Volcanostratigraphy, Lithogeochemistry and U-Pb Geochronology of the Upper Hazelton Group, West-Central British Columbia: Implications for Eskay Creek–Type VMS Mineralization in Southwest Stikinia

By S.M. Gordee[1], J.K. Mortensen[1], J.B. Mahoney[2] and R.L. Hooper[2]

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INTRODUCTION

The Hazelton Group is one of the most widely exposed Mesozoic volcanic-arc successions in the Canadian Cordillera, occurring along nearly the entire length and breadth of the Stikine Terrane (Fig. 1). Despite hosting a number of significant mineral deposits (e.g., Eskay Creek–type volcanogenic massive sulphide [ECT-VMS] deposits, epithermal gold and associated copper-gold porphyry deposits in subvolcanic intrusions; Diakow *et al*., 2002), there have been relatively few regional studies of the nature of Hazelton Group arc magmatism outside of the immediate vicinity of known deposits (e.g., Tipper and Richards, 1976; Marsden and Thorkelson, 1992; Thorkelson *et al*., 1995).

This study investigates Hazelton Group successions in the Bella Coola and Whitesail Lake map areas of west-central British Columbia in order to constrain the evolution of the volcanic package and assess its potential for economic mineralization. This study builds upon the framework established through a joint federal-provincial Targeted Geoscience Initiative (TGI) that operated in the area from 2001 to 2004 (e.g., Haggart *et al*., 2004 and references therein), and aims to refine our understanding of the tectonic setting and specific depositional environment(s) of rocks emplaced during Hazelton arc volcanism and sedimentation. This could provide controls on the existence and/or nature of syngenetic mineralization within the Hazelton Group in this area.

Bella Coola is located within a rugged part of the Coast Mountains, and includes the topographic divide and transition zone between the Coast and Intermontane morphogeological belts (Fig. 1, inset). Specifically, the northeastern Bella Coola (NTS 093D) – southeastern Whitesail Lake (NTS 093E) map area is situated in southwestern Stikinia of the Intermontane Superterrane (Fig. 1). In this area (predominantly the eastern half of NTS 093D/15 and 093E/02), thick, laterally continuous, dominantly eastward-younging successions of Early to Middle Jurassic Hazelton Group form the high jagged massifs along the western boundary of Tweedsmuir Provincial Park. To the east of this area, exposures of the Hazelton Group are unconformably overlain by remnants of a moderately dissected Miocene peralkaline shield volcano that form the Rainbow Range (Diakow *et al*., 2002 and references therein). Exposures of Hazelton Group decrease progressively to the west, where they are unconformably overlain by the Cretaceous Monarch Assemblage and intruded by numerous Jurassic to Eocene plutons of the Coast Plutonic Complex. Volcanogenic strata within the study area are relatively structurally intact, in contrast to Hazelton Group and Monarch Assemblage exposures further to the west, which are variably deformed within the Waddington Fold and Thrust belt (Mahoney *et al*., this volume).

PRELIMINARY RESULTS FROM GEOLOGICAL MAPPING

Two summers of field mapping (2003–2004) in the northeastern Bella Coola – southeastern Whitesail Lake map area focused on the area between Jumble Mountain in the south and Mount Preston in the north (Fig. 2). Hazelton Group volcanosedimentary successions in this area represent a northwestern continuation of the package of mainly felsic volcanic strata that hosts the Nifty VMS occurrence in the east-central Bella Coola map area (e.g., Ray *et al*., 1998; Diakow *et al*., 2002; Haggart *et al*., 2004). Uranium-lead dating of a dacite breccia that hosts mineralization at Nifty indicates an age of 163.7 ± 0.4 Ma (M. Villeneuve, unpublished data), and this, together with several ca. 176 Ma dates and Early-Middle Jurassic fossil collections from the northeastern Bella Coola map area, demonstrates that Hazelton Group rocks in this area are roughly age equivalent to hostrocks of the Eskay Creek deposit.

This study targeted four main areas in the 30 km transect between Jumble Mountain and Mount Preston, including (from south to north): the Jumble Mountain – Ramsey Peak area, the Tsaydaychuz Peak – Butler Peak area, Tesla Mountain and the Rivers Peak – Mount Preston

[1]*Mineral Deposit Research Unit, Department of Earth and Ocean Sciences, The University of British Columbia, Vancouver, B.C.*

[2]*Department of Geology, University of Wisconsin at Eau Claire, Wisconsin, U.S.A.*

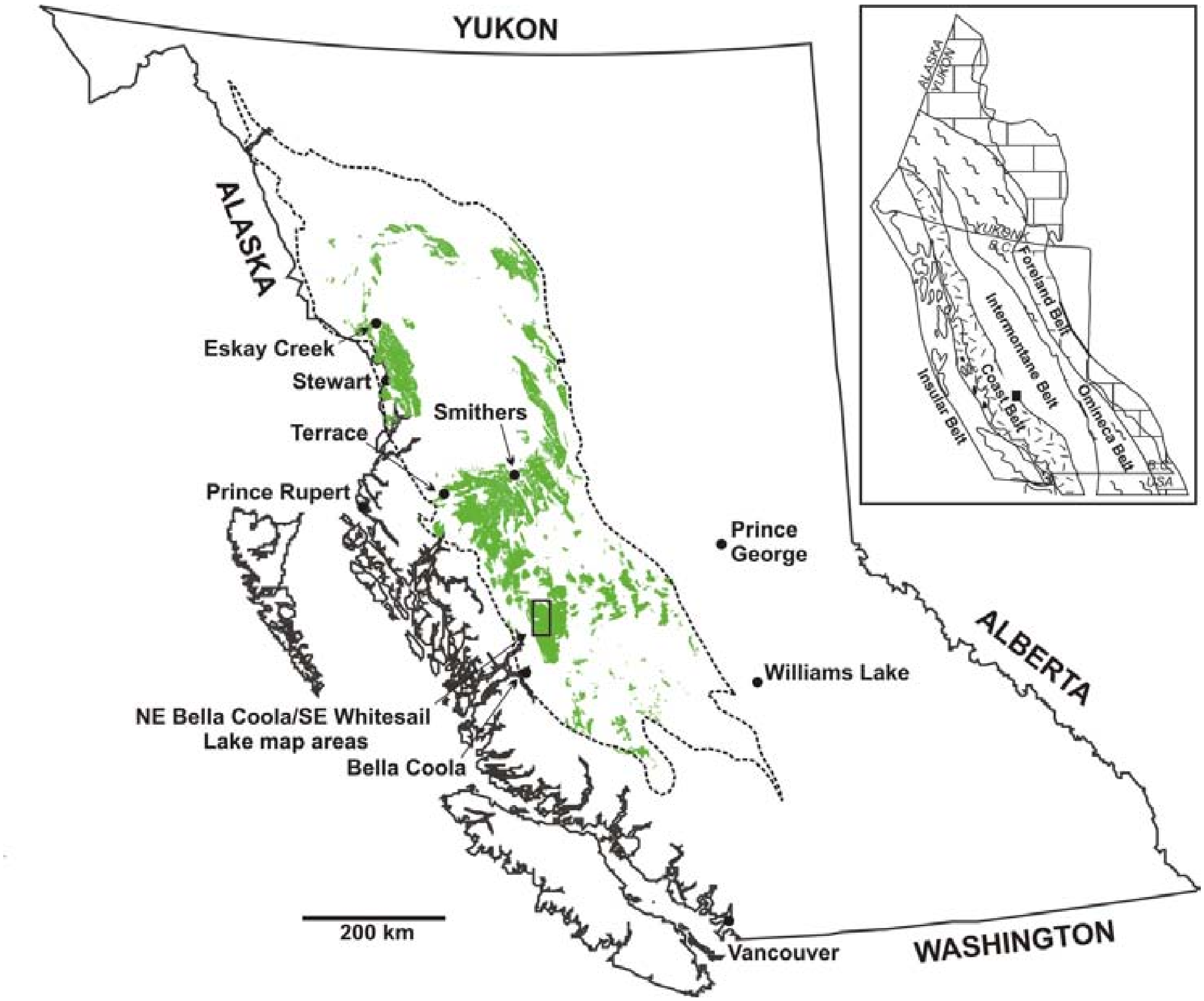

Figure 1. Distribution of Early-Middle Jurassic volcanosedimentary strata of the Hazelton Group (shown in green) within the Stikine Terrane of British Columbia (outlined with dashed boundary), showing specific localities referred to in the text, and the location of the northeast Bella Coola – southeast Whitesail Lake map area (black box). The inset map illustrates the morphogeological belts of the Canadian Cordillera (*modified after* Wheeler and McFeely, 1991).

area (Fig. 2). Fly camps were placed in central locations within these areas, and traverses were completed in accessible subalpine regions, where outcrop is continuous among snow and ice fields. Inaccessible areas were spot-checked with helicopter support.

Field investigations focused on the identification and development of large-scale lithological subdivisions; detailing and measuring volcanostratigraphic sections; defining large-scale structures; geochemical, isotopic and geochronologic sampling; and characterization of mineral occurrences recognized within the study area.

VOLCANOSTRATIGRAPHY

Geological mapping and analysis of numerous volcanostratigraphic sections in studied areas throughout the 2003 and 2004 field seasons permits a number of key observations to be made, based on interpretation of large-scale lithological subdivisions across the map area. Figure 3 shows a schematic volcanostratigraphic fence diagram of measured sections within the field area (section lines drawn in Fig. 2), and can be referred to throughout this section. Horizontal and vertical distances are scaled accordingly; U-Pb dates, fossil ages and lithological associations are used to correlate between the sections.

TSAYDAYCHUZ PEAK AND BUTLER PEAK AREAS

Map patterns and crosscutting relationships suggest that the Tsaydaychuz Peak – Butler Peak area forms the base of the volcanosedimentary sequence in the map area. Rocks of this area overlie mafic to intermediate, dominantly fragmental successions west of the East Sakumtha River, where a U-Pb date from a quartz-phyric dacite brec-

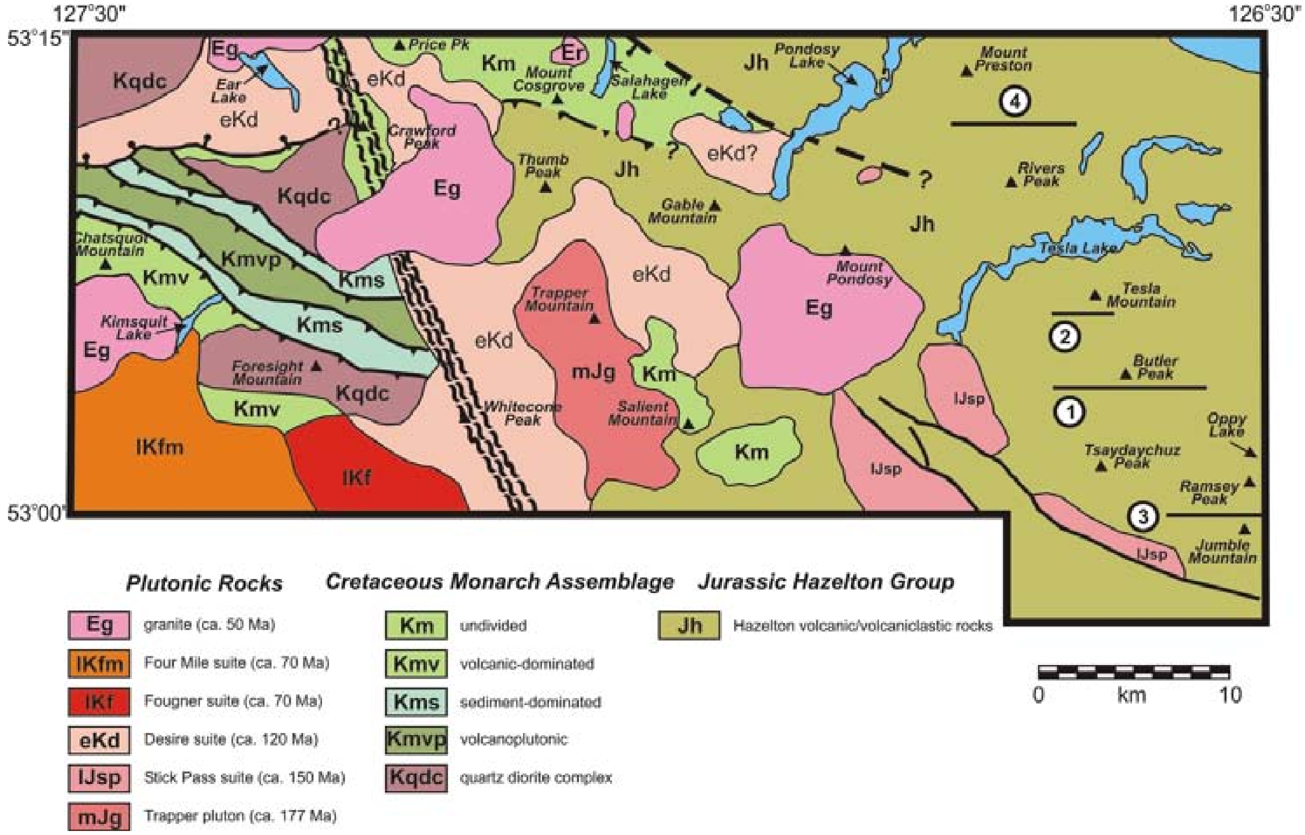

Figure 2. Generalized geologic map of the northeast Bella Coola/southeast Whitesail Lake map area, showing major lithologic subdivisions, structures and physiographic features referred to in the text (modified after Mahoney *et al*., 2005, this volume). Location of measured sections is indicated by bold lines adjacent to encircled numbers.

cia indicates an age of 191 ± 12 Ma (R.M. Friedman, unpublished data). Separating the two sections is a broad, northwest-trending belt of complexly interfingering aphanitic basalt, and very fine to medium-grained diorite and lesser quartz diorite ('microdiorite'); the latter may represent recrystallized mafic flows and/or small pyroxene diorite plug-like intrusions (Haggart et al., 2004). Importantly, this belt of mafic-intermediate rocks may record the early stages of the widespread basaltic-andesitic volcanism that characterizes the Tsaydaychuz Peak – Butler Peak region.

Tsaydaychuz Peak is the highest massif within the Whitesail Lake map sheet. At 9085 feet (2769 m) in elevation, its vertical walls and extensive ice cover render the mountain completely inaccessible, and has limited us to numerous spot checks along its flanks. Extensive traversing has been completed in the Butler Peak area and, assuming that no major structure exists between the two peaks, volcanogenic strata and field relationships observed at Butler Peak are presumed to extend to its sister mountain to the south. Traverses completed in the Butler Peak area encompass the subalpine region between north Tsaydaychuz Peak and north Butler Peak (Fig. 2). Strata in the area generally strike north-northwesterly and dip gently to moderately to the east; exposures west of Butler Peak are dominated by volcaniclastic rocks, while rock types farther upsection to the east are dominated by intermediate and lesser mafic flows and subvolcanic intrusions.

Volcanostratigraphy west of Butler Peak is dominated by orange-purple, massive, coarse-grained tuff-breccia, lapilli tuff and lesser tuff. Tuff-breccia and lapilli tuff units range from 1 to 25 m in thickness and are dominantly very lithic and crystal-rich; modal phenocryst assemblages (plagioclase and rare quartz) suggest an intermediate to felsic composition for these fragmental rocks. Tuffs rare throughout this area; these units, which range from <1 to 5 m in thickness, are typically very light grey to tan in colour, and plagioclase is locally observed as the only phenocryst phase. Pyroclastic rocks constitute about 45 vol % of exposed bedrock in the west Butler Peak region, and are intercalated with lesser (~15%) sandstone and mudstone beds. Ignimbrite units commonly display a gradational upper contact with overlying sedimentary beds, which are sharply overlain by subsequent ignimbrite units. Volcaniclastic rocks are typically either a deep purple-maroon and dark green (more typical of Hazelton Group sediments throughout the Bella Coola and Whitesail Lake map areas) or white to tan to grey in colour. They generally consist of interbedded, thin to medium-bedded, dominantly parallel, wavy and locally ripple crosslaminated, ± granule ± pebble mudstone and lesser conglomerate, sandstone and siltstone. Sedimentary rocks are typically immature, ranging from poorly to moderately well sorted, with

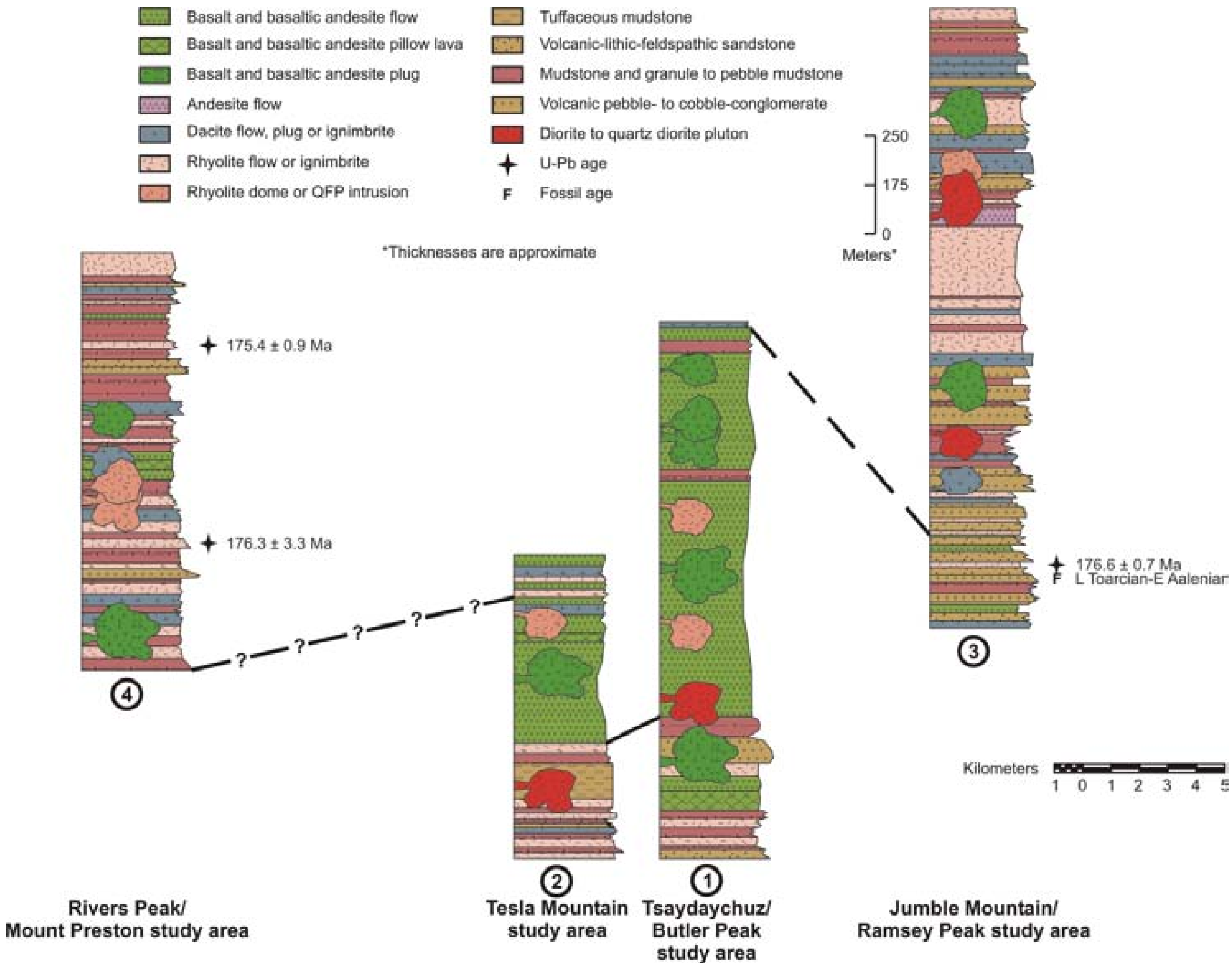

Figure 3. Measured volcanostratigraphic sections of the Hazelton Group within the northeast Bella Coola – southeast Whitesail Lake map area.

angular to subangular clasts of aphanitic to plagioclase±hornblende–phyric basalt, andesite, dacite and rhyolite. Fossils have not been found in this area.

The remaining 40% of outcrop in the west Butler Peak region consists of mafic lava flows, which occur in two broad, north-trending belts across the map area. The bases and tops of these flows are commonly not exposed but, where present, occur as metre-scale brecciated zones. Flows range from dark grey-purple to dark grey-green, are aphyric to plagioclase±pyroxene phyric, variably amygdaloidal (epidote and quartz-filled) and remarkably poorly layered. Crude compositional and/or textural boundaries (on a scale of tens of metres) within flow(s) that are approximately concordant with local strike trends may represent differences between individual flows, or may simply be variations within a single flow. One spectacular exposure of radiating cooling joints within the sequence (approximately 25 m high) may represent a cross-section through a lava feeder tube. Part of the volcanosedimentary sequence in this region is assumed to be subaqueous on the basis of an outcrop of orthogonally dissected, pillowed basaltic andesite, which is exposed along a vertical cleft on the southwestern margin of the field area (Fig. 4). A number of small, bladed-plagioclase, andesite porphyry plugs and associated dikes cut the volcanic successions in the area, and are interpreted to represent hypabyssal subvolcanic intrusions.

Geological mapping suggests that the Tsaydaychuz Peak region, which lies directly along strike to the south, likely represents the southern continuation of the volcanostratigraphic section documented in the Butler Peak region. Numerous spot checks and sample collections completed along the flanks of the massif yielded similar rock types and lithological associations, which supports this generalization.

The size and abundance of basalt to basaltic andesite lava flows and bladed-plagioclase porphyry plugs increases dramatically east of Butler Peak. The area is being collectively described as the Butler Peak andesitic complex, and is characterized by a complexly interfingering assemblage of basalt to basaltic andesite lava flows, dikes and hypabyssal intrusions, gabbroic to dioritic plugs, widespread microdiorite and <10% welded lapilli tuff and intercalated volcanogenic sediments; the latter are commonly locally folded around intrusive units. As in the lower portion of the section, individual lava flows in this area are commonly difficult to subdivide; lava flow margins, where observed, are highly brecciated over a thickness of 3–5 m. Intrusive relationships are complex and the relative timing between units is often ambiguous; this, coupled with the compositional similarities shared between rock types, leads to the interpretation that this area comprises a mafic eruptive centre. Geochemical comparisons and U-Pb dating studies are currently underway to test this hypothesis and potentially confirm the coeval nature of rocks in this area.

At least four rhyolite domes have been identified that intrude the volcanic sequences in the Tsaydaychuz Peak – Butler Peak area. Domes are pink to white in colour, aphanitic to plagioclase±quartz -phyric, massive to flow-banded, rarely fragmental, and associated with gossans characterized by disseminated pyrite west of Butler Peak. It is uncertain whether these units represent intrusive and/or extrusive domes.

TESLA MOUNTAIN AREA

The Tesla Mountain area comprises a low, east-trending ridge immediately south of Tesla Lake, approximately 4 km north of Butler Peak (Fig. 2). Structural trends suggest that this area should represent the northern continuation of the east-dipping outcrop belt in the Tsaydaychuz Peak – Butler Peak region; although this can be assumed based upon lithological and structural similarities between the two areas, a number of differences were noted. Important differences include a) a decrease in mafic volcanic rocks; b) a subsequent increase in the proportion of volcaniclastic material, including a thick section of pyritiferous tuffaceous mudstones; c) the existence of several mineral showings; and d) a pervasive, well-developed deformation fabric throughout the area.

Figure 4. Cross-section through a stack of basaltic andesite pillow lavas in the west Butler Peak region. Note the large pillow in the upper left corner. Ice axe (~60 cm) for scale.

The widespread mafic volcanic rocks that characterize the Tsaydaychuz Peak – Butler Peak region extend northward into the Tesla Mountain area, but decrease in volume significantly across the 4 km distance; mafic flows and subvolcanic intrusions are subordinate to volcaniclastic rocks and fine-grained volcanogenic sediments in this area. In general, the western half of this mountain consists of volcanogenic sedimentary rocks and lesser welded ignimbrite sequences with interbedded mafic lava flows that increase in thickness and number to the east across the summit of Tesla Mountain. Complex, outcrop-scale folding is developed west of Tesla Mountain, where mafic plugs intrude volcaniclastic sequences, a lithological association that is consistent with observations made in the west Butler Peak region. Possible pillows in flow-banded basaltic flows northwest of Tesla Mountain suggest that part of this section may represent a submarine sequence.

A thick section of tuffaceous mudstone exposed west of Tesla Mountain is unique to the field area. This sequence is approximately 100 m thick and consists of interbedded, thin to medium-bedded, parallel-laminated mudstone and rhyolitic tuffaceous mudstone, and lesser siltstone and sandstone (Fig. 5). Outcrops weather rusty orange in part, and upon initial examination appear to be devoid of sulphides; however, cut slabs reveal thin conformable layers of disseminated to semimassive pyrite. Petrographic studies are in progress to determine whether this represents syngenetic or epigenetic mineralization.

Several small rhyolite plugs and associated dikes similar to those described near Butler Peak cut the volcanic sequence near the summit of Tesla Mountain. These rhyolites are highly silicified and are responsible for wide alteration haloes and minor disseminated pyrite in the surrounding country rock. At least one claim has been staked and several prospecting pits excavated on or near the margins of these intrusions. Mineralization, in the form of narrow veins of hematite, pyrite, chalcopyrite and malachite, has been observed within mafic dikes at two locations in the west Tesla Mountain area. A zone of fracture-controlled, comb-textured quartz veins occurs near the top of Tesla Mountain; these veins are devoid of mineralization, but may be related to "rather disappointing", narrow and low-grade Cu and Au-bearing veins described in this area by Duffell (1959).

The Tesla Mountain region displays a very well developed, pervasive, east-trending closely spaced cleavage. This fabric extends to the south into the northwest Butler Peak region, where it is locally well developed, but does not extend across Tesla Lake into the Rivers Peak region to the north. The nature and localization of this fabric suggests that Tesla Mountain represents a zone of localized strain associated with regional deformation. Much of the vein and dike-hosted mineralization observed in the Tesla Mountain area appears to be concentrated along these zones of structural weakness.

It has been hypothesized that the large linear lakes and valleys in the Tesla Lake area may represent major faults bounding large structural blocks (e.g., Duffell, 1959). South of Tesla Mountain, Lower to Middle Jurassic volcanic stratigraphy forms an east-dipping, eastward-younging homocline, based on geological mapping, paleontology and U-Pb ages. Conversely, north of Tesla Lake between Rivers Peak and Mount Preston, strata dip and young to the west and northwest, demonstrating the existence of an east-trending structure that lies within the Tesla Lake basin.

UPPERMOST VOLCANOSTRATIGRAPHY

Uranium-lead dating of tuffs within the Rivers Peak – Mount Preston and Jumble Mountain – Ramsey Peak areas has established that the two homoclines are of similar age, and geological mapping suggests that they represent the youngest Hazelton Group strata in the study area. Individual units cannot be traced between the two areas; however, broadly similar rock types on a scale of hundreds of metres, together with U-Pb dating, demonstrate that these areas represent similar volcanic and sedimentary depositional environments.

JUMBLE MOUNTAIN AND RAMSEY PEAK AREAS

Detailed geological mapping carried out during the 2004 field season in the Jumble Mountain – Ramsey Peak area has significantly expanded the area covered during the 2003 field season. Previous work concentrated on the area between northeast Jumble Mountain and Ramsey Peak, whereas work during the 2004 field season focused on the area further to the north, between Ramsey Peak and Oppy Lake. Results from work completed in this area during the 2003 field season are detailed in Mortensen *et al*. (2004).

In general, the area between Jumble Mountain and Oppy Lake consists of an eastward-younging succession of thick ignimbrites, intercalated with lesser marine sandstone and siltstone, mudstone, conglomerate and mafic lava flows near the base. Near Jumble Mountain, the section is cut by numerous mafic plugs, sills and dikes, which may be the source of these minor basaltic lava flows. Mafic flows are generally dark green to red, aphanitic and variably flow banded and brecciated, whereas the intrusive equivalents are dark green to grey and range from aphanitic to plagioclase±pyroxene±hornblende phyric basalt to andesite to microdiorite plugs. Mafic rocks in this area presumably represent the southern extent of the mafic eruptive centre in the Tsaydaychuz Peak – Butler Peak area, which lies directly along strike to the north.

Ignimbrites in this area are pink to purple to grey, massive, unstructured, poorly to moderately welded, lithic and crystal rich, and range from tuff to lapilli tuff to tuff-breccia.

Sedimentary rocks are variably fossiliferous and consist of fine to coarse-grained feldspathic lithic wacke and calcareous lag deposits. Fossils present in the coquinas include a diverse assemblage of bivalve taxa, high-spired gastropods, rare belemnoids, and possibly mollusc fragments, most of which are thick-shelled and robust, and of shallow-marine forms that characterize the sublittoral region. Many shells have been abraded due to high-energy postmortem processes; this, coupled with a distinct grading and lateral continuity of shell beds, suggests that these beds represent storm deposits. The articulated nature of shells in some beds implies a rapid sedimentation rate. Ammonites recovered from this section during previous field seasons have been identified as probable Early Aalenian taxa (T.P. Poulton, personal communication, 2003), and a U-Pb zircon age of 176.6 ± 0.7 Ma was obtained from an overlying rhyolitic crystal-lithic tuff (R.M. Friedman, unpublished data; Mortensen *et al*., 2004).

Volcanic composition changes to a more intermediate to felsic-dominated system farther upsection between Ramsey Peak and Oppy Lake, as evidenced by a decrease in mafic lavas and subvolcanic intrusions and a subsequent increase in intermediate to felsic ignimbrites and associated plugs and dikes. Ignimbrites range from tuff to lapilli tuff to tuff-breccia and are purple to pink to dark grey, massive, poorly to moderately welded, crystal- and lithic-rich, and typically 5–20 m thick. Several very coarse grained volcanic units within this section may represent vent-proximal and/or intracaldera facies. These coarse facies range from lapillistone to tuff-breccia to block tuff, and commonly include lapilli to block-size, chloritized pumice/fiamme. At least two anomalously thick tuffaceous units exist within this section, each of which includes a very thick, very densely welded facies. These units are homogeneous throughout their observed lateral extent, and are purple,

Figure 5. Tuffaceous mudstone sequence with possible syngenetic sulphide mineralization at Tesla Mountain. Rock hammer (~40 cm) for scale.

massive, very densely welded, rhyolitic±lithic crystal-vitric tuff to lapilli tuff, with unwelded and lithic and crystal-rich basal and upper contacts (Fig. 6). The calculated thickness of one of these units exceeds 400 m, a thickness that may also support an intracaldera or near- vent setting for rocks in this area.

As in the Tsaydaychuz Peak – Butler Peak region, primary volcanic units in this area commonly display a gradational upper contact, transitioning into lithic and crystal-rich wacke and mudstone units that, in turn, are sharply overlain by succeeding ignimbrite units. Sedimentary rocks in this package are dark maroon, thin to medium-bedded to massive, parallel-laminated to structureless mudstone to granule to pebble mudstone. Individual mudstone beds commonly contain up to 10% articulate to inarticulate armored accretionary lapilli up to 1 cm in diameter, which are interpreted to represent the erosional remains of a phreatoplinian eruption (Fig. 7). This section also contains several thick exposures of massive, matrix-supported, polymict, pebble to cobble conglomerate. Clasts are subangular to rounded and comprise a variety of rock types, including mafic to felsic lavas, hypabyssal intrusions and rare intermediate plutons. These conglomerate beds are massive and homogeneous, containing very few sedimentary structures. Rare parallel and locally crosslaminated sandstone lenses have been observed within these conglomerate sequences. Rocks within this volcanostratigraphic section are remarkably devoid of fossils and, where observed, fossil fragments are always associated with very coarse grained facies.

Field mapping for this study terminated at the ridgeline 3.5 km north of Ramsey Peak, approximately 4 km southwest of Oppy Lake; however, this homoclinal volcanosedimentary succession extends at least as far as Oppy Lake, where Late Bathonian or Early Callovian fossils have been recovered (H. Frebold, unpublished data).

Figure 6. Densely welded rhyolitic ignimbrite unit within the upper Ramsey Peak section. This ~400 m thick unit may represent an intracaldera facies. Pencil (~8 cm) for scale.

RIVERS PEAK AND MOUNT PRESTON AREAS

The Rivers Peak – Mount Preston area consists of an isolated west-dipping block that is presumably separated from the Tesla Mountain block to the south by a fault beneath Tesla Lake, and from the Mount Pondosey massif to the west by a north-trending structure that forms the Pondosey Pass and South Creek topographic low (Fig. 2). A U-Pb zircon age of 176.3 ± 3.3 Ma from a rhyolite lapilli tuff near the base of the section southeast of Mount Preston, together with a U-Pb zircon age of 175.4 ± 0.9 Ma from the top of the section immediately south of Mount Preston, indicates that volcanogenic strata in this area are coeval with strata in the Jumble Mountain region. Broad-scale volcanostratigraphic similarities between the two areas reinforce this correlation. Specifically, rock types in the Rivers Peak – Mount Preston area are consistent with those documented in the north Ramsey Peak area, which lies along strike 30 km to the south.

Rocks in this area are characterized by coarse-grained, intermediate to felsic volcanic facies and minor intercalated sedimentary rocks, which increase in abundance and eventually predominate over ignimbrite units near the top of the section south of Mount Preston. Primary volcanic units in this area include andesitic to rhyolitic lapilli tuff to tuff-breccia units that are pink to purple to maroon in colour, thick and massive, poorly to moderately welded, and notably lithic and crystal-rich. Sedimentary rocks consist of maroon mudstone to granule to pebble mudstone and lesser feldspathic lithic wacke intercalated with thin (10–30 cm thick) lithic- and crystal-rich chloritic lapilli tuff sequences. These intermediate composition tuff units are spatially and temporally associated with, and may be the eruptive source of, ballistic blocks that produce block sag structures within several mudstone horizons in this area. Northeast of Rivers Peak, a thin, thinly bedded limestone unit is immediately overlain by a 25 m thick section of massive, unstructured, very coarse grained, quartz-eye feldspathic sandstone (Fig. 8). Quartz and plagioclase grains are euhedral to subrounded and broken, respectively, and are assumed to represent detritus shedding off a proximal rhyolite flow or granitic pluton. Rare (<1%), subangular to rounded, aphanitic mafic to intermediate and quartz-phyric rhyolite clasts occur along the base of this unit. This anomalous sandstone unit is laterally discontinuous, and may be infilling a paleovalley or channel. A collection of marine fossils recovered from a calcareous sandstone unit near the summit of Rivers Peak is currently being examined to provide additional age constraints for this section and to assist in determining the environment of deposition.

Sedimentary rocks dominate in the Mount Preston area, where they are characterized by maroon mudstones intercalated with lesser rhyolitic lapilli tuff and mafic to intermediate flows and sills. The top of the section in this area is marked by a thick, purple, massive, very densely welded rhyolite lapilli tuff unit, which may correlate regionally with one of the aforementioned units observed in the Ramsey Peak area.

Southeast of Mount Preston, near the base of the measured section in the area, mudstones and lesser rhyolitic tuffs are intercalated with a series of plagioclase-phyric to aphyric, variably amygdaloidal basalt to basaltic andesite flows, pillow lavas and broken pillow breccia, which are intruded by an aphanitic basaltic plug. These basaltic pillow lavas are intruded by a dacitic to rhyodacitic flow-dome complex with a well-developed carapace breccia (refer to Mortensen *et al*., 2004 for photograph). Geological mapping in this area during the 2004 field season has demonstrated the existence of numerous other extrusive felsic (dacitic to rhyolitic) domes in this area. The domes are highly fractured and silicified, with well-developed carapace breccias, and are aphanitic to sparsely quartz phyric. Geochemical analysis of several dome samples yielded 68–98% silica; this high degree of silicification makes the domes more resistant to weathering than local country rock, and they subsequently form round knobs along a linear outcrop belt. The linear distribution of these domes follows the trace of an east-trending extensional fault south of Mount Preston. This fault is characterized by zones of intense fracturing with abundant slip surfaces, and well-developed ferricrete overlying fault breccia. It may represent a synvolcanic extensional structure — a zone of weakness through which the spatially and potentially temporally associated rhyolite domes were intruded. A small granite stock intrudes the fault-dome sequence; this intrusion is lithologically similar to a suite of ca. 148–149 Ma plutons mapped to the south in the northeastern Bella Coola map sheet (Fig. 9). Uranium-lead dating studies of felsic dome samples and this granite stock are currently underway, and will assist in constraining the age of this extensional structure.

The Pond – Rivers Peak mineral occurrence in this area (BC MINFILE 093E 058) and impressive gossans developed south of Mount Preston are characterized by finely disseminated pyrite, and occur in wallrocks immediately adjacent to this structure. Small (centimetre-scale) bodies of chalcopyrite±bornite–bearing vein breccia were observed in several areas in the Mount Preston – Rivers Peak area.

YOUNGER MAGMATISM

The upper Ramsey Peak section is cut by a small pyroxene-hornblende quartz diorite stock, which is texturally and compositionally similar to other small dioritic stocks documented throughout the field area. Argon-argon (hornblende) dating of this pluton indicates an age of 136.4 ± 1.5 Ma, which is temporally consistent with a ca. 139–132 Ma intrusive suite documented immediately to the south in the Bella Coola area (T.D. Ullrich, unpublished data; Haggart *et al*., 2004).

The entire field area is cut by numerous grey-green, centimetre- to metre-scale (up to 10 m in width), aphanitic to plagioclase±pyroxene±hornblende–phyric basalt to andesite dikes. These dikes are typically randomly oriented but are locally consistently oriented where they intrude local fracture sets and faults; one such dike swarm has been observed at Butler Peak. The aforementioned quartz diorite pluton at Ramsey Peak is cut by these dikes, suggesting that these dikes are at least partly post–ca. 136 Ma, and therefore represent a younger magmatic event in the area.

The upper Mount Preston volcanostratigraphic section is cut by a biotite-quartz–phyric rhyolite porphyry dike, which has been dated (Ar-Ar biotite) at 51.87 ± 0.79 Ma (T.D. Ullrich, unpublished data). This Early Eocene age is interpreted to represent the youngest magmatic event within the study area, and suggests correlation with the Ootsa Lake Group, which is diffusely exposed throughout the eastern half of the Whitesail Lake map sheet.

GEOCHRONOLOGY

In addition to the four U-Pb and Ar-Ar dates completed from samples collected during the 2003 field season (several samples yielded insufficient zircon for dating), 15 samples collected throughout the study area in the 2004 field season are currently in the mineral-separation stage for U-Pb zircon dating.

Several rhyolite tuff samples from the study area are being dated, which will assist in constraining the age range for each measured volcanostratigraphic section. A number of rhyolitic intrusive (?) and extrusive dome samples from the Rivers Peak and Butler Peak areas are being dated to de-

Figure 7. Articulate armored accretionary lapilli in rhyolitic vitric-lithic crystal tuff in the Ramsey Peak area. Accretionary lapilli are quite common throughout the entire field area, and occur as primary and reworked fragments within maroon mudstone and fine-grained tuffaceous units. Rock hammer for scale. Field of view is approximately 30 cm.

termine if the domes represent synvolcanic intrusions. A sample of microdiorite from the Butler Peak andesitic complex may help constrain the age of the thick pile of mafic lavas and subvolcanic intrusions in this area. Detrital zircons studies from one or more sandstones throughout the field area, including the quartz-eye feldspathic sandstone from the Rivers Peak section, may provide controls on the source regions that were eroding during the Middle Jurassic.

Figure 8. Very coarse-grained quartz-eye feldspathic sandstone in the Rivers Peak area. Gritty-looking regions comprise euhedral to subrounded and broken quartz and plagioclase. Rusty orange and green, more coherent splotches comprise aphanitic, mafic to intermediate volcanic clasts that occur near the base of this unit. Pencil (~8 cm) for scale.

LITHOGEOCHEMISTRY

Geochemical studies of volcanic rock units from the northeastern Bella Coola – southeastern Whitesail Lake map area are underway to characterize the geochemical affinity of Middle Jurassic Hazelton Group volcanic rocks in this area and place constraints on the paleotectonic setting in which they were emplaced.

Complete major, trace and rare earth element analyses have been obtained from 64 representative samples of lava flows, ignimbrites, intrusive and extrusive domes, sills, dikes and hypabyssal intrusions from the study area. Geochemical analyses from samples collected in the 2004 field season have only recently been obtained, and have not yet been examined in detail. These new data and the analyses from the study area completed in 2003, together with reconnaissance data from host volcanic rocks at the Nifty VMS occurrence in the east-central Bella Coola map area (e.g., Ray *et al*., 1998) are shown on several geochemical discriminant plots in Figure 10. Mafic dike samples are not included on these discriminant plots.

Volcanic and subvolcanic rock units in the northeastern Bella Coola – southeastern Whitesail Lake map area geochemically resemble the broadly age equivalent Middle Jurassic host volcanic rocks at the Nifty VMS occurrence, which is on strike to the southeast. When plotted on a TAS diagram, samples from the study area are moderately bimodal in composition (mainly basaltic to basaltic andesitic and dacitic to rhyolitic); however, on a discriminant plot of immobile trace element ratios (Nb/Y vs. Zr/TiO_2), the samples span the basaltic to rhyolitic compositional range, and the Nifty samples show a distinctly higher Nb/Y ratio than do samples from the current study area. The felsic units are all subalkaline, but the mafic units include both subalkaline and alkaline compositions. On an AFM diagram, the Nifty samples and the felsic intrusive and extrusive samples from the study area are calcalkaline to transitional in composition, whereas mafic intrusive and extrusive samples from the study area fall almost exclusively into the tholeiitic field. A plot of Rb vs. Y+Nb suggests that all of the volcanic rocks formed in a volcanic-arc setting; however, immobile trace element plots such as V vs. TiO_2 indicate that the mafic volcanic and subvolcanic units from the study area include both island-arc tholeiites and back-arc tholeiites. These mixed volcanic-arc–back-arc geochemical signatures are very similar to those described by Barrett and Sherlock (1996) at Eskay Creek, and are consistent with an overall rifted arc (intra-arc or back-arc) setting.

ALTERATION AND IMPLICATIONS FOR VMS POTENTIAL

Mafic rocks throughout the entire study area have undergone a high degree of alteration, which is characterized by pervasive epidotization in basaltic and basaltic andesitic flows, plugs, dikes and sills. The resulting epidosite occurs as large (up to 1 m in diameter) clots, and is commonly spatially associated with intense quartz and epidote-veining and large jasperite clots, and may reflect semiconformable, synvolcanic alteration above a subvolcanic intrusion. Although no Middle Jurassic intrusions have been recognized within the study area, at least one Middle Jurassic pluton has been identified, ~30 km to the west-southwest: the Trapper Pluton is a large (exposed over 200 km^3), coarse-grained granite pluton with a U-Pb zircon age of 177.4 ± 0.7 Ma (P. van der Heyden, unpublished data; Fig. 2; for more details, *see* Mahoney *et al*., this volume). We speculate that the Trapper and possibly other coeval intrusions that are not exposed at the present level of erosion may have been subvolcanic equivalents of the locally abundant rhyolitic ignimbrite units that have been recognized throughout the study area and yielded similar U-Pb zircon ages. These intrusions may have driven hydrothermal circulation that produced widespread, semiconformable alteration (characterized by development of epidosite and jasperoid) in more permeable portions of the sequence.

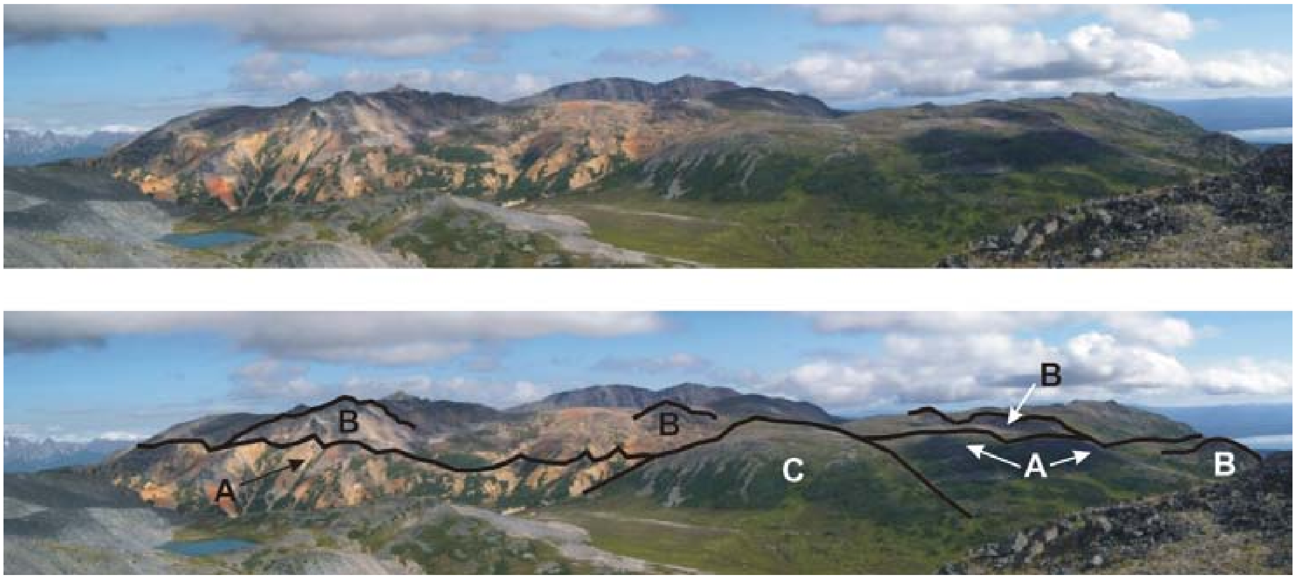

Figure 9. View to the north toward Mount Preston (not visible) from the north Rivers Peak region. The trace of an east-trending extensional fault is indicated by (A), which may represent a synvolcanic extensional structure along which Jurassic (?) rhyolite domes (B) intruded. (C) represents a small biotite-hornblende granite stock that intrudes Jurassic volcanogenic strata in the area. Width of image is ~5 km.

Specific results of our study that emphasize the high potential for VMS mineralization in Hazelton Group volcanogenic strata in the Bella Coola – Whitesail Lake map areas include 1) the linear arrangement of extrusive felsic domes; together with 2) indications of a synvolcanic extensional structure in the Rivers Peak – Mount Preston area; 3) evidence for shallow water, submarine deposition, as indicated by specific fossil assemblages, sedimentary structures and pillow lavas; 4) the presence of known Middle Jurassic syngenetic (e.g., Nifty) and epigenetic mineral occurrences (e.g., Mortensen, this volume); 5) stratiform pyrite occurring locally within tuffaceous mudstones at Tesla Mountain; and 6) widespread epidosite clots that may reflect semiconformable alteration above a buried subvolcanic intrusion.

ONGOING RESEARCH

Ongoing research for this study includes: (1) compilation of detailed measured volcanostratigraphic sections; (2) petrographic studies of volcanic and sedimentary rocks from the study area; (3) processing of U-Pb samples collected during the 2004 field season; (4) detailed lithogeochemical comparisons with other Hazelton Group suites available from throughout Stikinia and volcanic hostrocks for the Eskay Creek deposit; and (5) studies of the specific volcanologic, sedimentologic, and large scale tectonic processes operating during deposition of Middle Jurassic Hazelton Group rocks in this area.

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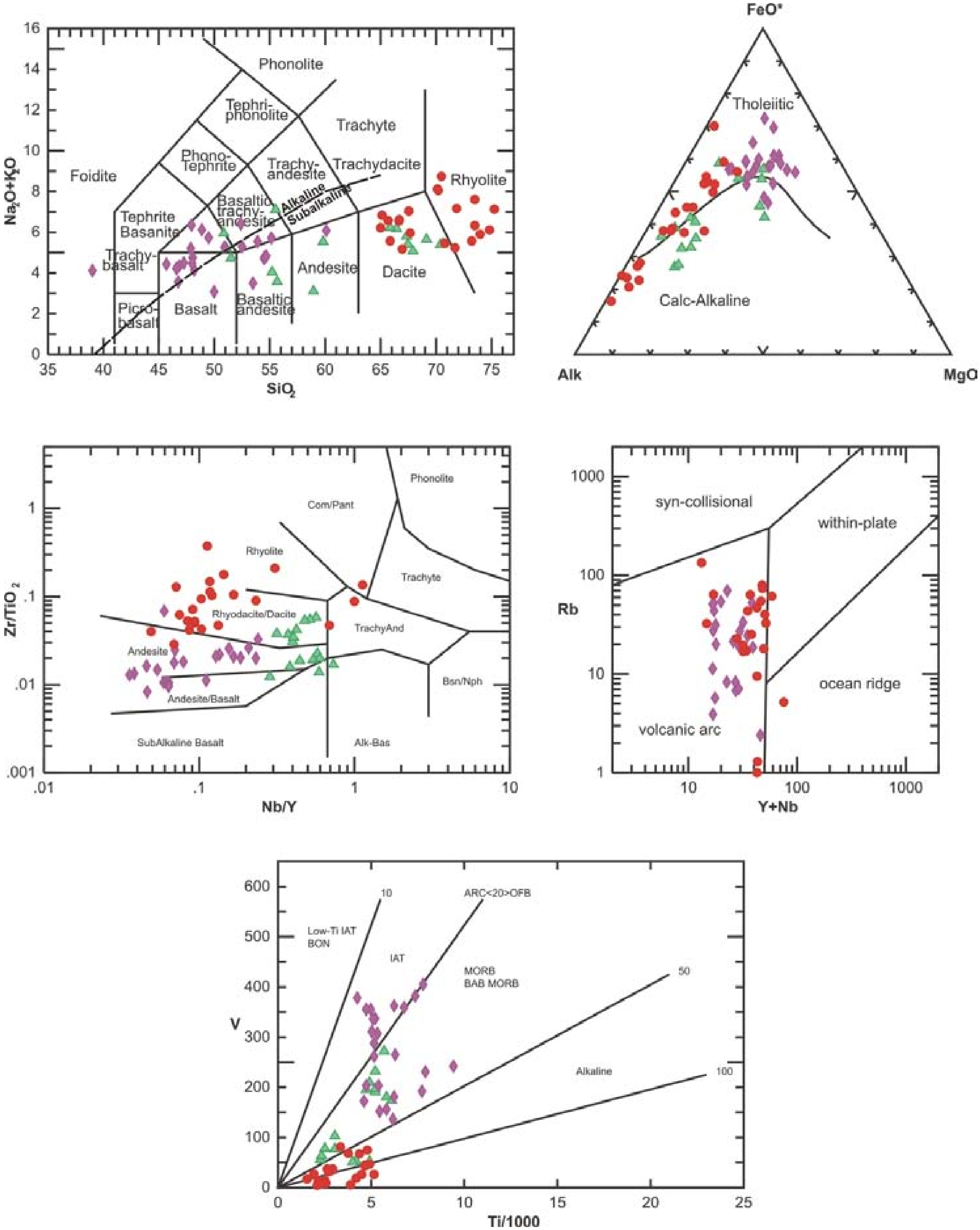

Figure 10. Geochemical discriminant diagrams for volcanic and hypabyssal rocks in the northeastern Bella Coola – southeastern Whitesail Lake map area. Diamonds indicate mafic to intermediate lava flows and plugs, and circles indicate intermediate to felsic lava flows, ignimbrites and plugs. Triangles represent analyses of mafic to felsic samples from the vicinity of the Nifty prospect (data from Ray *et al*., 1998).

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