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Geochemical data of the northern Cache Creek and Stikine terranes and their overlap assemblages, British Columbia and Yukon

Alexandre Zagorevski

Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario, K1A 0E8

The Geo-mapping for Energy and Minerals (GEM) program is laying the foundation for sustainable economic development in the North. The Program provides modern public geoscience that will set the stage for long-term decision making related to investment in responsible resource development. Geoscience knowledge produced by GEM supports evidence-based exploration for new energy and mineral resources and enables northern communities to make informed decisions about their land, economy and society. On-going GEM-Cordillera project is focused on improving the regional stratigraphy and tectonic models in northern British Columbia and Yukon and producing publically available, regional-scale geoscience knowledge in Canada’s North.

The following report presents a compilation of the whole-rock geochemical data collected in the course of regional mapping, re-analysis of archival samples and unpublished archival analyses within the GEM-Cordillera project footprint. The geochemical data presented herein provide assistance in the regional correlation of units, as well as for determination of the tectonic setting of Phanerozoic volcanic and plutonic rocks. The report is intended to provide users with access to essential geochemical data and analytical background information.

Regional Geology

The northern Canadian Cordillera was assembled through accretion of peri-Laurentian and exotic terranes which where emplaced onto the Laurentian margin by the Middle Jurassic (Nelson et al., 2013). Accretion of these terranes was progressive, with Slide Mountain, Yukon-Tanana and Quesnel terranes being emplaced onto the margin first, followed by Cache Creek, Stikine and composite Wrangellia-Alexander terranes (Nelson et al., 2013). Stikine and Cache Creek terranes are extremely important in the development of the regional tectonic framework as these have distinctly different faunal assemblages (Monger and Ross, 1971). Stikine terrane is characterized by faunas similar to Quesnel terrane, and is generally accepted to have been proximal to the Laurentian margin throughout its development (e.g., Belasky et al., 2006). In contrast, the Cache Creek terrane contains Tethyan fauna which is exotic to Laurentia (e.g., Monger and Ross, 1971; Orchard et al., 2001). The entrapment of the exotic Cache Creek terrane inboard of the Stikine terrane is tectonically problematic and has led to several hypotheses for the present configuration (Mihalynuk et al., 1994 and references therein), however both terranes are incompletely characterized and geological relationships within and between adjacent terranes is, at least locally, controversial or speculative.

Stikine terrane

Carboniferous to Jurassic rocks of the northwestern Stikine terrane (Fig. 1) comprise thick successions of sedimentary, volcaniclastic and related plutonic rocks. The oldest rocks in the Stikine terrane are included in the Stikine assemblage (Devonian to Permian; Monger, 1977b). The Stikine assemblage comprises predominantly Mississippian arc and backarc volcanic, epiclastic, and plutonic rocks that are overlain by Pennsylvanian to Permian limestone and chert (e.g., Brown et al., 1991; Logan et al., 2000; Mihalynuk et al., 2012). The Stikine assemblage is unconformably overlain by Triassic rocks of the Stuhini Group and intruded by the Stikine (ca. 229 to 210 Ma) and Copper Mountain (ca. 214 to 203 Ma) plutonic suites (e.g., Brown et al., 1991; Logan et al., 2000; Mihalynuk et al., 2012). The Stuhini Group comprises characteristic augite porphyritic volcanic and volcaniclastic rocks, sedimentary rocks, and minor felsic volcanic

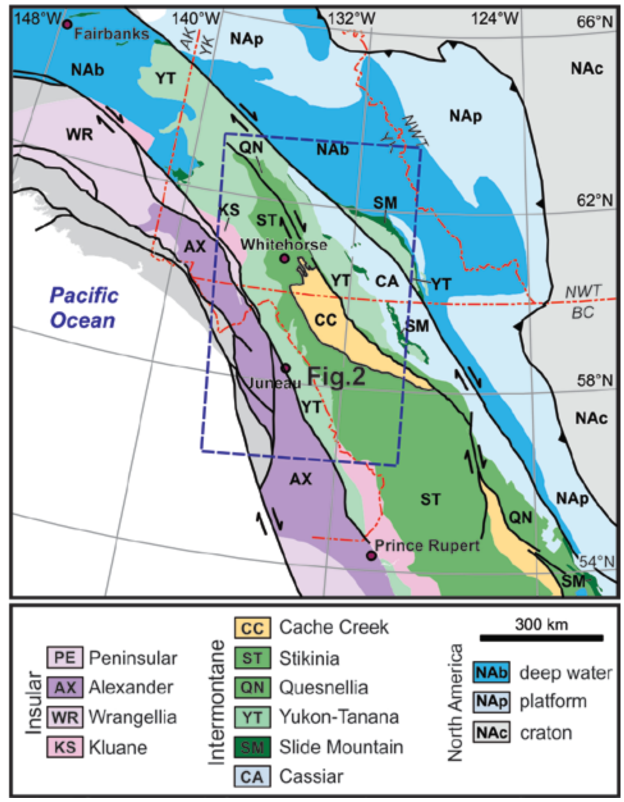

Figure 1 *Terrane assemblage map of the Canadian Cordillera, showing the location of the northern Cache Creek terrane (from Colpron and Nelson, 2011).*

rocks. Stuhini Group volcanic rocks and related intrusions have yielded ca. 223 to 213 Ma U-Pb zircon crystallization ages (Logan et al., 2000; Lewis et al., 2001) and Ladinian to Rhaetian fossil collections (e.g., Logan et al., 2000). Overall, the Stuhini Group and related plutonic suites have been interpreted to have formed in an intra-oceanic arc setting; however, Upper Triassic alkalic magmatism with Precambrian inheritance (Bevier and Anderson, 1991) suggests a more complex tectonic setting. Stuhini Group magmatism ended in the Late Triassic and was followed by erosion, exhumation of plutonic complexes, development of a regional angular unconformity (Brown et al., 1991; Logan et al., 2000; Shirmohammad et al., 2011; Mihalynuk et al., 2012), initiation of Laberge Group deposition to the north (Gabrielse, 1998; English et al., 2004; Shirmohammad et al., 2011), and initiation of Hazelton Group deposition and related plutonism in northwestern British Columbia (Brown et al., 1991; Anderson, 1993; Thorkelson et al., 1995; Logan et al., 2000; Mihalynuk et al., 2012; Nelson and Kyba, 2014; van Straaten and Nelson, 2016).

The Early to Middle Jurassic Hazelton Group overlies Stuhini Group strata above an angular unconformity (e.g., Henderson et al., 1992; Brown et al., 1996; van Straaten and Nelson, 2016). The lower sequence of the Hazelton Group includes a basal sedimentary unit that is overlain by andesitic to rhyolitic volcanic rocks that in turn are overlain by turbiditic siliclastic rocks. The age of the lower sequence is constrained by Hettangian to Upper Aalenian fossil collections and ca. 194-186 Ma U/Pb zircon ages (Macdonald et al., 1996). The upper sequence of the Hazelton Group is dominated by c. 181-173 Ma (Childe et al., 1994) bimodal volcanic rocks that occupy the Eskay rift of Alldrick et al. (2005) and Aalenian to Bajocian (?) fossil collections (Nadaraju, 1993). Hazelton group is coeval with the Texas Creek and Cone Mountain plutonic suites (Brown et al., 1991; Woodsworth et al., 1991; Anderson, 1993; Logan et al., 2000).

The Stikine terrane hosts Carboniferous Kuroko-type volcanogenic massive sulphide, Triassic Besshi-type volcanogenic massive sulphide, Triassic and Jurassic calc-alkaline and alkaline Cu-Au-Ag±Mo porphyry, skarn and Jurassic submarine exhalative Au-Ag-rich volcanogenic massive sulphide mineralization (Nelson et al., 2013). The petrographic similarity of many of the host sequences leads to ambiguity in correlations of units, hampering the establishment of a coherent stratigraphic framework, however geochemistry has been shown to facilitate division and correlation of volcanic and plutonic units (e.g., Zagorevski et al., 2012).

Cache Creek terrane

The Cache Creek terrane (Fig. 1) comprises an imbricated stack of carbonate, chert, basalt, gabbro and ultramafic rocks that are exposed from southern British Columbia to southern Yukon. Its components have been variably interpreted to represent fragments of accreted seamounts, ophiolites and rifted arc complexes. The Cache Creek terrane contains Tethyan fauna-bearing limestone that is exotic to Laurentia (e.g., Monger and Ross, 1971; Monger, 1977b). The apparent entrapment of exotic Tethyan fauna between the less exotic Stikinia and Quesnellia terranes has guided the development of the tectonic models for the evolution of the northern Cordillera far beyond the boundaries of the Cache Creek terrane itself (e.g., Mihalynuk et al., 1994 and references therein).

The Cache Creek terrane is recognized as being a composite terrane along its entire length (e.g., Gabrielse, 1998; Mihalynuk et al., 2003; Mihalynuk et al., 2004; English et al., 2010; Bickerton et al., 2013). The northern Cache Creek terrane exposed in the Cry Lake and Dease Lake areas (NTS 104I, J), is divided into two major units: the Cache Creek Complex and the Kutcho assemblage (Fig. 2; Gabrielse, 1998). The Nahlin Fault separates the two and, in most places, marks the southwest limit of the Cache Creek complex. The Kutcho assemblage to the southwest is interpreted as an Early to Middle Triassic rifted arc complex (e.g., Childe and Thompson, 1997; Gabrielse, 1998; Schiarizza, 2011), and hosts the Kutcho Creek volcanogenic massive sulphide deposit. Located in the hanging-wall of the King Salmon Fault, Kutcho assemblage comprises felsic to mafic volcanic and hypabyssal rocks and associated epiclastic sediments; all are unconformably overlain or structurally imbricated with the Jurassic Inklin Formation. Correlatives of the Kutcho assemblage (Fig. 2) are reported to the northwest in the Nakina (Mihalynuk et al., 2003; English et al., 2010) and Teslin Lake areas (Gordey et al., 1998; Bickerton, 2013).

Initial studies of the Cache Creek complex interpreted the mafic-ultramafic rocks as ophiolite segments (i.e. spreading centre; e.g., Terry, 1977) and/or a seamount (i.e. ocean island/plateau with carbonate atoll; e.g., Monger, 1977a) that were in part coeval with and overlain by deep water basin strata characterized by chert and fine-grained siliciclastic rocks. Subsequent workers followed these interpretations and noted that ophiolitic components were predominant (e.g., Ash, 1994; English et al., 2010; Schiarizza, 2011); however, a consistent tectono-stratigraphy has not been developed across the northern Cache Creek terrane largely because of lack of constraints on the tectonic setting of the petrographically similar mafic-ultramafic sequences. As such, the relationship between interpreted seamount and ophiolite components remains enigmatic, as does their relationship to the abundant mantle tectonites and rare crustal cumulates. Whole rock geochemistry does allow improved division and correlation of units (e.g., English et al., 2010).

Overlap assemblages

Following the deposition of the Hazelton Group and related plutonic rocks, Stikine and Cache Creek terranes were intruded by middle Jurassic stitching plutons of the Three Sisters Plutonic suite and overlain by coeval and younger volcanic rocks. This phase of magmatism is generally considered to be

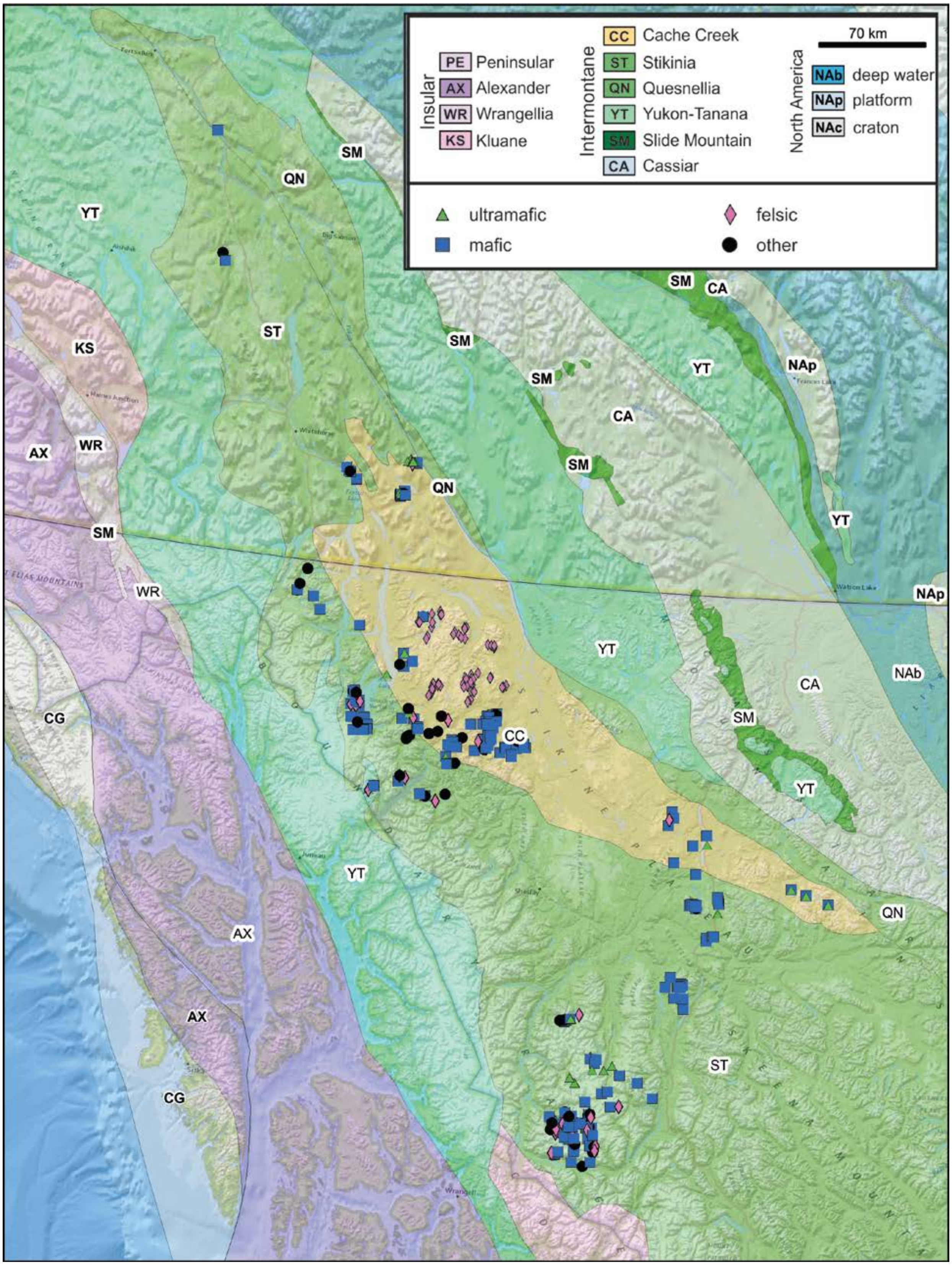

Figure 2 *Terrane assemblage map of the northern Cache Creek and Stikine terranes (from Colpron and Nelson, 2011) showing distribution of samples in this report.*

part of the overlap assemblages because these plutonic suites cross established terrane boundaries and cut tectonic fabrics in the host rocks (Mihalynuk et al., 1992). Jurassic magmatism was succeeded by Cretaceous magmatism, volcanism and sedimentation related to the Surprise Lake Batholith and coeval Windy Table Group (Mihalynuk et al., 1999). There rocks were overlapped by Eocene volcanic and related plutonic rocks of the Sloko-Hyder plutonic suite and the Coast Mountain Batholith (Mihalynuk et al., 1999).

The Neogene to Quaternary Northern Cordilleran Volcanic Province (NCVP) comprises predominantly alkaline volcanic rocks which form a sporadic overlap assemblage that extends from northwestern British Columbia to the Yukon-Alaska Border. The NCVP erupted during dextral-oblique transtension of western North America (e.g., Edwards and Russell, 2000). Over most of its geographical extent, the NCVP is dominated by short-lived, monogenetic mafic volcanic centres (see review in Edwards and Russell, 2000) with a few long-lived and polygenetic centres (Souther, 1992).

Geochemical Data

This open file report contains 496 whole rock geochemical analyses of volcanic, epiclastic, plutonic and sedimentary rocks from northern British Columbia and southern Yukon. The background information is presented as Adobe Acrobat®, Microsoft Word® documents or Microsoft Excel® tables, as required, with the data type indicated by the file names. The background information includes the unfiltered data tables and certificates as produced by the laboratories, including quality control information and certificates of analysis where available. All samples were trimmed of obvious weathered surfaces prior to submission to laboratories. Samples were pulverized using mild steel which can contaminate samples with iron, but reduces contamination by Cr, Ni, Si, Al, Ba, Co and other elements from other methods. Samples processed at the Activation Laboratories (Ancaster, Ontario) were processed using 4Lithoresearch analytical package (ICP-OES+ICP-MS) following lithium metaborate/tetraborate fusion (http://www.actlabs.com/) and 1B1/1B2 Nickel Sulphide Fire Assay (INAA+ICP-MS). Samples processed at the Bureau Veritas (formerly Acme Laboratories, Vancouver, BC) using 4A4B (LF202) Total Whole Rock Characterization analytical package (ICP-OES+ICP-MS) following lithium metaborate /tetraborate fusion (http://acmelab.com/).

Combined geochemical data are presented in *OF_8039_data.xls*. This Microsoft Excel® file contains sample number, location, basic rock type, laboratory, source file of analytical data, and geochemical data. Sample location coordinates are presented in

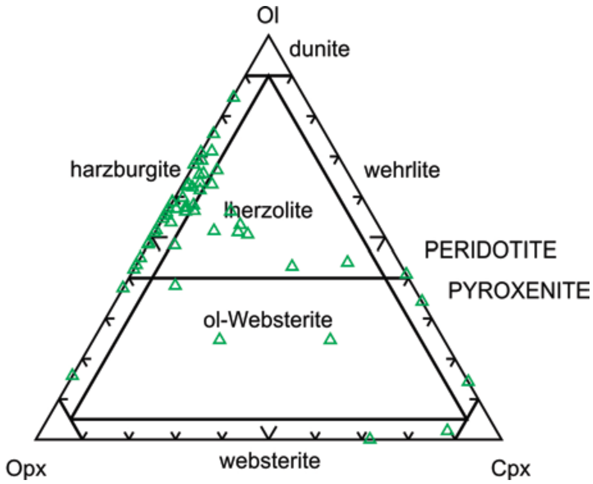

Figure 3. *Modal classification of ultramafic rocks. Mineral modes were calculated using IgPet 2014.*

geographic decimal degree format (NAD83). The stratigraphic unit is excluded from this table as stratigraphy and plutonic affiliation are in the process of revision (Zagorevski et al., 2015a; Zagorevski et al., 2015b).

Description of data

Samples are generally divided into plutonic, volcanic and sedimentary types and ultramafic, mafic, intermediate, and felsic subtypes. Ultramafic rocks are generally characterized by high MgO concentrations and calculated modal compositions are indicative of predominantly harzburgite compositions with minor lherzolite, websterite and pyroxenite (Fig. 3). Mafic volcanic rocks predominantly plot in the basalt, alkali basalt and basaltic andesite fields on immobile trace element classification diagram (Fig. 4a). They formed in a variety of tectonic settings as

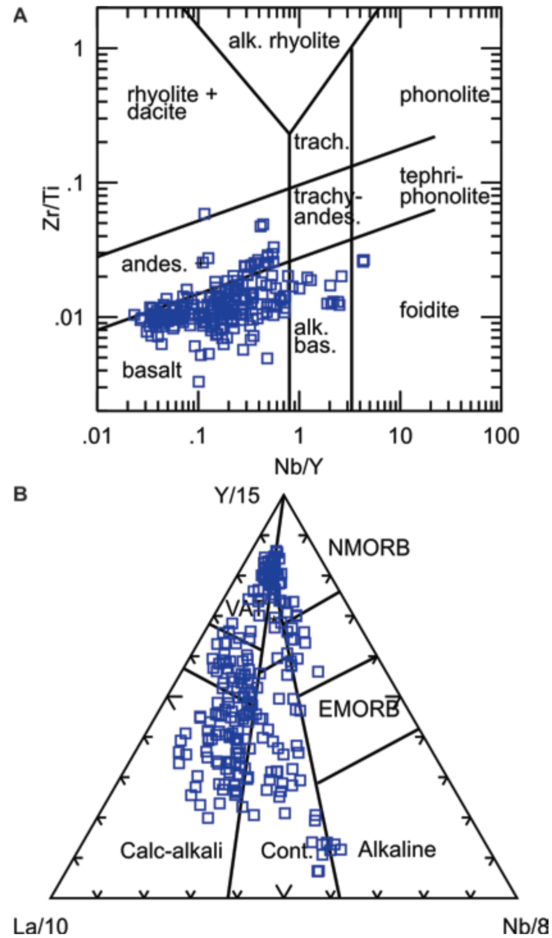

Figure 4. *Geochemical characteristics of mafic rocks. A. Rock type classification plot indicates predominantly basaltic composition (Pearce, 1996). B. Tectonic setting discrimination diagram indicates a variety of predominantly arc-like settings (Cabanis and Lecolle, 1989).*

indicated by the range of compositions on immobile trace element tectonic discrimination diagram, where they plot in the volcanic arc tholeiite, calc-alkali basalt, backarc basin basalt, continental rift and minor mid-oceanic ridge basalt field (Fig. 4b). These settings can also be generally inferred from normalized

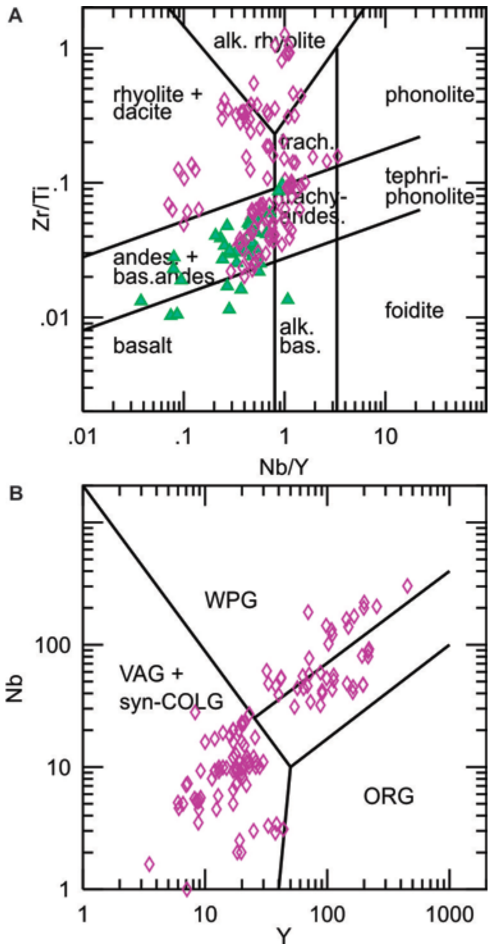

Figure 5*. Geochemical characteristics of felsic and intermediate rocks. A. Rock type classification plot indicates predominantly intermediate to felsic compositions (Pearce, 1996). B. Tectonic setting discrimination diagram indicates both arc and within-plate settings (Pearce et al., 1984).*

extended trace element plots where samples are characterized by volcanic arc tholeiite, calc-alkali basalt, backarc basin basalt, and continental rift/ocean island basalt trace element profiles.

Felsic to intermediate volcanic rocks plot in the andesite, trachyandesite, trachyte, rhyolite and alkaline rhyolite fields on the immobile trace element classification diagram (Fig. 5a). They formed in a variety of tectonic settings as indicated by the range of compositions on immobile trace element tectonic discrimination diagram, where they plot in the volcanic arc, syn-collisional and within-plate tectonic setting fields (Fig. 5b).

Acknowledgements

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