDS: geochemistry, isotopes, geochronology, Mesozoic, batholiths, porphyry, Quesnellia, Stikinia, Thuya, Takomkane, Okanagan, Topley, Endako, Nicola Group, Rossland Group, Takla Group, Jurassic, Triassic, Copper Mountain, Iron Mask

INTRODUCTION

The record of arc magmatism is widespread in the Canadian Cordillera (*e.g.*, Armstrong, 1988; Woodsworth *et al.*, 1991), particularly in the Quesnel and Stikine terranes, where plutonic rocks related to Mesozoic arcs host most of the porphyry-style mineral deposits in the Cordillera (Anderson, 1985; Woodsworth *et al.*, 1991; McMillan *et al.*, 1995; Fig. 1). Isotopic characterization of arc rocks is a powerful tool for distinguishing source and contamination signatures of magmas, and has direct applications to developing economic and tectonic models for Mesozoic magmatism. Despite the importance of the plutonic hostrocks, there is a lack of reliable and complete geochemical and radiogenic isotope compositions for these intrusions in southern British Columbia. Previous geochemical studies have emphasized the volcanic units, particularly the Late Triassic to Jurassic (?) Nicola Group (Schau, 1970; Preto *et al.*, 1979; Mortimer, 1987; Smith *et al.*, 1995). Effective use of radiogenic isotope geochemistry requires knowledge of the absolute age of individual samples, and identification of temporal suites of intrusions from different regions. Poor age constraints on the Nicola Group and its complex structural style (Schau, 1970; Preto, 1979) have hindered widespread application of detailed studies (*e.g.*, Preto *et al.*, 1979; Mortimer, 1987; Smith *et al.*, 1995), particularly those involving Sr and Nd isotopes. Published Sr and Nd isotope compositions are available for a number of scattered intrusions (Ghosh, 1995), which provides an important basis for further geochemical study.

This study addresses the paucity of compositional information for Mesozoic igneous rocks of metallogenic importance in southern British Columbia (Fig. 2). The work is

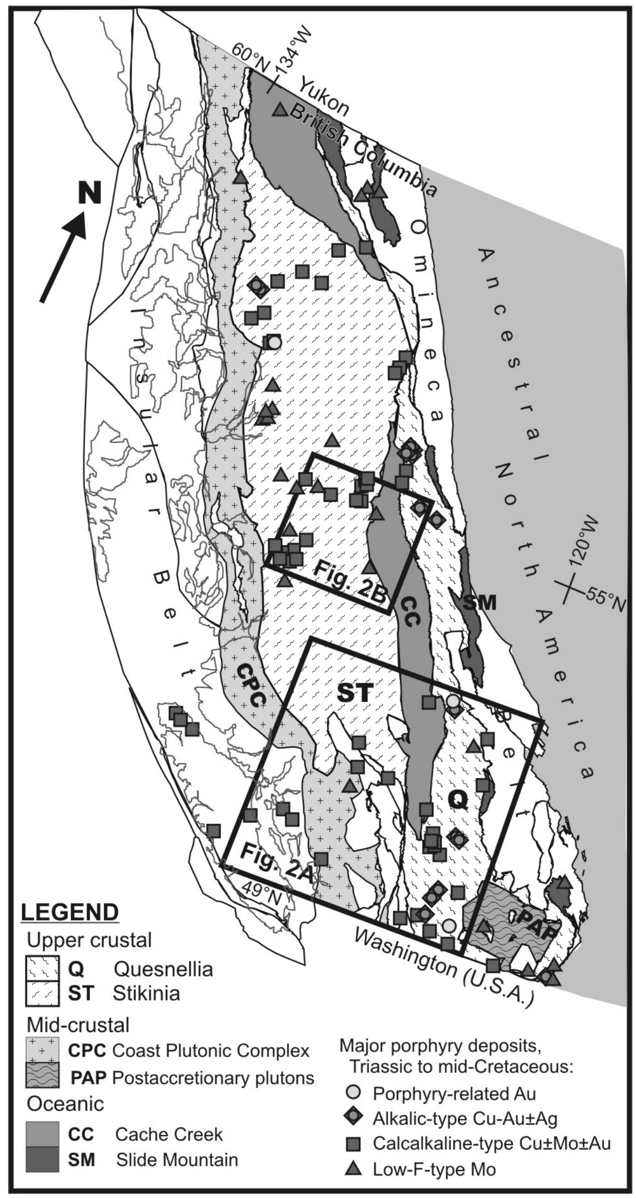

Figure 1. Major terranes of the Coast and Intermontane belts, and distribution of major Triassic to mid-Cretaceous porphyry-style deposits in the Canadian Cordillera; deposit information from MINFILE (2006) and CordMinAge 2006 (Madsen *et al.*, 2006); terrane polygons from MapPlace (2006).

---

[1] *Geoscience BC contribution GBC037*

[2] *Pacific Centre for Geochemical and Isotopic Research, Department of Earth and Ocean Sciences, University of British Columbia, Vancouver, BC*

[3] *Geological Survey of Canada, Vancouver, BC*

This publication is also available, free of charge, as colour digital files in Adobe Acrobat® PDF format from the BC Ministry of Energy, Mines and Petroleum Resources website at http://www.em.gov.bc.ca/Mining/Geolsurv/Publications/catalog/catfldwk.htm

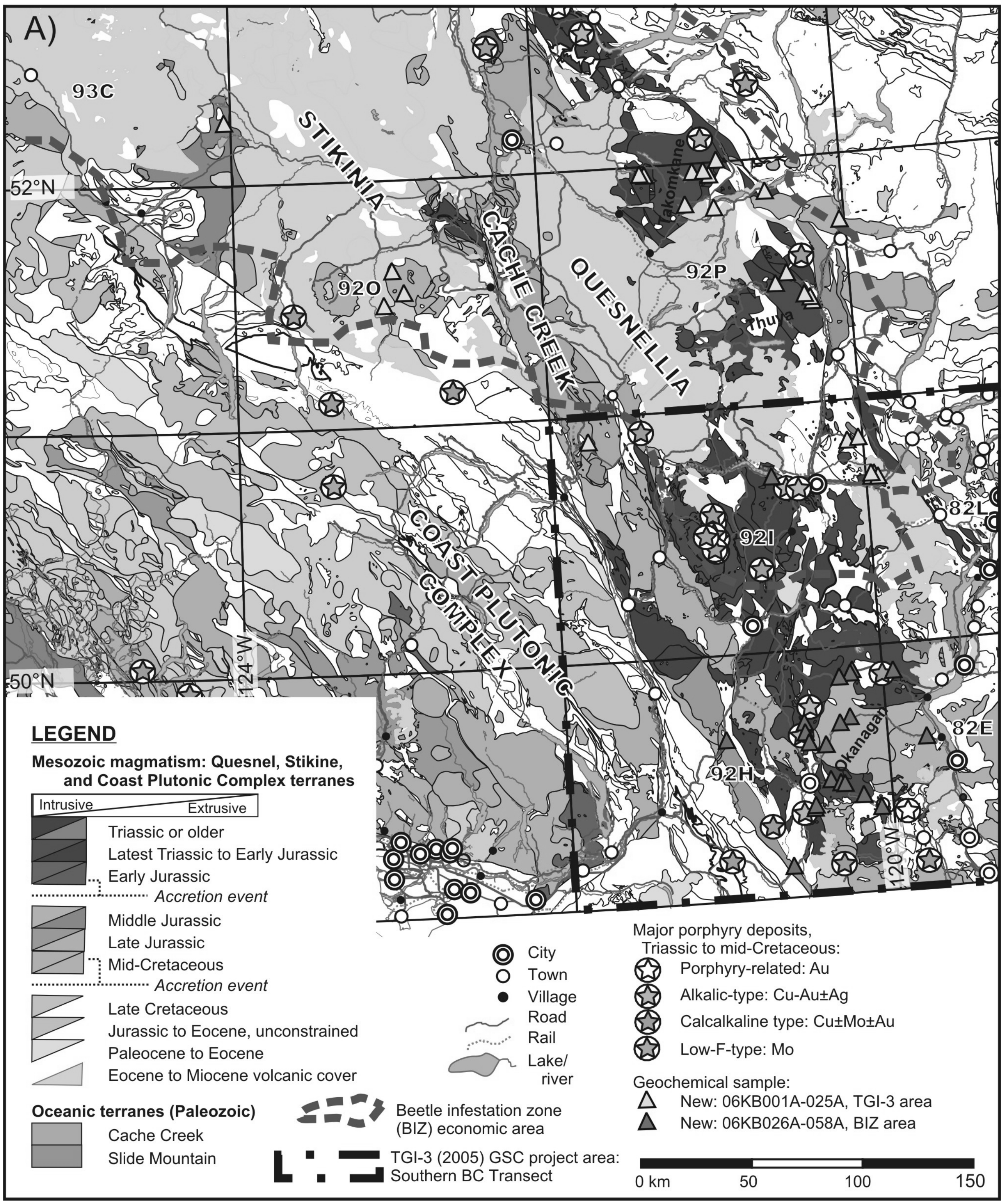

Figure 2. Distribution of Late Triassic to mid-Cretaceous igneous suites and related porphyry deposits in southern British Columbia, showing new geochemistry and geochronology sample localities: A) Kamloops-Chilcotin-Cariboo area, and B) Nechako area (facing page). Yellow symbols denote sample subset funded by Geoscience BC (mountain pine beetle infestation zone [BIZ]); blue symbols denote sample subset funded by Geological Survey of Canada (TGI-3 2005 "Southern British Columbia Transect" area). Geology *from* Massey *et al.* (2005).

timely because 1) of recent improvements in mass spectrometry (*e.g.*, Hf and Pb isotopes by multicollector inductively coupled plasma mass spectrometer); and 2) a significant number of reliable U-Pb zircon ages, which are critical for age corrections and the determination of initial isotopic ratios, have been reported from southern British Columbia since the previous geochemical studies were published. The purpose of this initial report is to provide an inventory and preliminary characterization for 57 new samples collected for high-precision geochemical analysis (major and trace element geochemistry, and Sr-Nd-Hf-Pb isotopic compositions). The primary objective is to provide compositional 'fingerprints' for mineralized suites, in order to characterize the 'mineralizer' phase(s) and to provide a basis for comparison of prospective suites identified in frontier exploration. The identification of variations in source or contamination with respect to geographic location and age in the Cordillera is potentially important in identifying the plutonic suites most likely responsible for the mineralizing event (*e.g.*, McMillan *et al.*, 1995). If metal enrichment is related to source and/or processes of magma genesis of the host (mineralized) rocks, then definition of their petrology will lead to an improved understanding of the origins of the base metal endowments of the porphyry systems that characterize the southern Cordillera.

The Triassic and Early Jurassic rocks of Quesnellia and Stikinia have been interpreted to predate, or are coeval with, accretion of those terranes to the western edge of North America *ca.* 185 to 180 Ma (Monger *et al.*, 1982; Struik *et al.*, 2001; Monger and Price, 2002). New geochemical and isotopic compositions for arc rocks from the Quesnel Terrane, particularly the Hf and Pb isotopes, will be used to discern whether the pre–185 Ma lavas and plutonic rocks contain any component of radiogenic (Precambrian) crust. This will provide a test of an alternate hypothesis to the established accretionary-tectonism paradigm, which suggests an autochthonous (continental arc; Struik, 1988; Erdmer *et al.*, 2002; Thompson *et al.*, 2006) rather than allochthonous (island arc; Monger *et al.*, 1982; Ghosh, 1995; Monger and Price, 2002) origin for the Quesnel Terrane.

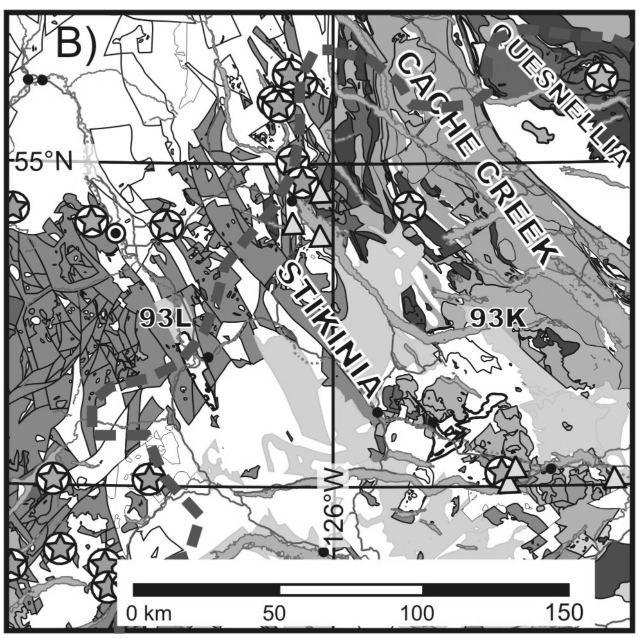

Figure 2B

GEOCHEMICAL SAMPLING

Fifty-seven new samples for geochemical investigation, as summarized at Table 1, were collected in the spring (TGI-3 area samples, Fig. 2) and summer (BIZ area samples, Fig. 2) of 2006. Magnetic susceptibility readings were recorded for the majority of the sampled outcrops, and the average of multiple measurements at each outcrop is reported in Table 1. The samples represent four time-slices of the evolution of the arc system (Fig. 3A): latest Triassic (202 +6/–4 Ma), Early Jurassic (190 ±4 Ma), Middle Jurassic (170 ±4 Ma) and Late Jurassic (150 ±5 Ma). The criteria for selecting the mean age of each time-slice was to target those suites with demonstrable economic merit (202 Ma, 193 Ma and 150 Ma suites) or tectonic relevance (170 Ma suite: provides baseline composition for postaccretionary magmatism). The intent of the time-slice approach is to minimize local effects such as crystal fractionation at any given igneous complex, in favour of providing a snapshot of compositions across the arc system. A given time-slice age is expanded to allow inclusion of rocks that are within error of the median error reported for a given suite (Table 1), which is done to ensure that truly cogenetic intrusions are not excluded from sampling of a suite on the basis of the error associated with a given age. Several Late Jurassic and mid-Cretaceous intrusive samples were collected in advance of an anticipated future phase of the project, which will test the possibility of a correlation between Stikinia and the Coast Plutonic Complex (*e.g.*, Rusmore and Woodsworth, 1991; Israel and Kennedy, 2003). Such a correlation poses an intriguing alternative to the widely accepted tectonic model in which older phases of the Coast Plutonic Complex form the midcrustal counterpart to the Wrangell Terrane of the Insular Belt (Fig. 1; *e.g.*, Nelson, 1979; Monger *et al.*, 1982; Friedman *et al.*, 1995).

Most of the samples in this study are from the Quesnel Terrane. The Okanagan, Thuya and Takomkane batholiths are ideal targets, because they contain intrusive phases from more than one of the targeted time-slices that are apparently contained within a single crustal (fault) block. This will be an advantage when interpreting the geochemical results with respect to crustal assimilation or source, in a region that is fragmented by pervasive, large-scale, strike-slip deformation (*e.g.*, Ewing, 1980; Struik, 1993; Irving *et al.*, 1996). For example, at the Okanagan batholith, samples from the Early Jurassic, Middle Jurassic and mid-Cretaceous intervals are not reportedly separated by major strike-slip faults, and thus their paleogeography with respect to one another is constrained. Thus, one assumption, namely that of emplacement into and assimilation by a common, albeit evolving, crustal assemblage, is removed at the interpretive stage.

In addition to the three major batholiths, samples were collected from intrusions of similar age that occur to the north and west of the Okanagan batholith. These include the latest Triassic Copper Mountain stock (Similco-Ingerbelle deposits; Preto, 1972; Preto *et al.*, 2004), the Allison Lake diorite (Axe deposit; Preto *et al.*, 1979) and the Cherry Creek phase of the Iron Mask batholith (Afton-Ajax deposits; Logan and Mihalynuk, 2004). The Quesnellia sample base is complemented by several samples of volcanic rocks from the Nicola Group in the vicinity

TABLE 1. SUMMARY, 2006 GEOCHEMICAL SAMPLING. SEE FIGURE 2 FOR SAMPLE LOCATIONS.

Sample no.	UTM: zone, E, N	Elev. (m)	NTS ref	Map unit	Rock description	Age, method source x-ref age o/c, proximity:	Mag. Susc.
Latest Triassic							
06KB013A	10 680376 5614658	832	92I/09	Iron Mask/ Cherry Crk	medium-grey weathering, reddish-pink, fine-grained fractured diorite	204.5 0.6, U(z), [1]	0.2
06KB014A	10 669347 5619598	467	92I/10	Iron Mask/ Cherry Crk	reddish-pink weathering, pinkish-grey, fine- grained, fractured hornblende monzodiorite	"	17.8
06KB020A	10 682440 5469869	1010	92H/07	Copper Mtn/ Voigt Stock	medium-grey weathering, dark-brown, fine-grained fractured hornblende *diorite*	202.7 +4.4/-0.5, U(z), [1]	2.9
06KB021A	10 681810 5469001	1059	92H/07	Copper Mtn/ Voigt Stock	light-grey weathering, medium-grey, medium-grained, massive hornblende monzodiorite	"	20.6
06KB025A	10 679300 5508479	920	92H/10	Allison Lake diorite	reddish-pink weathering, pinkish-grey, fine-grained fractured hornblende monzodiorite	*204 10, K(b),* [2] **NEW U-Pb in progress**	n/a
06KB017A	10 701743 5530152	1614	92H/16	Nicola Group (east)	dark-grey weathering, medium-grey, fine-grained, veined augite plagioclase-phyric andesite	*< 212 Ma*	7.2
06KB023A	10 679459 5502199	877	92H/10	Nicola Group (east)	rusty weathering, dark-grey, aphanitic, fractured augite plagioclase-phyric basalt	*< 212 Ma*	24.6
06KB024A	10 679056 5508035	945	92H/10	Nicola Group (east)	light-grey weathering, greenish-grey, epidote-veined plagioclase-porphyritic, basaltic trachy-andesite	*< 212 Ma*	n/a
06KB053A	10 709567 5635368	1006	92I/16	Hefley Creek pluton	light-grey weathering, medium-grey, medium-grained pyritized hornblende *quartz monzodiorite*	208.1 6.1, U(z,t), [3] GR00-17, <5m	6.4
06KB044A	10 674757 5705921	1137	92P/08	North Thuya granodiorite	light-grey weathering, salt and pepper, coarse-grained, pyritized biotite hornblende *quartz monzodiorite*	201.3 2.3, U(z)[4] 01PSC-341, 2m	3.7
06KB039A	10 650533 5762839	1174	92P/15	Takomkane/ Boss Creek	cream weathering, medium-grey, medium-grained hornblende *quartz monzodiorite*	l.Tri U(z) (preliminary) [5] 05PSC-047, <1m	26.8
06KB045A	10 680201 5712047	1446	92P/09	Deer Lake stock	light-grey weathering, coarse-grained hornblende-megacrystic epidotized hornblende *diorite*	197.8 1.4, U(z), [7] 01PSC-161, <1m	0.2
06KB050A	10 617454 5757942	1408	92P/14	Nicola Group	light-grey weathering, medium-grey, K-feldspar veined *trachy-andesite* with potassic alteration	203 4 U(z), [6] RW-95-97, 200m	38.3
06KB051A	10 616449 5757946	1408	92P/14	Takomkane/ satellite	orange weathering, dark-grey, fractured hornblende *quartz monzodiorite*	"	12.9
06KB030A	09 687693 6072806	739	93L/16	Topley (Stikine)	orange weathering, pinkish-grey, coarse-grained, foliated K-feldspar megacrystic hornblende *granodiorite*	210 2, A(h), [8]	0.5
06KB033A	09 678716 6076754	786	93L/16	Takla Group (Stikine)	dark-grey weathering, medium-grey, augite plagioclase-porphyrytic *andesite*	208 2, A(h), [8]	-
Early Jurassic							
06KB006A	10 705082 5473992	553	92H/08	Okanagan/ Bromley	medium-grey weathering, salt and pepper, K-feldspar megacrystic biotite hornblende granodiorite	193 1 U(z), [9] MV-84-41, 400m	n/a
06KB002A	10 697857 5479121	586	92H/08	Okanagan/ Bromley	green-grey weathering, salt and pepper, K-feldspar porphyritic biotite hornblende granodiorite	"	0.0
06KB003A	10 694801 5480344	596	92H/08	Okanagan/ Bromley	medium-grey weathering, light-grey, medium-grained biotite hornblende granodiorite	"	0.7
06KB004A	10 690217 5481297	591	92H/08	Okanagan/ Bromley	medium-grey weathering, light-grey, biotite hornblende granodiorite	"	8.1
06KB018A	11 289090 5529561	1327	82E/13	Okanagan/ Pennask	pinkish-grey weathering, light-grey, coarse-grained, fractured biotite hornblende granodiorite	194 1 U(z), [9]	8.6
06KB016A	10 701216 5529637	1581	92H/16	Okanagan/ Pennask	medium-grey weathering, light-grey, coarse-grained biotite hornblende quartz monzodiorite	"	6.8
06KB019A	11 300155 5498079	686	82E/12	Okanagan/ Pennask	medium-grey weathering, light-grey, coarse-grained biotite hornblende granodiorite	**NEW U-Pb in progress**	7.7
06KB054A	10 704003 5634909	1256	92I/16	Mt Fleet alk. complex	orange weathering, medium-pink, pyritized nepheline-megacrystic *foid-bearing monzonite*	186.9 1.7, U(z), [3] GR00-08	0.1
06KB055A	11 292240 5618517	898	82L/12	"Rossland" Group	rusty weathering, green-grey, fine-grained pyritized augite plagioclase-phyric *andesite*	< Early Jurassic ammonite [11]	0.3
06KB056A	11 291680 5618114	904	82L/12	"Rossland" Group	dark-grey weathering, green-grey, pyritized aphanitic augite plagioclase-phyric *basalt*	"	13.8
06KB057A	11 293269 5617923	840	82L/12	"Rossland" Group	medium-grey weathering, dark-grey, olivine (iddingzitized) *basalt* with potassic alteration, quartz veins and hematite	"	12.3
06KB058A	11 293633 5618252	795	82L/12	"Rossland" Group	grey-brown weathering, dark-grey, augite olivine (iddingsitized) phyric *basalt*	"	12.7
06KB049A	10 691744 5697853	1046	92P/08	Thuya granodiorite	light-grey weathering, salt and pepper, coarse-grained biotite hornblende *quartz monzodiorite*	192.7 0.9, U(z), [7] 00PSC-388, 25m	2.1
06KB047A	10 688400 5701994	1215	92P/08	Thuya/ Dum Lake	light-grey weathering, medium-grey, coarse-grained biotite hornblende *quartz monzodiorite*	eJ U(z), preliminary[5] 01PSC-296 200m	4.9
06KB040A	10 638838 5758074	923	92P/15	Takomkane/ Schoolhouse	cream weathering, light-pink, coarse-grained fractured biotite hornblende *granodiorite*	eJ U(z), preliminary[5] 05PSC-374, 100m	7.4
06KB043A	10 635702 5743233	865	92P/14	Takomkane granodiorite	light-pink weathering, medium-pink, coarse-grained, fractured biotite *granodiorite*	193.5 0.6, U(z), [6] RW95-122, 100m	8.7

TABLE 1 (CONTINUED)

Sample no.	UTM: zone, E, N	Elev. (m)	NTS ref	Map unit	Rock description	Age, method source x-ref age o/c, proximity:	Mag. Susc.
Early Jurassic (continued)							
06KB042A	10 644831 5758161	1027	92P/15	Takomkane/ Iron Lk u.m.	dark-grey (fresh and weathered) coarse-grained lineated pyroxene *hornblendite*	eJ A(h,b)[5a]; eJ U(z)[5] preliminary 05PSC-397	90.0
06KB041A	10 644560 5758541	1049	92P/15	Takomkane/ Iron Lk u.m.	dark-grey weathering, black, medium-grained brecciated *pyroxenite*	"	26.1
06KB048A	10 689368 5701087	1179	92P/08	Thuya / ultramafic	orange weathering, medium grey, medium-grained veined *pyroxenite*	?Early Jurassic	58.60
**05PSC-323*	10 672101 5747556		92P/16	Aqua Creek ultramafic	hornblende *monzodiorite*	eJ A(h), preliminary[5a] 05PSC-323; identical	
**05PSC-373*	10 648418 5741998		92P/15	South Canim stock	hornblende-biotite *quartz monzodiorite*	eJ U(z) preliminary[5] 05PSC-373; identical	
**05PSC-375*	10 647472 5756215		92P/15	Takomkane/ Iron Lk u.m.	hornblende *diorite*	eJ U(t) preliminary[5] 05PSC-375; identical	
06KB032A	09 687759 6087800	900	93L/16	Topley (Stikine)	cream weathering, orange, coarse-grained, massive *granodiorite*	*193 2 A(b),* [8] TO5, 100m	n/a
Middle Jurassic							
06KB005A	10 714114 5469284	521	92H/08	Okanagan/ Canim Cr stock	medium-pink weathering, salt and pepper, massive, biotite hornblende quartz monzonite	168.8 9.3 U(z), [12] HD 80, 900m	12.8
06KB007A	10 688750 5497584	820	92H/09	Okanagan/ Osprey	light-grey weathering, dark-grey, coarse-grained K-feldspar megacrystic biotite hornblende granodiorite	?166 1 U(z), [9]	14.8
06KB008A	10 696023 5506106	986	92H/09	Okanagan/ Osprey	light-grey weathering, light-pink, coarse-grained fractured monzogranite	**NEW U-Pb in progress**	8.0
06KB009A	10 700079 5510143	1097	92H/09	Okanagan/ Osprey	medium-grey weathering, light-grey, medium-grained, foliated monzogranite	"	6.1
06KB015A	10 695669 5528102	1568	92H/16	Okanagan/ Osprey	pinkish-grey (weathering and fresh), coarse-grained, K-feldspar megacrystic monzogranite	"	0.3
06KB026A	10 400157 5986305	739	93K/02	Stag Lake/ Sugarloaf (Stikine)	light-grey weathering, salt and pepper, heterogeneous (medium to coarse grained) *monzogranite*	171 1.7 A(b), [10]	26.0
06KB052A	10 429471 5788933	1095	93C/01	Palmer granite (Stikine)	light-pink weathering, pinkish-grey, medium-grained miarolitic fractured *monzogranite*	ca. 169.9 U(z), [13] Palmer-RMF, 300m	8.9
Late Jurassic (156 144 Ma)							
06KB001A	10 672021 5443091	1034	92H/02	Eagle tonalite	pinkish-grey weathering, medium-grey, medium-grained foliated biotite biotite granodiorite	*>157 4 U(z),* [14]	0.5
06KB012A	10 644301 5501350	-	92H/11	Eagle tonalite	light-grey weathering, salt and pepper, medium-grained, foliated biotite granodiorite	"	2.4
06KB038A	10 586883 5638843	798	92I/13	Mt Martley pluton	medium-grey weathering, salt and pepper, coarse-grained, equigranular hornblende *granodiorite*	155 1.6 U(z), [15] NM85-12A, 1500m	7.0
06KB028A	10 366717 5990717	913	93K/03	Endako/ Casey (Stikine)	cream weathering, orange, medium-grained equigranular *monzogranite*	145.1 0.2 U(z), [10]	0.2
06KB029A	10 364143 5986058	735	93K/03	Endako/ Endako (Stikine)	cream weathering, orange, coarse grained K-feldspar megacrystic miarolitic *monzogranite*	148.4 1.5 A(b), [10]	0.0
Age uncertain							
06KB035A	10 497445 5703038	1553	92O/06	Piltz Peak tonalite	light-grey weathering, salt and pepper, coarse-grained, massive *granodiorite*	Eocene? l.J? **New U-Pb in progress**	0.1
06KB036A	10 497538 5703542	1531	92O/06	Piltz Peak tonalite	medium-grey weathering, salt and pepper, coarse-grained, massive *granodiorite*	"	1.4
06KB022A	10 680572 5498160	887	92H/10	Summers Cr stock	medium-grey weathering, pinkish-grey, medium-grained, granodiorite	*101 5.2, K(b),* [2] **NEW U-Pb in progress**	14.6
06KB046A	10 705296 5734144	430	92P/09	Raft batholith	rusty weathering, pinkish-grey coarse-grained K-feldspar megacrystic foliated *monzogranite*	105.5 0.5, U(z), [4] - or 168 +14/-12 U(z)[16]	4.3
06KB034A	10 507909 5709920	1589	92O/10	Mt Alex pluton (Stikine)	medium-grey weathering, light-grey, medium-grained, *quartz monzodiorite*	**NEW U-Pb in progress**	0.2
06KB037A	10 501924 5719246	1381	92O/10	"	dark-grey weathering, rusty, coarse-grained *monzodiorite*	"	-

Notes:

05PSC-XXX samples collected by P. Schiarizza. All samples are from Quesnel Terrane, except where noted as Stikine .

Rock names in italic font are preliminary, based on visual estimates of mineral modes.

Abbreviations used for age method: A=Ar-Ar; K=K-Ar; U=U-Pb; b=biotite; h=hornblende; t=titanite; z=zircon.

Sources for age determinations are: 1 Mortensen et al., 1995; 2 Preto et al., 1979; 3 Friedman et al., 2002; 4 Schiarizza and Boulton, 2006a; 5 U-Pb dating in progress: R. Friedman and P. Schiarizza; 5a Ar-Ar dating in progress: T. Ullrich and P. Schiarizza; 6 Whiteaker et al., 1998; 7 Schiarizza et al., 2002a; 8 MacIntyre et al., 2001; 9 Parrish and Monger, 1992; 10 Villeneuve et al., 2001; 11 Beatty et al., 2006; 12 Ray and Dawson, 1994; 13 Friedman and Armstrong, 1989; 14 Greig et al., 1992; 15 Mortimer et al., 1990; 16 Calderwood et al., 1990.

Cooling ages are italicized, to distinguish them from igneous crystallization ages.

Samples from previously dated outcrops are listed with a cross-reference sample identification of the geochronology study, along with distance of the new sample from the reported co-ordinates for the dated outcrop in cases where the new sample was collected at or near to it.

UTM co-ordinate datum is NAD 83.

of the Okanagan batholith, and from volcanic rocks correlative with the Rossland Group northeast of Kamloops (Early Jurassic, reassigned from the Nicola Group; Beatty *et al.*, 2006). The Late Triassic to Early Jurassic Guichon batholith, which hosts major calcalkaline-type porphyry mineralization (Highland Valley, Bethsaida) is the subject of a concurrent detailed study (J. Whalen and R. Anderson, Geological Survey of Canada) and was not sampled.

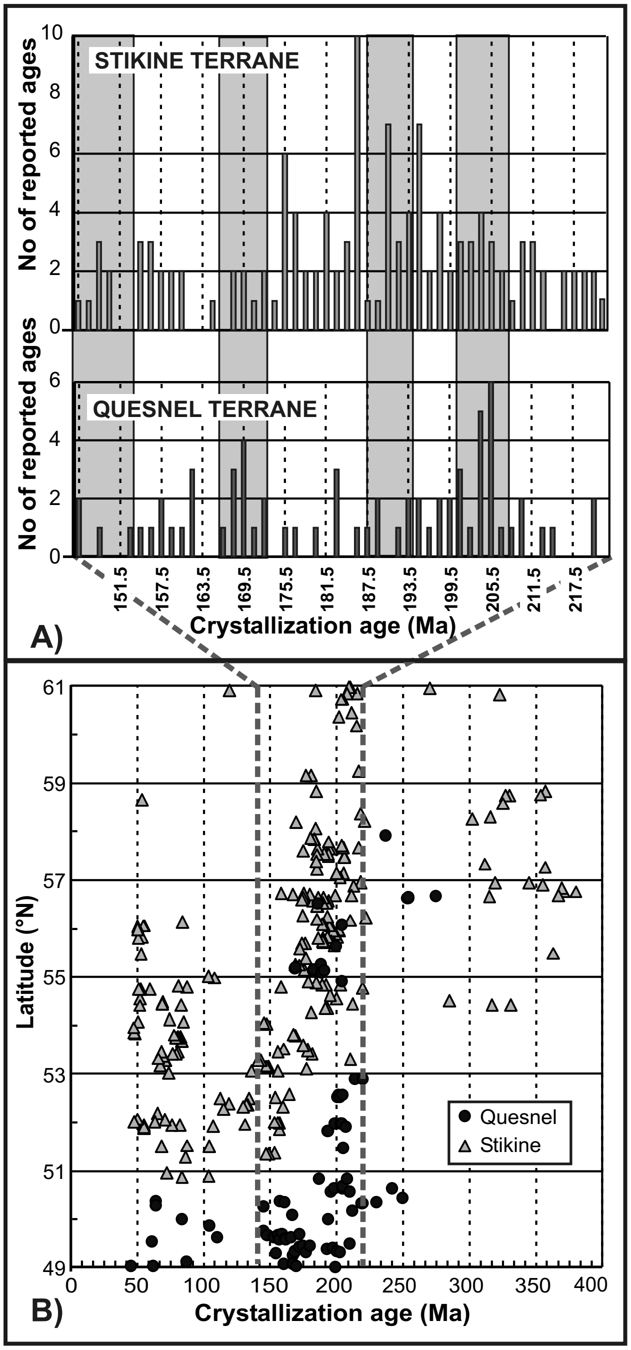

Figure 3. A) Histogram of reliable age determinations for igneous rocks of the Quesnel and Stikine terranes; shaded bands indicate time-slices targeted for geochemistry in this study. B) Latitudinal distribution of igneous rocks of the Quesnel and Stikine terranes. Source: BCAge 2004 (Breitsprecher and Mortensen, 2004), query criteria = A-rated (= 'reliable'; analytical quality criteria as specified in BCAge 2004 documentation), U-Pb, crystallization.

Minor sampling of Stikine intrusions is widespread, and generally occurs well north of Quesnel Terrane sampling. Significant variation in age distribution with latitude is evident within and between the two terranes (Fig. 3B). In general, the Late Triassic and Early Jurassic suites are not well represented in southern Stikinia, and first appear at a latitude of approximately 54°N (Nechako area samples, Fig. 2B), whereas all of the targeted suites are well represented and easily accessible in southernmost Quesnellia (southern British Columbia samples, Fig. 2A). Middle to Late Jurassic igneous rocks are present and accessible in the Stikine 'Terrane' (postdates accretion) between latitudes 51 and 54°N, where they are exposed in windows through extensive cover of the Miocene Chilcotin Group lava flows. Late Jurassic to mid-Cretaceous (*ca.* 145–115 Ma) rocks are apparently absent in the Quesnel 'Terrane', and are spatially restricted in a relatively tight across-arc trend (present-day latitudes of 51.75–52.5°N) in the Stikine 'Terrane'. Present-day latitudinal patterns do not necessarily preserve the original distribution of magmatism amongst the two terranes, due to Cretaceous and Eocene dextral strike-slip deformation within and between them (*e.g.*, Ewing, 1980; Struik, 1993; Irving *et al.*, 1996).

PRELIMINARY CHARACTERIZATION OF SAMPLED SUITES

The major element compositions determined by X-ray fluorescence spectroscopy (XRF) have been completed for a subset of the new samples (06KB001A–06KB0025A), and major element classifications from normative mineralogy and other relevant petrological indices are summarized below. Two samples (013A and 025A) are strongly altered, with loss-on-ignition values >5 wt%, and are not included in the descriptions below.

Latest Triassic (202 +6/–4 Ma): Alkalic 'Monzodiorite-Diorite' Suite

Late Triassic intrusions of southern Quesnellia form a belt of alkaline Cu-Au±Ag-type porphyry deposits from Copper Mountain in the south to Mount Polley in the north (Fig. 2A). Samples from the Copper Mountain, Allison Lake and Iron Mask intrusions are microcrystalline, exhibit varying degrees of potassic alteration and typically contain abundant hornblende needles. The Allison Lake diorite phase is undated; a new geochronology sample (06KB025A) is in progress for U-Pb dating (Geochronology Laboratory, Geological Survey of Canada, Ottawa). The microcrystalline intrusive samples (Copper Mountain, Iron Mask) are silica-undersaturated (normative olivine) calcalkaline monzodiorite (Fig. 4A, B), with an intermediate but tightly restricted range in Mg# (0.49–0.51; Fig. 4C), where Mg# = Mg / (Mg + Fe^{2+}). The Nicola Group volcanic rocks are basalt, basaltic trachyandesite and andesite, and are variably alkaline and silica undersaturated (olivine normative) or calcalkaline and silica oversaturated, with a wider range of Mg# (0.45–0.64). All samples of this suite are metaluminous (Fig. 4D) and potassic ([Na_2O – K_2O] <2 wt%). Magnetic susceptibility (ms) in these rocks varies widely from weakly magnetic (ms = +4) to magnetic (ms = +25), and appears to be inversely correlated with degree of alteration and outcrop fracturing (*i.e.*, depth and volume of

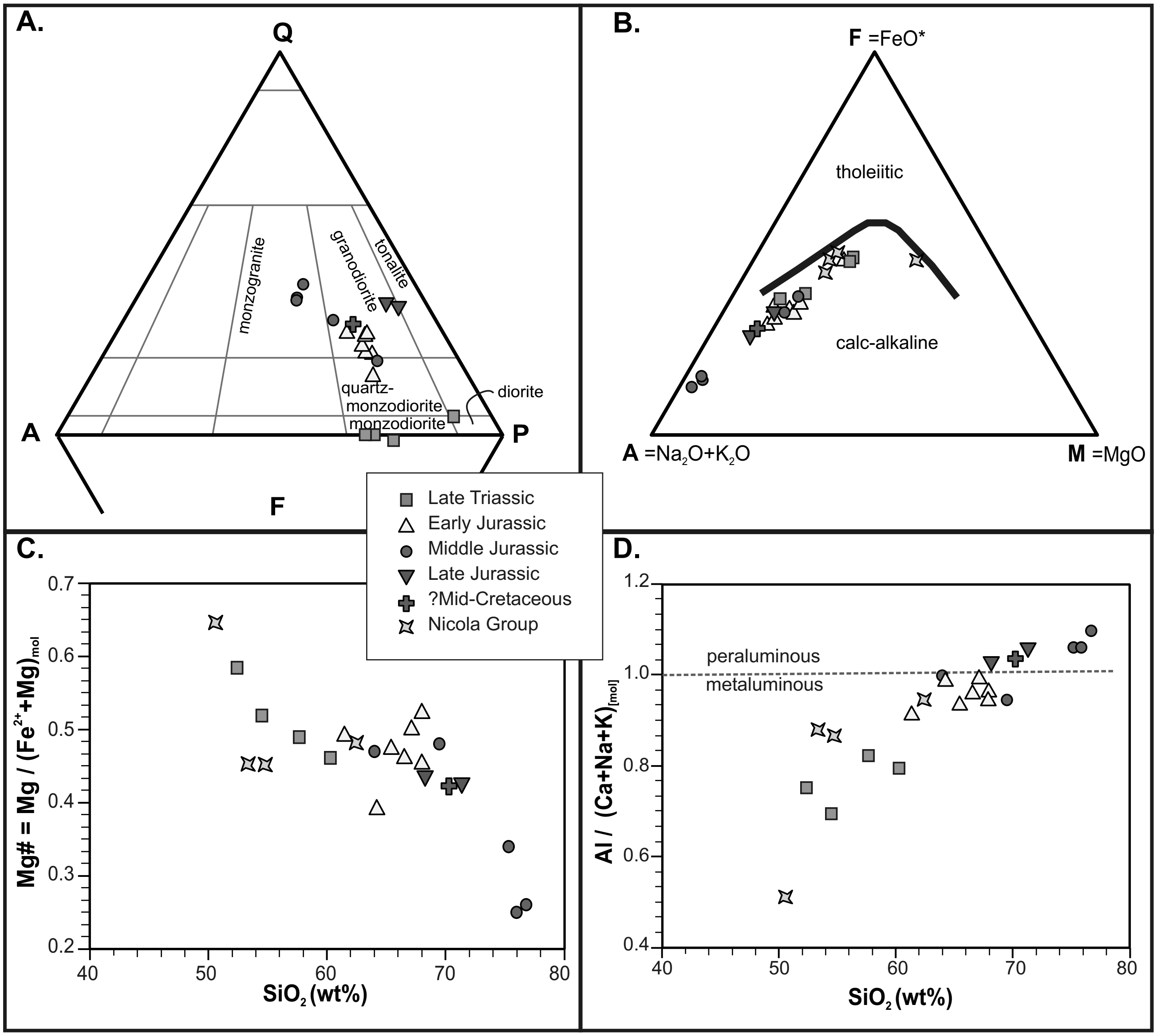

Figure 4. Major element classification of samples 06KB001A to 025A: A) QAPF diagram, based on CIPW normative mineralogy in wt%; B) AFM diagram (*after* Irvine and Baragar, 1971); C) Mg# versus SiO_2; D) alumina saturation versus SiO_2.

intact rock on which the magnetic susceptibility meter can act).

Observations for the more northerly samples indicate broad similarities to the characteristics outlined above for the southerly samples, although they include slightly more siliceous rocks and exhibit a wider range of textures. The Heffley Lake pluton, northeast of Kamloops, is a medium-grained quartz monzodiorite with well-developed pyrite crystals up to 2 mm in diameter. Samples from the Thuya and Takomkane batholiths are medium to coarse-grained quartz monzodiorite to hornblende-megacrystic recrystallized diorite. Magnetic susceptibility for samples from all three localities varies from weakly magnetic to magnetic (ms = +4 to +38). Potassium feldspar–epidote and/or pyrite alteration are common features in the majority of sampled outcrops of this suite. Correlative samples from Stikinia, collected on the west side of Babine Lake near Topley Landing (Fig. 2B), include a coarse-grained K-feldspar megacrystic granodiorite of the Topley intrusive suite (MacIntyre *et al.*, 2001) and two samples (flow top and flow bottom) of augite and plagioclase-porphyritic andesite of the Takla Group volcanic rocks.

Early Jurassic (190 ±4 Ma): 'Hornblende-Biotite Granodiorite' Suite

In the Quesnel Terrane, Early Jurassic magmatism is typified by large (>900 km^2), hornblende and biotite-bearing granodioritic intrusions. Seven samples were collected from the Pennask and Bromley batholiths of the Okanagan complex (Monger, 1989; Monger and McMillan, 1989) to provide a robust geochemical dataset for type intrusions of this age. The samples from the Pennask and Bromley plutons are calcalkaline biotite-hornblende granodiorite (Fig. 4A, B) with the exception of sample 06KB016A, which is from the Pennask pluton within 100 m of its contact with Nicola Group andesite. At that locality, the outcrop grades from 30 to 10 vol% andesitic xenoliths over an interval of approximately 250 m (Fig. 5); crustal assimilation may explain the anomalous composition. Biotite typically occurs as large (up to 6 mm), well-formed, relatively unaltered books, and hornblende and biotite together account for 10 to 15 vol% of the rock. All samples from the Okanagan complex and vicinity are silica oversaturated (normative quartz 15–25%), metaluminous and potassic, with whole-rock Mg# ranging from 0.45 to 0.53 (Fig. 4C, D). At the Okanagan batholith, Early Jurassic rocks have relatively restricted magnetic susceptibility readings (ms = +7 to +9).

Farther north, Early Jurassic intrusive phases from the Thuya and Takomkane batholiths are volumetrically dominated by biotite and hornblende-bearing granodiorite to quartz monzodiorite bodies, with a wide range of other rock types locally present (Schiarizza *et al.*, 2002 a–c; Schiarizza and Boulton, 2006a, b). Sampled rock types from the lower portion of this time-slice (194–190 Ma) include biotite-hornblende-bearing granodiorite and quartz monzodiorite (Table 1). Magnetic susceptibility is typically low to moderate (ms =+0.1 to +14). Sampled rock types from the upper portion of the time-slice (190–186 Ma) include nepheline-megacrystic syenite of the Mount Fleet alkalic complex (sample 06KB054A) from north of Kamloops, and hornblende diorite and pyroxenite from the mafic-ultramafic units at the Thuya and Takomkane complexes (Table 1). The ultramafic outcrops are extremely magnetic (ms > +90). Volcanic rocks include basalt from the Lions Head succession of the Rossland Group, collected northeast of Kamloops (Beatty *et al.*, 2006). A sample of granodiorite of the Topley intrusive suite (MacIntyre *et al.*, 2001) from the east side of Babine Lake (Fig. 2B) represents correlative magmatism in the Stikine Terrane.

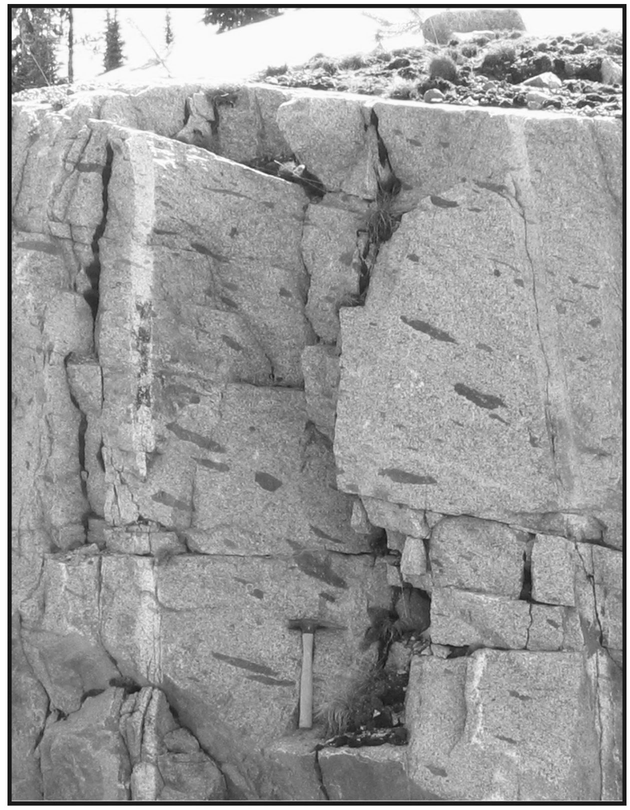

Figure 5. Partly digested elongate xenoliths of Nicola Group basalt in Pennask granodiorite, at the northeastern contact of the pluton on Highway 97C (UTM Zone 10, 701215E, 5529637N).

Middle Jurassic (170 ±4 Ma): 'K-Feldspar Megacrystic Monzogranite' Suite

In the southern part of the Quesnel study region, Middle Jurassic magmatism is represented by the Osprey pluton. A previous geochronological study did not provide definitive results (Parrish and Monger, 1992); a new geochronology sample (06KB008A) is in progress for dating by the U-Pb method (Geochronology Laboratory, Geological Survey of Canada, Ottawa). On the basis of conflicting K-Ar and Rb-Sr age determinations, the phase immediately east of the Osprey pluton has been variably assigned as either Pennask (Early Jurassic) or Osprey (Middle Jurassic); a new geochronology sample from this easterly phase (06KB019A) has been collected for U-Pb analysis. The Osprey pluton samples are K-feldspar megacrystic monzogranite, except for 06KB007A (granodiorite), which was sampled near the western contact with the Summers Creek stock. The Cahill Creek satellite stock sample (06KB005A), collected just east of the town of Hedley, is a medium-grained biotite-hornblende quartz monzodiorite (Fig. 4A). These latter two samples are metaluminous and have intermediate Mg# not inconsistent with the previous magmatic suites (0.47–0.48), whereas those closer to the Osprey core are peraluminous and have significantly lower Mg# (0.25–0.34; Fig. 4C, D). The suite is moderately magnetic (ms = +6 to +15).

Farther north, K-feldspar megacrystic monzogranite of the Raft batholith (06KB046A), which is geographically situated between the Thuya and Takomkane batholiths, was collected from the west side of the Clearwater River, northwest of the town of Clearwater. Correlative samples from the Stikine Terrane include monzogranite of the Sugarloaf phase, Stag Lake suite (Villeneuve *et al.*, 2001), collected south of the town of Fraser Lake, and monzogranite of the Palmer granite (Friedman and Armstrong, 1989), collected north of Chilanko Forks.

Late Jurassic (150 ±5 Ma): 'Hornblende-Biotite Tonalite' Suite

In the study area, Late Jurassic intrusions have typically been classified by previous workers as 'tonalite' (Greig *et al.*, 1992). The samples collected from this suite (Eagle tonalite, Piltz Peak tonalite, Mount Martley pluton) are granodiorite on the basis of their CIPW normative mineralogy, but are shifted towards the tonalite field on a QAPF diagram relative to the Early Jurassic suite (Fig. 4A). Potassium-feldspar staining reveals small amounts of potassic feldspar within these rocks, either as secondary fracture fill or as primary phases. The Eagle 'tonalite' is sodic and peraluminous, and has intermediate to evolved Mg# (0.43–0.44). The suite is weakly magnetic (ms =+0.1 to +2.4), with the exception of the moderately magnetic Mount Martley pluton (ms = +7.0). Two monzogranite samples from the Endako suite of the Stikine Terrane complement the sample subset; they are characterized by distinctively dark orange K-feldspar relative to samples from any suite of the Quesnel Terrane.

Mid-Cretaceous

Several samples of mid-Cretaceous age were included in the sampling program in anticipation of a future phase of the project. A sample of granite from the Summers Creek stock, which intrudes the southwestern part of the Osprey pluton north of Princeton, is peraluminous and potassic, and has a Mg# of 0.42. The age of the stock is constrained by a K-Ar biotite cooling age of 101 ±5.2 Ma (Preto *et al.*, 1979); a new geochronology sample (06KB022A) was collected for dating by the U-Pb method. In the Stikine 'Terrane', the undated Mount Alex pluton is inferred to be of mid-Cretaceous age (Massey *et al.*, 2005). Two geochemistry samples were collected, and additional material for one (06KB034A) was collected for dating by the U-Pb method.

FURTHER WORK

The samples in this study have been collected primarily based on their economic importance as hosts to metallogenic porphyry-style deposits and on their tectonic relevance. Geochemical analysis to be undertaken includes 1) major element determination (XRF) for samples 06KB026A to 06KB058A, which is in progress (Applied Analytical Geochemistry Laboratory, Memorial University of Newfoundland); 2) trace element determination (including the rare earth elements) by high-resolution inductively coupled plasma mass spectrometry, using a Finnigan™ Element2 instrument (Pacific Centre for Isotopic and Geochemical Research (PCIGR) at the University of British Columbia); and 3) determination of radiogenic isotopic compositions (Rb-Sr, Sm-Nd, Pb-Pb and Lu-Hf) for a subset of 40 samples (PCIGR). Six new geochronology samples are planned; two are in progress at the Geochronology Laboratory, Geological Survey of Canada (Ottawa). The application of radiogenic isotope systematics will lead to a better understanding of middle Mesozoic magmatism and tectonics in southern British Columbia. In addition, it is anticipated that this study will result in the geochemical mapping of crustal domains, based on the large areal extent of sampling and the inclusion of at least two known major crustal domains or terranes.

ACKNOWLEDGMENTS

We thank P. King for the XRF analyses at the Memorial University of Newfoundland. Voluntary field assistance by R. McQuinn, K. Medig, F. Henriques and C-E. Morisset is greatly appreciated. Sample material for the 05PSC-XXX samples was provided by P. Schiarizza. Discussions with R. Friedman and B. Struik helped to improve the sample-target planning. Significant financial support from both Geoscience BC and the Geological Survey of Canada (TGI-3, 2005 program) for fieldwork and analytical costs is crucial to achieving the project objectives, and we are grateful for this support. K. Breitsprecher is supported by the Natural Sciences and Engineering Research Council of Canada (NSERC; PGS-A).

REFERENCES

Anderson, R.G. (1985): An overview of some Mesozoic and Tertiary plutonic suites and their associated mineralization in the northern Canadian Cordillera; *in* Recent Advances in the Geology of Granite-related Mineral Deposits, Taylor, R.P. and Strong, D.F., Editors, *Canadian Institute of Mining and Metallurgy*, Special Volume 39, pages 96–113.

Armstrong, R.L. (1988): Mesozoic and early Cenozoic magmatic evolution of the Canadian Cordillera; *in* Processes in Continental Lithospheric Deformation, Clark, S.P., Burchfiel, B.C. and Suppe, J., Editors, *Geological Society of America*, Special Paper 218, pages 55–91.

BC Geological Survey (2006): MapPlace GIS internet mapping system; *BC Ministry of Energy, Mines and Petroleum Resources*, MapPlace website, URL <http://www.MapPlace.ca> [November 2006].

Beatty, T.W., Orchard, M.J. and Mustard, P.S. (2006): Geology and tectonic history of the Quesnel terrane in the area of Kamloops, British Columbia; *in* Paleozoic Evolution and Metallogeny of Pericratonic Terranes at the Ancient Pacific Margin of North America, Canadian and Alaskan Cordillera, Colpron, M. and Nelson, J.L., Editors, *Geological Association of Canada*, Special Paper 45, pages 483–504.

Breitsprecher, K. and Mortensen, J.K., Compilers (2004): BCAge 2004: a database of isotopic age determinations for rock units from British Columbia; *BC Ministry of Energy, Mines and Petroleum Resources*, Open File 2004-3, 7763 records, 9.1 Mb.

Calderwood, A.R., van der Heyden, P. and Armstrong, R.L. (1990): Geochronometry of the Thuya, Takomkane, Raft, and Baldy batholiths, south-central British Columbia; *Geological Association of Canada – Mineralogical Association of Canada – Canadian Geophysical Union,* Joint Annual Meeting, Program with Abstracts, volume 15, page 19.

Erdmer, P.E., Moore, J.M., Heaman, L., Thompson, R.I., Daughtry, K.L. and Creaser, R.A. (2002): Extending the ancient margin outboard in the Canadian Cordillera: record of Proterozoic crust and Paleocene regional metamorphism in the Nicola horst, southern British Columbia; *Canadian Journal of Earth Sciences*, volume 39, pages 1605–1623.

Ewing, T.E. (1980): Paleogene tectonic evolution of the Pacific Northwest; *Journal of Geology*, volume 88, pages 619–639.

Friedman, R.M. and Armstrong, R.L. (1989): U-Pb dating of Permian, Jurassic, and Eocene granitic rocks between the Coast Plutonic complex and Fraser–Pinchi fault systems (51 degrees–54 degrees N), BC; *Geological Society of America*, Abstracts with Programs, volume 21 (5), page 81.

Friedman, R.M., Mahoney, J.B., and Cui, Y. (1995): Magmatic evolution of the southern Coast Belt: constraints from Nd-Sr isotopic systematics and geochronology of the southern Coast Plutonic Complex; *Canadian Journal of Earth Sciences,* volume 32, pages 1681–1698.

Friedman, R., Ray, G. and Webster, I. (2002): U-Pb zircon and titanite dating of intrusive rocks in the Heffley Lake area, south-central British Columbia; *in* Geological Fieldwork 2001, *BC Ministry of Energy, Mines and Petroleum Resources,* Paper 2002-1, pages 109–118.

Ghosh, D.K. (1995): Nd-Sr isotopic constraints on the interactions of the Intermontane Superterrane with the western edge of North America in the southern Canadian Cordillera; *Canadian Journal of Earth Sciences,* volume 32, pages 1740–1758.

Greig, C.J., Armstrong, R.L., Harakal, J.E., Runkle, D. and van der Heyden, P. (1992): Geochronometry of the Eagle plutonic complex and the Coquihalla area, southwestern British Columbia; *Canadian Journal of Earth Sciences*, volume 29, pages 812–829.

Irvine, T.N. and Baragar, W.R.A. (1971): A guide to the chemical classification of the common volcanic rocks; *Canadian Journal of Earth Sciences*, volume 7, pages 523–547.

Irving, E., Wynne, P.J., Thorkelson, D.J. and Schiarizza, P. (1996): Large (1000 to 4000 km) northward movements of tectonic domains in the northern Cordillera, 83 to 45 Ma; *Journal of Geophysical Research*, volume 101B, pages 17 901–17 916.

Israel, S.A. and Kennedy, L.A. (2003): Geology of the Atnarko metamorphic complex, southern Tweedsmuir Park, west-central British Columbia; *Geological Survey of Canada*, Current Research 2003-A3, 8 pages.

Logan, J.M. and Mihalynuk, M.G. (2004): Porphyry Cu-Au deposits of the Iron Mask batholith, southeastern British Columbia; *in* Geological Fieldwork 2004, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 2005-1, pages 271–290.

MacIntyre, D.E., Villeneuve, M.E. and Schiarizza, P. (2001): Timing and tectonic setting of Stikine Terrane magmatism, Babine – Takla lakes area, central British Columbia; *Canadian Journal of Earth Sciences*, volume 38, pages 579–601.

Madsen, J.K., Breitsprecher, K. and Anderson, R.G., Compilers (2006): CordMinAge 2006: Isotopic ages for significant mineral deposits of the Canadian Cordillera; *Geological Survey of Canada*, Open File 4969, Release 1.1, 1.9 Mb.

Massey, N.W.D., MacIntyre, D.G., Desjardins, P.J. and Cooney, R.T. (2005): Geology of British Columbia; *BC Ministry of Energy, Mines and Petroleum Resources,* Geoscience Map 2005- 3, scale 1:1 000 000.

McMillan, W.J., Thompson, J.F.H., Hart, C.J.R. and Johnston, S.T. (1995): Regional geological and tectonic setting of porphyry deposits in British Columbia and Yukon Territory; *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 40–57.

MINFILE (2006): MINFILE BC mineral deposits database; *BC Ministry of Energy, Mines and Petroleum Resources*, URL <http://www.em.gov.bc.ca/Mining/Geolsurv/Minfile/> [November 2006].

Monger, J.W.H. (1989): Geology, Hope, British Columbia (92H); *Geological Survey of Canada*, Map 41-1989, sheet 1, scale 1:250 000.

Monger, J.W.H. and McMillan, W.J. (1989): Geology, Ashcroft, British Columbia (92I); *Geological Survey of Canada*, Map 42-1989, sheet 1, scale 1:250 000.

Monger, J.W.H. and Price, R. (2002): The Canadian Cordillera: geology and tectonic evolution; *Canadian Society of Exploration Geophysicists (CSEG) Recorder*, February, pages 17–36.

Monger, J.W.H., Price, R. and Tempelman-Kluit, D.J. (1982): Tectonic accretion and the origin of the two major metamorphic and plutonic welts in the Canadian Cordillera; *Geology*, volume 10, pages 70–75.

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 the Northwestern Cordillera of North America, *Canadian Institute of Mining, Metallurgy and Petroleum,* Special Volume 46, pages 142–158.

Mortimer, N. (1987): The Nicola Group: Late Triassic and Early Jurassic subduction-related volcanism in British Columbia; *Canadian Journal of Earth Sciences*, volume 24, pages 2521–2536.

Mortimer, N., van der Heyden, P., Armstrong, R.L. and Harakal, J. (1990): U-Pb and K-Ar dates related to the timing of magmatism and deformation in the Cache Creek Terrane and Quesnellia, southern British Columbia; *Canadian Journal of Earth Sciences*, volume 27, pages 117–123.

Nelson, J. (1979): The western margin of the Coast Plutonic Complex on Hardwicke and West Thurlow Islands, British Columbia; *Canadian Journal of Earth Sciences*, volume 16, pages 1166–1175.

Parrish, R.R. and Monger, J.W.H. (1992): New U-Pb dates from southwestern British Columbia; *in* Radiogenic Age and Isotopic Studies: Report 5, *Geological Survey of Canada*, Paper 91-2, pages 87–108.

Preto, V.A. (1972): Geology of Copper Mountain; *BC Ministry of Energy, Mines and Petroleum Resources*, Bulletin 59, 87 pages.

Preto, V.A. (1979): Geology of the Nicola Group between Merritt and Princeton; *BC Ministry of Energy, Mines and Petroleum Resources*, Bulletin 69, 90 pages.

Preto, V.A., Osatenko, M.J., McMillan, W.J. and Armstrong, R.L. (1979): Isotopic dates and strontium isotopic ratios for plutonic and volcanic rocks in the Quesnel Trough and Nicola Belt, south-central British Columbia; *Canadian Journal of Earth Sciences*, volume 16, pages 1658–1672.

Preto, V.A., Nixon, G.T. and Macdonald, E.A.M. (2004): Alkaline Cu-Au porphyry systems in British Columbia: Copper Mountain; *BC Ministry of Energy, Mines and Petroleum Resources*, Geoscience Map 2004-3, scale 1:15 000.

Ray, G.E. and Dawson, G.L. (1994): The geology and mineral deposits of the Hedley gold skarn district, southern British Columbia; *BC Ministry of Energy, Mines and Petroleum Resources*, Bulletin 87, 156 pages.

Rusmore, M.E. and Woodsworth, G.J. (1991): Distribution and tectonic significance of Upper Triassic terranes in the eastern Coast Mountains and adjacent Intermontane Belt, British Columbia; *Canadian Journal of Earth Sciences*, volume 28, pages 532–541.

Schau, M.P. (1970): Stratigraphy and structure of the type area of the Upper Triassic Nicola Group in south-central British Columbia*; in* Structure of the Southern Canadian Cordillera, Wheeler, J.O., Editor, *Geological Association of Canada*, Special Paper 6, pages 123–135.

Schiarizza, P., and Boulton, A. (2006a): Geology and mineral occurrences of the Quesnel Terrane, Canim Lake area (NTS 092P/15), south-central British Columbia; *in* Geological Fieldwork 2005, *BC Ministry of Energy, Mines and Petroleum Resources,* Paper 2006-1, pages 163–184.

Schiarizza, P. and Boulton, A. (2006b): Geology of the Canim Lake area (NTS 92P/15); *BC Ministry of Energy, Mines and Petroleum Resources,* Open File 2006-8, scale 1:50 000.

Schiarizza, P., Heffernan, S. and Zuber, J. (2002a): Geology of Quesnel and Slide Mountain terranes west of Clearwater, south-central British Columbia (92P/9, 10, 15, 16); *in* Geological Fieldwork 2001, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 2002-1, pages 83–108.

Schiarizza, P., Heffernan, S., Israel, S. and Zuber, J. (2002b): Geology of the Clearwater – Bowers Lake area (NTS 92P/ 9, 10, 15, 16); *BC Ministry of Energy, Mines and Petroleum Resources*, Open File 2002-15, scale 1:50 000.

Schiarizza, P., Israel, S., Heffernan, S. and Zuber, J. (2002c): Geology of the Nehalliston Plateau (NTS 92P/7, 8, 9, 10); *BC Ministry of Energy, Mines and Petroleum Resources*, Open File 2002-4, scale 1:50 000.

Smith, A.D., Brandon, A.D. and St. John Lambert, R. (1995): Nd-Sr isotope systematics of Nicola Group volcanic rocks, Quesnel terrane; *Canadian Journal of Earth Sciences*, volume 32, pages 437–446.

Struik, L.C. (1988); Crustal evolution of the eastern Canadian Cordillera; *Tectonics*, volume 7, page 727–747.

Struik, L.C. (1993): Intersecting intracontinental Tertiary transform fault systems in the North American Cordillera; *Canadian Journal of Earth Sciences*, volume 30, pages 1262–1274.

Struik, L.C., Schiarizza, P., Orchard, M.J., Cordey, F., Sano, H., MacIntyre, D.G., Lapierre, H. and Tardy, M. (2001): Imbricate architecture of the upper Paleozoic to Jurassic oceanic

Cache Creek Terrane, central British Columbia; *Canadian Journal of Earth Sciences*, volume 38, pages 495–514.

Thompson, R.I., Glombick, P., Erdmer, P., Heaman, L.M., Lemieux, Y. and Daughtry, K.L. (2006): Evolution of the ancestral Pacific margin, southern Canadian Cordillera: insights from new geologic mapping; *in* Paleozoic Evolution and Metallogeny of Pericratonic Terranes at the Ancient Pacific Margin of North America, Canadian and Alaskan Cordillera, Colpron, M. and Nelson, J.L., Editors, *Geological Association of Canada*, Special Paper 45, pages 433–482.

Villeneuve, M., Whalen, J.B., Anderson, R.G. and Struik, L.C. (2001): The Endako batholith: episodic plutonism culminating in formation of the Endako porphyry molybdenite deposit, north-central British Columbia; *Economic Geology*, volume 96, pages 171–196.

Whiteaker, R.J., Mortensen, J.K. and Friedman, R.M. (1998): U-Pb geochronology, Pb isotopic signatures and geochemistry of an Early Jurassic alkalic porphyry system near Lac la Hache, BC; *in* Geological Fieldwork 1997, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1998-1, pages 33.1–33.13.

Woodsworth, G.W., Anderson, R.G. and Armstrong, R.L. (1991): Plutonic regimes; *in* Geology of the Cordilleran Orogen in Canada, Gabrielse, H. and Yorath, C.J., Editors, *Geological Society of America*, The Geology of North America, volume G-2, pages 491–531.