

# Geochemistry of Mesozoic Intrusions, Quesnel and Stikine Terranes (NTS 082; 092; 093), South-Central British Columbia: Preliminary Characterization of Sampled Suites<sup>1</sup>

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## 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

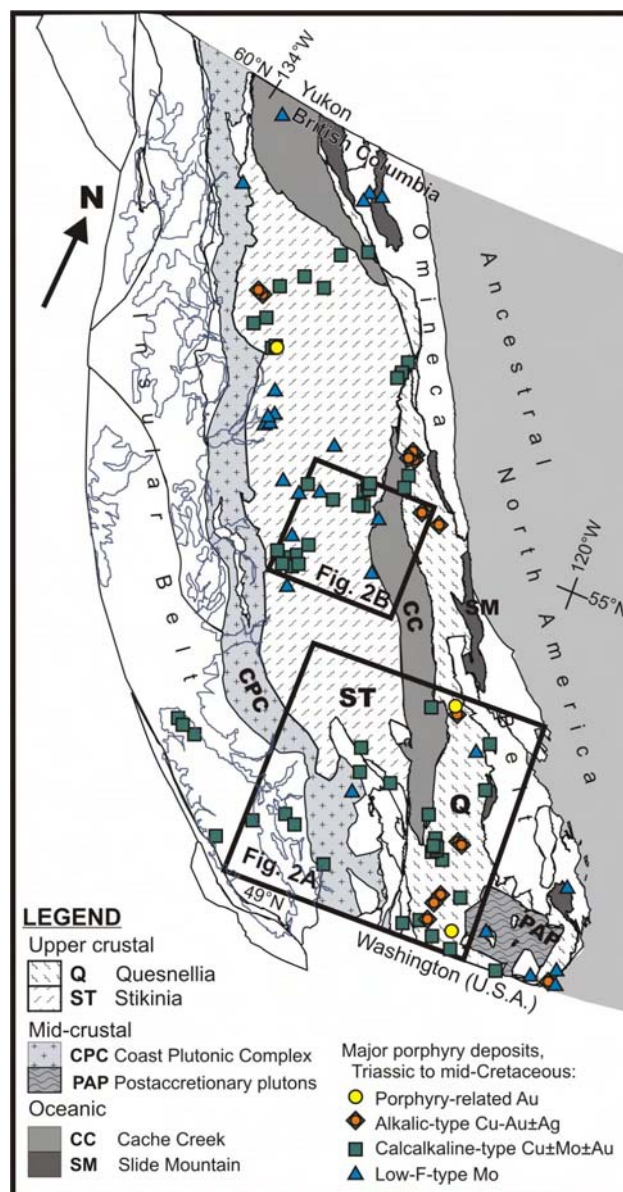


Figure 1. Major terranes of the Coast and Intermontane belts, and distribution of major Triassic to mid-Cretaceous porphyry-style deposits in the Canadian Cordillera; deposit information from MINFILE (2006) and CordMinAge 2006 (Madsen *et al.*, 2006); terrane polygons from MapPlace (2006).

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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.

## GEOCHEMICAL SAMPLING

Fifty-seven new samples for geochemical investigation, as summarized at Table 1, were collected in the spring (TGI-3 area samples, Fig 2A) and summer (BIZ area samples, Fig 2A, B) 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  $\pm$  6/-4 Ma), Early Jurassic (190  $\pm$  4 Ma), Middle Jurassic (170  $\pm$  4 Ma) and Late Jurassic (150  $\pm$  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 sam-

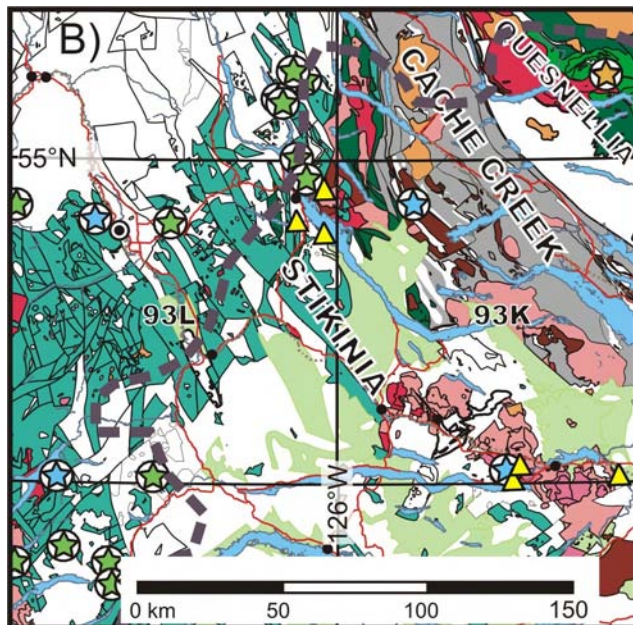


Figure 2B (caption on opposite page)

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 <sup>source</sup> x-ref age o/c, proximity:	Mag. Susc.
<b>Latest Triassic</b>							
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), <sup>1</sup>	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), <sup>1</sup>	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), <sup>2</sup> <b>NEW U-Pb in progress</b>	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-porphyrific, 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), <sup>3</sup> 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) <sup>4</sup> 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) <sup>5</sup> 05PSC-047, <1m	26.8
06KB045A	10 680201 5712047	1446	92P/09	Deer Lake stock	light-grey weathering, salt and pepper, coarse-grained hornblende-megacrystic epidotized hornblende diorite	197.8 1.4, U(z), <sup>7</sup> 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), <sup>6</sup> 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), <sup>8</sup>	0.5
06KB033A	09 678716 6076754	786	93L/16	Takla Group (Stikine)	dark-grey weathering, medium-grey, augite plagioclase-porphyrific andesite	208 2, A(h), <sup>8</sup>	-
<b>Early Jurassic</b>							
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), <sup>9</sup> 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), <sup>9</sup>	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	<b>NEW U-Pb in progress</b>	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), <sup>3</sup> 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 <sup>11</sup>	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, light-grey, olivine (iddingsitized) 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), <sup>7</sup> 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 <sup>5</sup> 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 <sup>5</sup> 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), <sup>6</sup> RW95-122, 100m	8.7

TABLE 1 (CONTINUED)

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

**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.

ples of volcanic rocks from the Nicola Group in the vicinity 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.

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 ( $[Na_2O - K_2O] < 2\text{ wt}\%$ ). 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

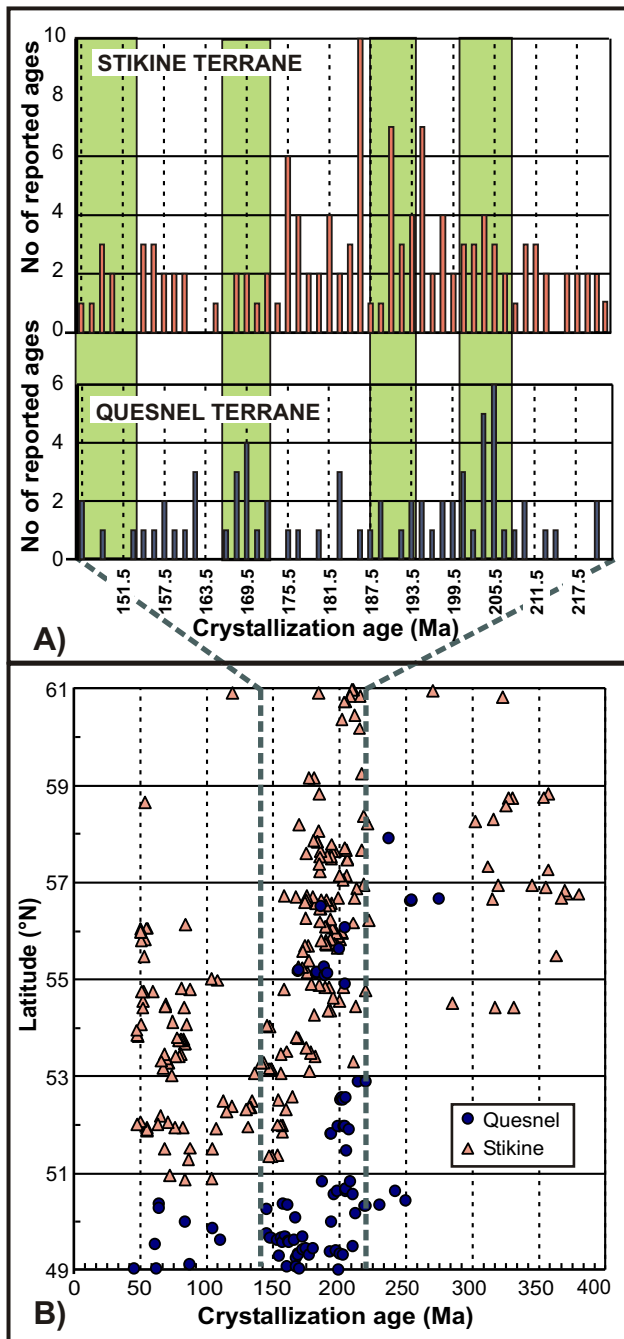


Figure 3. A) Histogram of reliable age determinations for igneous rocks of the Quesnel and Stikine terranes; shaded bands indicate time-slices targeted for geochemistry in this study. B) Latitudinal distribution of igneous rocks of the Quesnel and Stikine terranes. Source: BCAGE 2004 (Breitsprecher and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

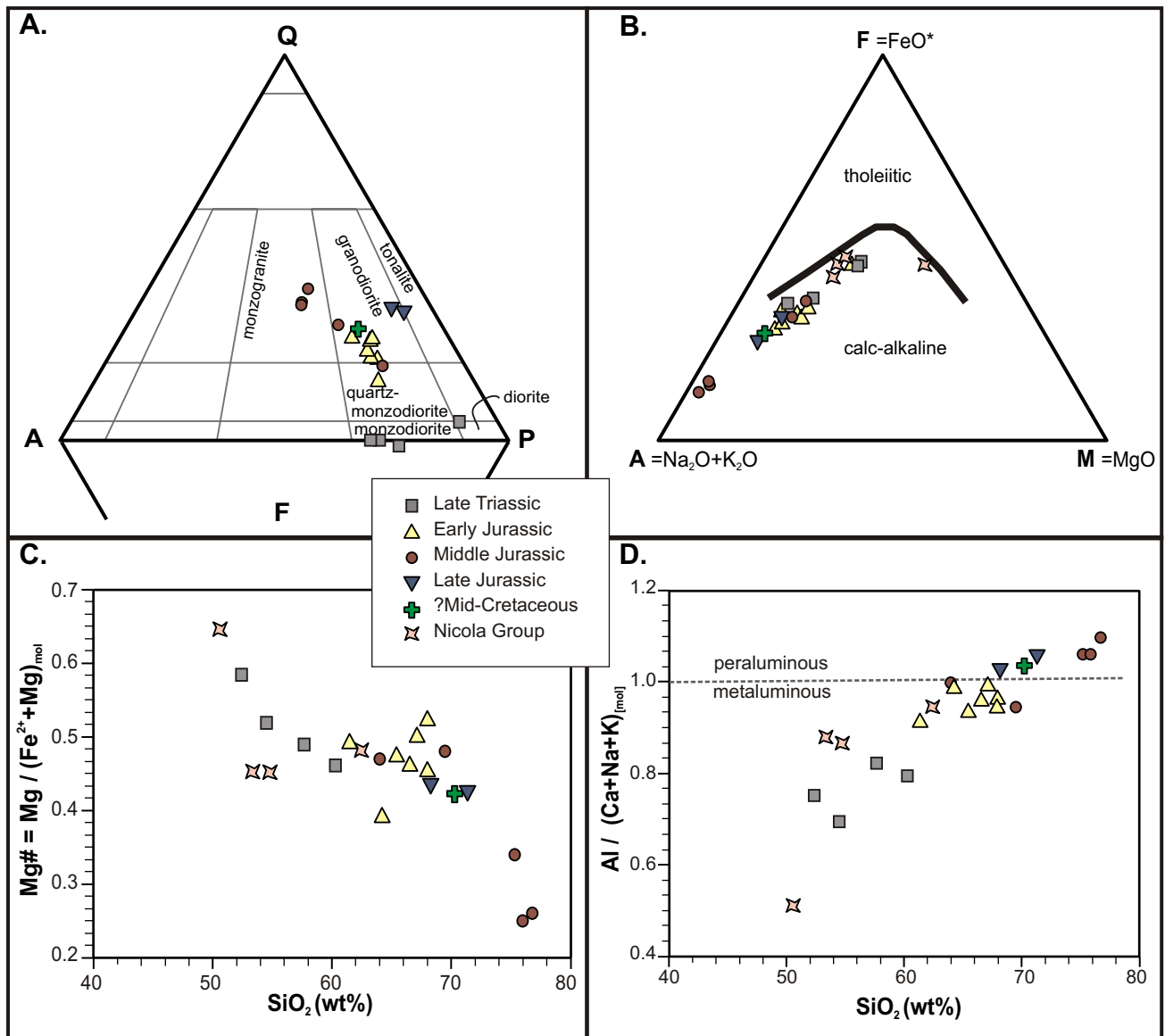


Figure 4. Major element classification of samples 06KB001A to 025A: A) QAPF diagram, based on CIPW normative mineralogy in wt%; B) AFM diagram (after Irvine and Baragar, 1971); C) Mg# versus SiO<sub>2</sub>; D) alumina saturation versus SiO<sub>2</sub>.

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-feld-

spar megacrystic granodiorite of the Topley intrusive suite (MacIntyre *et al.*, 2001) and two samples (flow top and flow bottom) of augite and plagioclase-porphyrific 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<sup>2</sup>), 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 con-

tact 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.

### **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



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).

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  $101 \pm 5.2$  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.

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