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

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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of the whole-rock geochemical data collected in the course of regional mapping, re-analysis of archival samples and unpublished archival analyses within the GEM-Cordillera project footprint.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. This 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 is interpreted to be progressive, with Slide Mountain, Yukon-Tanana and Quesnellia terranes being emplaced onto the margin first, followed by Cache Creek and (Nelson et al., 2013). Cache Creek terrane forms the cornerstone of the tectonic models of the Cordillera as it contains distinctly different faunal assemblage from adjavent terranes (e.g., Monger and Ross, 1971; Orchard et al., 2001). The apparent entrapment of the Cache Creek terrane between adjacent terranes has led to several hypotheses to explain the present configuration (e.g., Mihalynuk et al., 1994 and references therein); however most terranes are incompletely characterized and geological relationships within and between adjacent terranes are, at least locally, controversial or speculative. This open file 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 from Stikinia, Quesnellia, and Slide Mountain terranes as well as their Jurassic to Eocene overlap assemblages. This report incorporates all of the data from and supersedes Zagorevski (2016). Tectono-stratigraphic units are specifically excluded from these data as these data are intended to be used for revising the tectono-stratigraphy of the region.

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 rocks.

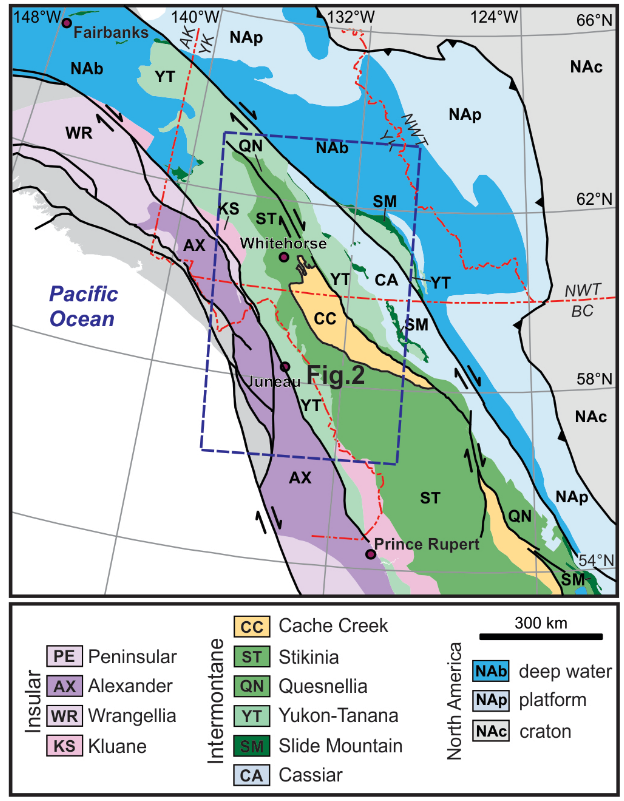

***Figure 1** Terrane assemblage map of the Canadian Cordillera, showing the location of the northern Cache Creek terrane (from Colpron and Nelson, 2011).*

Stuhini Group volcanic rocks and related intrusions yield ca. 223 to 213 Ma U-Pb zircon crystallization ages (Lewis et al., 2001; Logan et al., 2000) 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; Mihalynuk et al., 2012; Shirmohammad et al., 2011), initiation of Laberge Group deposition to the north (English et al., 2004; Gabrielse, 1998; Shirmohammad et al., 2011), and initiation of Hazelton Group deposition and related plutonism in northwestern British Columbia (Anderson, 1993; Brown et al., 1991; Logan et al., 2000; Mihalynuk et al., 2012; Nelson and Kyba, 2014; Thorkelson et al., 1995; van Straaten and Nelson, 2016).

The Early to Middle Jurassic Hazelton Group overlies Stuhini Group strata above an angular unconformity (e.g., Brown et al., 1996; Henderson et al., 1992; 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 (Anderson, 1993; Brown et al., 1991; Logan et al., 2000; Woodsworth et al., 1991).

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 were interpreted to be exotic to Laurentia (e.g., Monger, 1977b; Monger and Ross, 1971). 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., Bickerton et al., 2013; English et al., 2010; Gabrielse, 1998; Mihalynuk et al., 2004; Mihalynuk et al., 2003). 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, has been interpreted to mark 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, the 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 (English et al., 2010; Mihalynuk et al., 2003) and Teslin Lake areas (Bickerton, 2013; Gordey et al., 1998).

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; McGoldrick et al., 2017; Schiarizza, 2011). A consistent tectono-stratigraphy however 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 and indicates that ophiolites are not related to the seamounts (e.g., English et al., 2010; McGoldrick et al., 2017).

Slide Mountain terrane

Similar to the Cache Creek terrane, the Slide Mountain terrane comprises an imbricated stack of carbonate, chert, basalt, gabbro and ultramafic rocks that are exposed from southern British Columbia to southern Yukon (e.g., Nelson, 1993). Its components have are generally interpreted to represent fragments of ophiolites, rifted arc complexes and basinal sediments that, in part, unconformably overlie Yukon-Tanana terrane and the Laurentian margin (Murphy et al., 2006; Nelson, 1993; Nelson and Colpron, 2007). Recent studies of the mafic-ultramafic complexes previously included in the Slide Mountain terrane revealed that they are dominated by island arc geochemical characteristics and are too young to represent the floor of the Slide Mountain Ocean (Parsons et al., in press; van Staal et al., 2018). This is not particularly surprising in the global context, where majority of ophiolites do not represent the subducting ocean floor but rather parts of the overriding arc, and commonly form either immediately prior or during the collision with a continental margin or ribbon continent (e.g., Dilek, 2003; Dilek and Furnes, 2014). We have reanalyzed sample powders collected by Nelson (1993) which lacked the resolution to accurately determine tectonic setting of Slide Mountain terrane mafic-ultramafic complexes in northern British Columbia.

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 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 that 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 1622 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

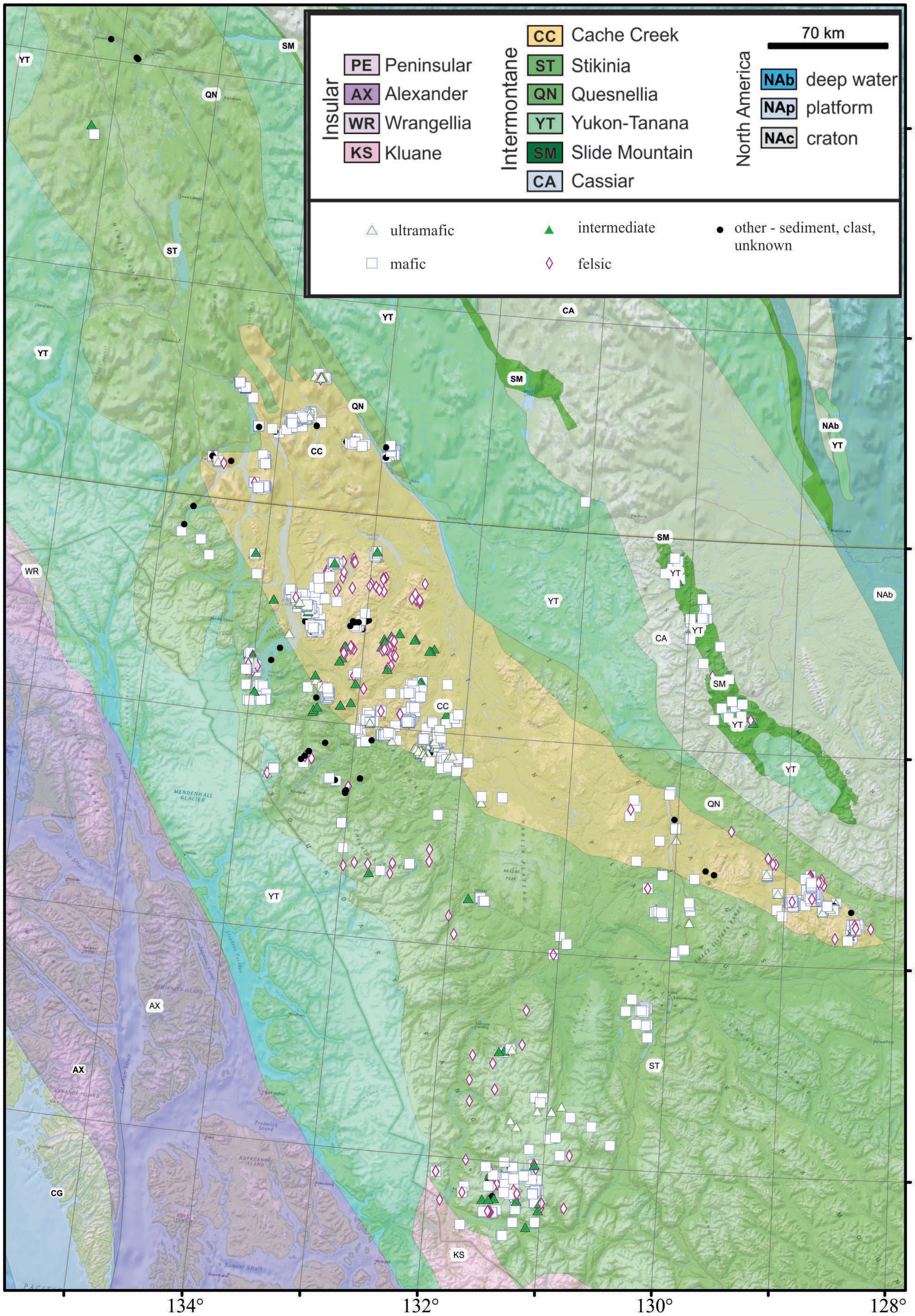

Figure 2 *Terrane assemblage map of the northern Cache Creek and Stikine terranes (from Colpron and Nelson, 2011) showing distribution of samples in this report.*

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 Fe, 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_8395_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 geographic decimal degree format (NAD83). Stratigraphic units and terrane assignments are excluded from this table as stratigraphy and terrane affiliations are in the process of revision (Zagorevski et al., 2017; Zagorevski et al., 2015a; Zagorevski et al., 2015b).

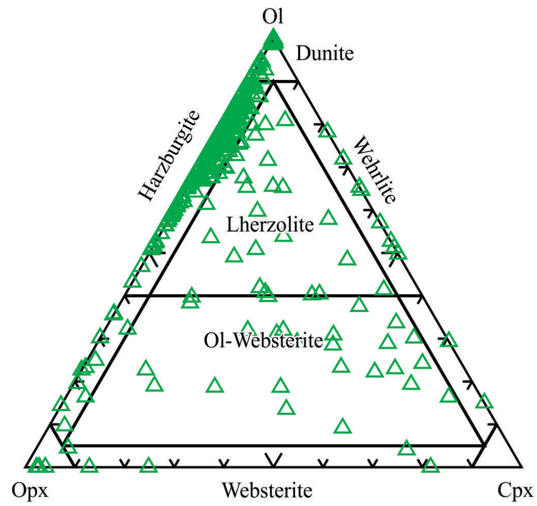

Figure 3. *Modal classification of ultramafic rocks. Mineral modes were calculated using IgPet 2018.*

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). They are also generally characterized by very low concentration of trace and REE elements. LREE determinations in these rocks may be unreliable (McGoldrick et al., 2018).

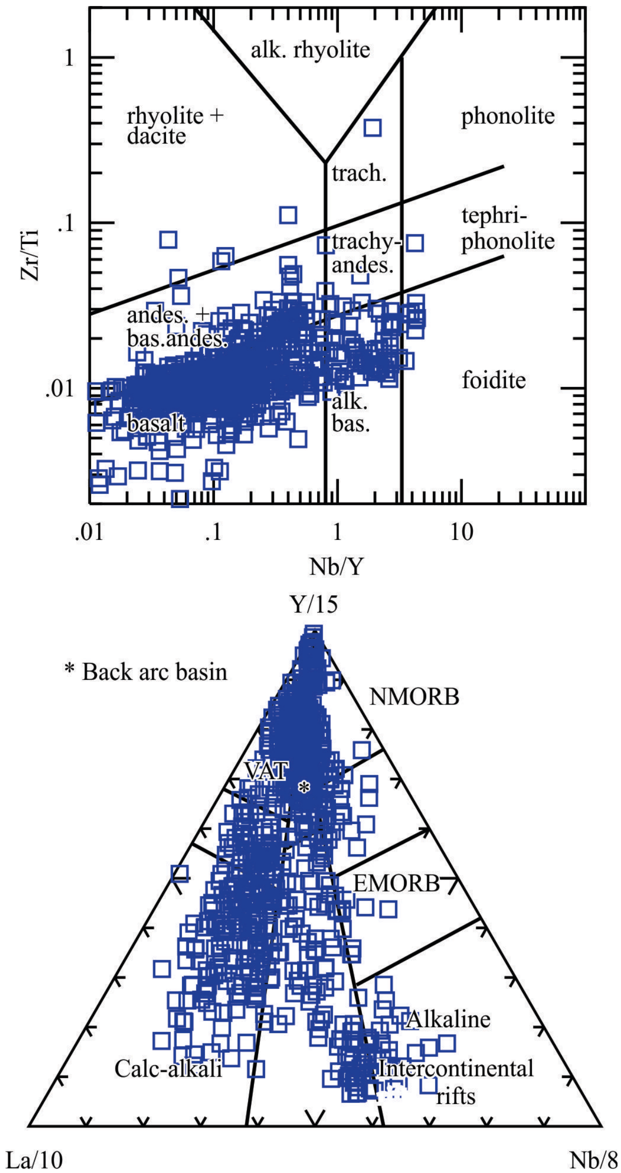

Figure 4. *Geochemical characteristics of mafic rocks. A. Rock type classification plot indicates predominantly basaltic composition (Pearce, 1996). B. Tectonic setting discrimination diagram indicates a variety of predominantly arc-like settings (Cabanis and Lecolle, 1989).*

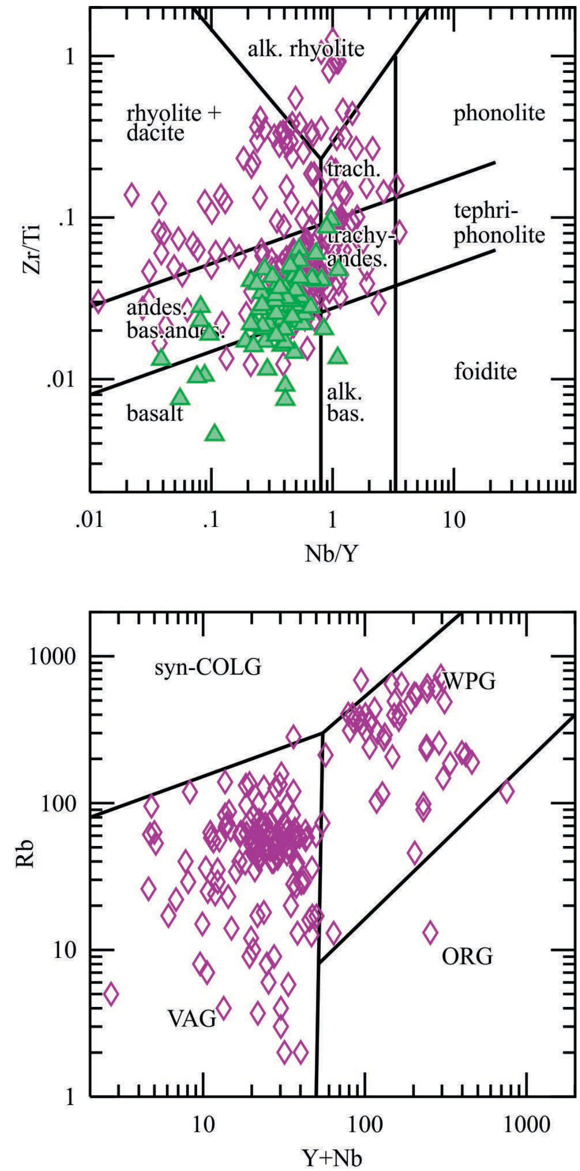

Figure 5*. Geochemical characteristics of felsic and intermediate rocks. A. Rock type classification plot indicates predominantly intermediate to felsic compositions (Pearce, 1996). B. Tectonic setting discrimination diagram indicates both arc and within-plate settings (Pearce et al., 1984).*

Mafic 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 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, and continental rift fields (Fig. 4b). These settings can also be inferred from normalized 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 (not shown).

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).

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