Geology of the Eastern Bella Coola Map Area (93 D), West-Central British Columbia[1]

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INTRODUCTION

Eastern Bella Coola map area (NTS 093D), in west-central British Columbia, is a rugged part of the Coast Mountains, and includes the topographic divide and transition zone between the Coast and Intermontane morphogeological belts. The principal objectives of the Bella Coola Targeted Geoscience Initiative (TGI) are to assess little known Mesozoic volcanic assemblages in eastern Bella Coola map area for their massive sulphide (VMS) potential, and to improve understanding of the geologic evolution of this part of the central Coast region. A significant component of the TGI program was a bedrock mapping study. It was undertaken during 2001-2002 and covered an area greater than 5000 km^2 between the Dean Channel and South Bentinck Arm on the west and the western boundary of Tweedsmuir Provincial Park on the east (Figure 1). The Geological Survey of Canada and the British Columbia Geological Survey in conjunction with the University of Wisconsin-Eau Claire and the University of British Columbia conducted the Bella Coola program.

This report briefly describes the geology of the eastern Bella Coola map area, which includes regions south of the Bella Coola River (093D/01, 02, 07, 08) and north of the Dean River (093D/15). Geological results from the first season are presented in a series of reports, including Diakow *et al.,* (2002), Hrudey *et al.,* (2002), Israel and Kennedy (2002), Mahoney *et al.,* (2002), Sparks and Struik (2002) and Struik *et al.,* (2002). Nomenclature used in this report, particularly that of the plutonic rocks, supersedes that utilized in those reports.

GENERAL GEOLOGY

The area eastern part of Bella Coola map area marks the transition from the Coast Plutonic Complex into the Intermontane Belt (Figure 1 inset). In general, the geology of the study area is dominated by two, northwest-trending, belts of volcanic and sedimentary rocks representing Jurassic and Cretaceous island arcs, elements of the Stikine tectonostratigraphic terrane of the Intermontane Belt (Figure 1). These rocks are intruded by westerly-increasing volumes of plutonic rocks, some considered comagmatic with Mesozoic arc assemblages and others comprising part of the Coast Plutonic Complex. The Coast Plutonic Complex is cut by the Coast Shear Zone, a major transpressional structure that may have accommodated significant early Tertiary displacement (Andronicos *et al.,* 1999).

Geology in the eastern Bella Coola map area (Figure 2), is dominated by three lithostratigraphic successions, including, from east to west: the Jurassic Hazelton Group (Baer, 1965; Diakow *et al*., 2002); the Early Cretaceous, informally named, Monarch volcanics (van der Heyden, 1990, 1991; Rusmore *et al*., 2000; Struik *et al*., 2002), herein referred to as the Monarch assemblage; and contrasting suites of Late Jurassic(?), Early Cretaceous, and Tertiary plutons (Baer, 1973; Hrudey *et al*., 2002). Additionally, spatially restricted volcanic rocks of Late Jurassic age may also be present within the region, but have yet to be identified. The plutonic rocks are subdivided into a plutonic suites based on textural and compositional characteristics, crosscutting relations, xenoliths, degree of alteration, and weathering character.

LOWER(?) AND MIDDLE JURASSIC HAZELTON GROUP

The oldest known rocks in the eastern Bella Coola region consist of Lower(?) to Middle Jurassic sedimentary and volcanic rocks which correlate regionally with the youngest part of the Hazelton Group. These rocks expand the known distribution of the Early-Middle Jurassic magmatic arc sequence, exposed extensively to the north in central Stikine terrane, south-southeast from Whitesail Lake map area (93 E) into the northeastern Bella Coola map area. North of the Bella Coola River, exposures of these rocks crop out intermittently east of the broad belt of Lower Cre-

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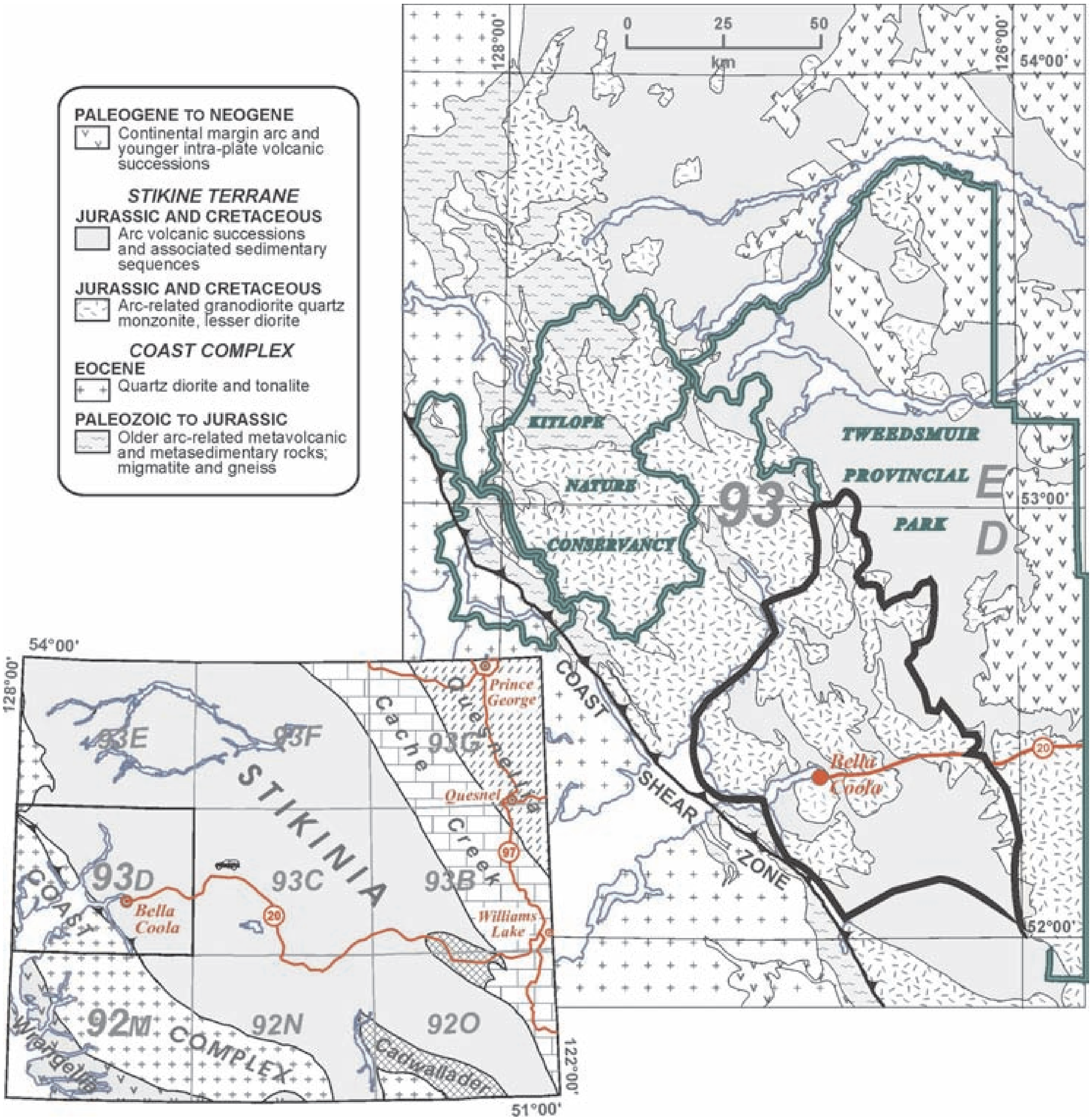


Figure 1. Schematic regional geologic map of Bella Coola (NTS 93D), Whitesail Lake (NTS 93E), and adjoining map areas. The black bordered polygon within eastern 93 D delimits the region mapped in 2001 and 2002. The inset map shows morphogeologic belts and tectonic terranes for west-central Canadian Cordillera.

taceous (Valanginian, in part) volcano-sedimentary rocks, within a northwest-trending corridor coinciding with the western boundary of Tweedsmuir Provincial Park. Also within this corridor, an unconformable contact between Middle Jurassic and a presumed Lower Cretaceous succession, that is not necessarily as old as the Valanginian stratigraphy farther west, is suspected; however, this relationship requires verification from isotopic dating in progress (*see* Upper Lower Cretaceous Volcanic Rocks, herein).

Along the northern margin of the Bella Coola map area, centered on Jumble Mountain, near continuous Jurassic stratigraphy consists of a superbly layered, east-dipping homocline more than 4 kilometres thick. The lower part of this succession is dominated by maroon and green, massively bedded basalt and basaltic andesite flows, intercalated with crudely stratified fragmental rocks. Dacitic to quartz-bearing rhyolitic block and finer tuffs comprise volumetrically significant deposits near Sakumtha Crag and immediately west of East Sakumtha River. Felsic rocks at these localities have been sampled for uranium-lead-zircon geochronometry in order to ascertain the age of deposits which are stratigraphically low in the homocline. We speculate that the lower part of this stratigraphic succession passes well down into the Lower Jurassic, possibly into the Pliensbachian.

Up-section of the mafic to intermediate volcanic sequence that forms the distinctly layered western slopes of Jumble Mountain, is a thick sedimentary succession composed of coarse-grained volcanic lithic arenite, arkosic sandstone and conglomerate. Rhyolitic tuff forms distinctive, light-weathered interbeds. Sedimentary structures within lithic arenites include crude parallel laminae, graded bedding, and rare trough cross-stratification. Minor medium to thickly bedded calcareous sandstone and sandy limestone occur, and are richly fossiliferous locally, yielding a diverse assemblage of gastropods, bivalves, and ammonites. The earliest Aalenian ammonite *Troitsaia westermanni* and the accompanying bivalve assemblage in the middle part of the homoclinal succession, resembles that reported at Troitsa Peak, Whitesail Lake map area (Poulton and Tipper, 1991). Farther east, near Sigutlat Lake, stratigraphically higher sedimentary beds contain Early Bajocian stephanoceratid ammonites and the type specimens of *Myophorella dawsoni* (Whiteaves), characteristic of the Smithers Formation, which is widespread in the Whitesail Lake map area.

YOUNGER MIDDLE JURASSIC VOLCANIC ROCKS

A unique, comparatively young Middle Jurassic (Bathonian and Callovian?) sequence composed of volcanic and volcaniclastic-epiclastic rocks crops out between the Dean and Bella Coola rivers, and is mainly exposed in a small area between Stack Peak, Mount Collins, and Tzeetsaytsul Peak. These rocks are significant for several reasons. Firstly, stratabound massive sulphide lenses of volcanogenic origin are associated with silica-bimodal volcanic rocks of this succession at the Nifty property, hence they are a prospective stratigraphic unit for mineral exploration. Secondly, volcanic rocks of Bathonian age are not known anywhere else in Stikinia. They record an eruptive pulse that may either represent the last “gasp” of the Hazelton magmatic arc, or vestiges of a more extensive, but previously-unrecognized volcanic event marking terminal arc magmatism in Stikinia, prior to widespread basinal sedimentation of the Bowser Lake Group.

The nature of the contact separating Lower Bajocian from Bathonian rocks is unknown in the study area. Aphanitic rhyolitic flows and associated quartz-phyric dikes, and basalt to andesitic volcanic rocks, occupy topographically low-lying terrain east of the headwaters of Noosgulch River. Felsic country rocks near the Nifty VMS prospect dated as part of this project have yielded a U-Pb age similar to that for a previously dated crosscutting dike (164.2+1.2/-0.9 Ma; Ray *et al*., 1998). Farther north, toward Mount Collins, aphanitic rhyolitic volcanic rocks are succeeded up section by several hundred metres of felsic, volcanic-derived turbidites and volumetrically minor interspersed pyroclastic flows. Welded rhyolites from this sequence yield a U-Pb date on zircons of 164.7±2.0 Ma, indicating rapid aggradation of submarine fan deposits proximal to a contemporaneous subaerial rhyolite volcanic center. Near Mount Collins, more than 500 metres of massive, parallel bedded, dark grey-black siltstone, sandstone and subordinate grit beds represent a deeper water, more distal sedimentary facies. Still farther north, in the vicinity of Stack Peak, thence to the Dean River, laminated black mudstone and siltstone alternating with distinctive white ash-tuff layers and sparse arkosic sandstone interbeds, dominate a moderately deep water, partly turbiditic facies. Belemnoids occur throughout all sedimentary facies, but are particularly abundant in darker, more organic-rich, siltstone beds, which in places are accompanied by sparse limey beds and lenses containing rare bivalves and ammonites. Rare and poorly preserved ammonite fragments from a limestone lens in black siltstone (GSC Loc. C-306159) are not firmly identified, but resemble Middle Bathonian to Middle Callovian *Cadoceras* or *Lilloettia*. This unit resembles the Bowser Lake Group in its probable age and abundance of belemnites. However, the prominence of Bathonian volcanic rocks in the Bella Coola area distinguishes them from exclusively marine and younger, Lower Callovian sedimentary rocks assigned to the Bowser Group in the adjacent Whitesail Lake and Nechako River map areas.

LATE JURASSIC (?) MICRODIORITE-BASALT INTRUSIVE-EXTRUSIVE COMPLEX

A belt of undivided mafic rocks, mapped primarily as microdiorites, is situated in the easternmost part of the study area between Sea Lion Peak and the eastern Dean River area. It is difficult to discern the origin of many of these rocks as either intrusive hypabyssal *versus* an extrusive origin and this relates to their characteristic fine-grained, felted appearance, as well as the absence of significant textural variations or associated bedded rocks.

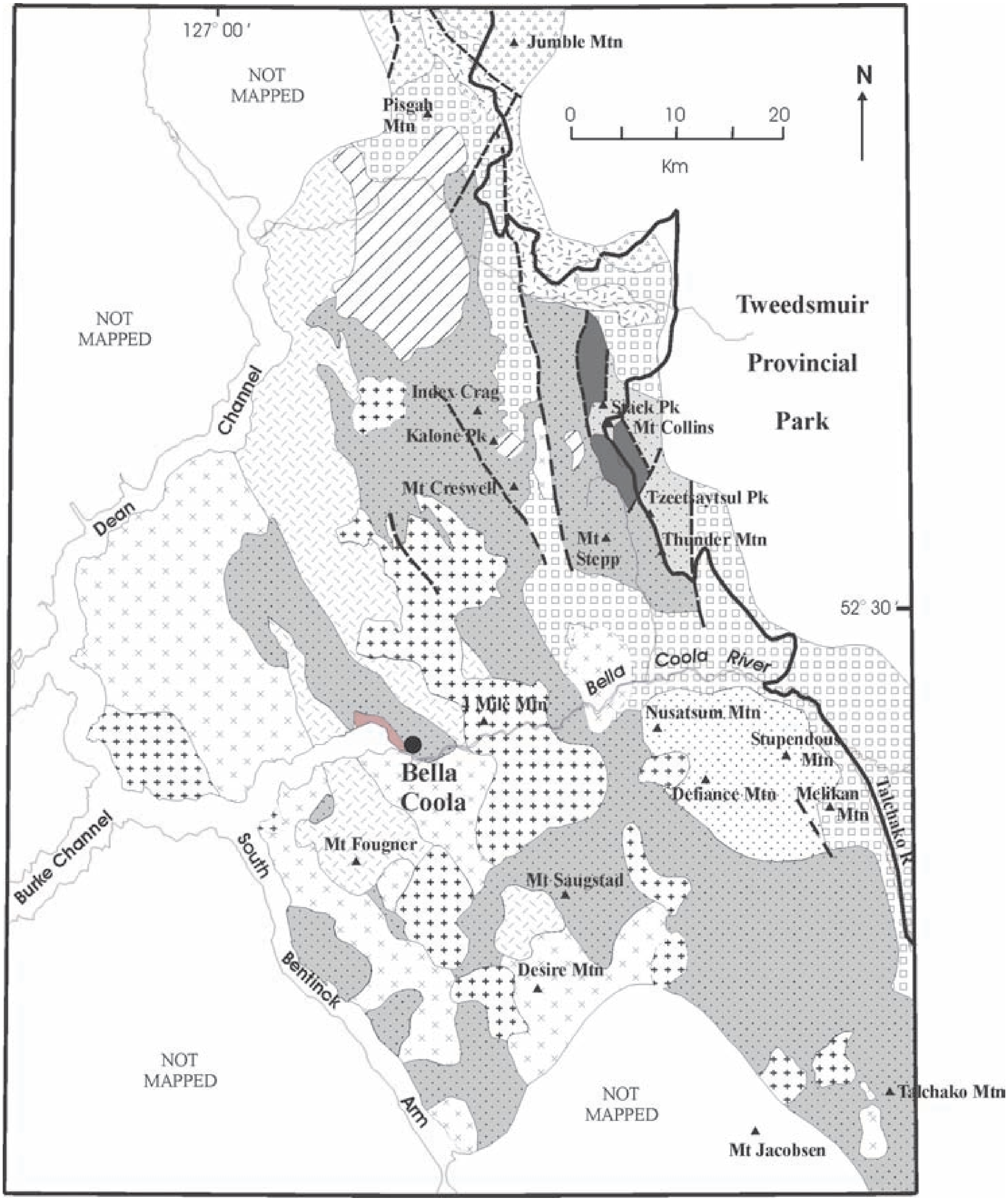
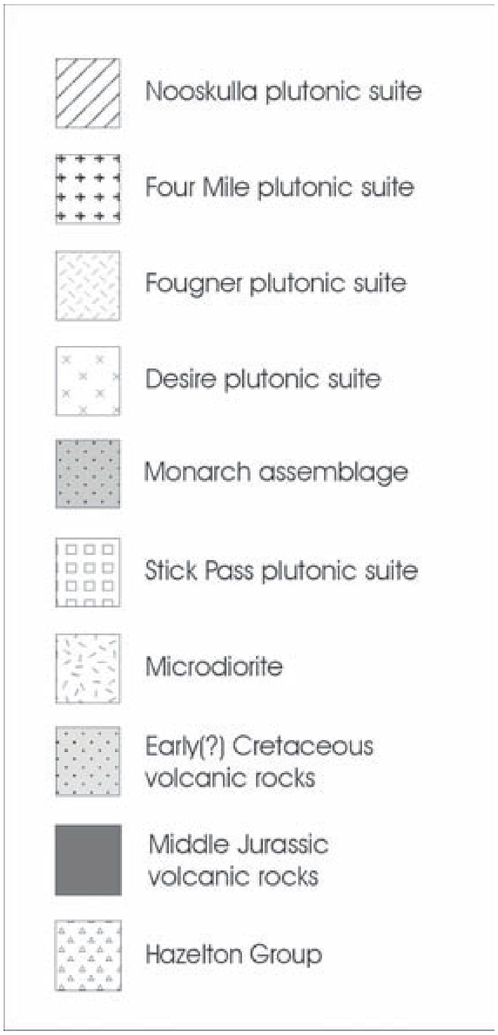


Figure 2. Schematic geological map of the eastern portion of the Bella Coola map area bordering Tweedsmuir Provincial Park.



Legend for Figure 2.

Rock exposures are typically dark green, massive, and most commonly exhibit minute plagioclase laths and anhedral intercrystalline mafic grains. Also included within this unit is medium grained hornblende diorite, cut by a north-south set of basaltic dikes, forming Sakumtha Crag and extending to the northwest across the East Sakumtha River. Similar smaller bodies of medium-grained diorite occur elsewhere in gradational contact with more widespread microdiorite. Near Mount Bernhardt, dikes of white weathered aphanitic felsite and chloritized hornblende-biotite granodiorite trend northwest and cut the microdiorites. The granodiorite dikes closely resemble rocks comprising the Stick Pass plutonic suite.

Immediately north of Sea Lion Peak, a rare, distinctive white quartz porphyritic rhyolite flow dome underlies a thick sequence of basaltic volcanic rocks. About 25 metres of massive rhyolite, containing potassium feldspar megacrysts and abundant phenocrysts of quartz and biotite, are directly overlain by a block-lapilli tuff that contains fragments of the underlying rhyolite. Samples of this quartz-rich rhyolite flow have been collected for isotopic dating to provide a crystallization age for the mafic rocks. A Late Jurassic age is possible for the succession, if crosscutting biotite-hornblende granodiorite dikes are, in fact, part of the Early Cretaceous Stick Pass suite.

EARLY CRETACEOUS STICK PASS PLUTONIC SUITE

Probable Jurassic microdiorite and volcanogenic strata are intruded by a suite of medium grained, equigranular biotite-hornblende granodiorite to diorite, referred to as the Stick Pass suite after exposures on Stick Pass Mountain. The suite appears restricted to the eastern part of the map area between Pisgah Mountain north of the Dean River, and Melikan Mountain south of the Bella Coola River. It is characterized by extensively chloritized biotite and hornblende, saussuritized plagioclase, and dark pink interstitial and phenocrystic potassium feldspar. The mineralogy and alteration result in a mottled green and pink coloration. Quartz and epidote veins are common. The suite contains abundant xenoliths of microdiorite, and is cut by abundant basaltic and microdiorite dikes. North of the Bella Coola valley and east of Noosgulch River, a swarm of north-trending microdiorite dikes cutting older granodiorite accounts for up to 70% of exposure. The mafic dikes exhibit chilled margins grading inward to porphyritic or sparsely amygdaloidal textures.

Basal conglomerates of the Lower Cretaceous Monarch assemblage nonconformably overlie rocks of the Stick Pass suite. The suite includes the Firvale pluton of van der Heyden (1991), which yields several U-Pb ages of circa 134 Ma.

LOWER CRETACEOUS MONARCH ASSEMBLAGE

A thick succession of andesitic flows, fragmental rocks, volcaniclastic sandstone, tuffs and argillites occupy a northwest-trending belt between Noosgulch River-Kalone Creek and Christenson Creek-Jump Across Creek (Struik *et al*., 2002). This succession is herein referred to as the Monarch assemblage. It is dominated by olive green amydaloidal dacite to basaltic andesite flows and associated breccias and tuff breccias, and contains intercalated argillite, siltstone and volcanic lithic sandstone that form locally continuous stratigraphic sections up to 2.5 kilometres thick. Stratigraphy, within this sequence, is complex, a result of abrupt lateral facies changes complicated by structural deformation. The Monarch assemblage nonconformably overlies several plutons assigned to the Stick Pass suite. Nowhere in the study area are the oldest stratigraphic units of the Monarch assemblage observed resting on Jurassic strata. This may be due, in part, to differential uplift within an intervening belt of Early Cretaceous intrusions that separates older Cretaceous strata in the west from Jurassic rocks in the east, in the region north of the Bella Coola River valley. The erosional base of the Monarch assemblage is exposed in four localities, listed from north to south:

1. South of Stick Pass Mountain. The base of the section here consists of polymict boulder conglomerate nonconformably overlying granodiorite of the Stick Pass suite. The conglomerate contains boulder-sized clasts of altered biotite granodiorite identical to the underlying pluton, and is overlain by a succession of sandy limestone, lapilli tuff, tuff breccia and volcanogenic sandstone and thick amygdaloidal flows.
2. Necleetsconnay headwaters. At this locale, a thick succession of highly cleaved argillite overlies a leucocratic granodiorite that yields a U-Pb date indicating Early Cretaceous intrusion. Numerous basaltic dikes intrude the granodiorite and overlying argillite. The contact is interpreted as a nonconformity that has been subsequently faulted.
3. North of Salloomt Peak. Polymictic plutonic and volcanic conglomerate overlies a quartz diorite pluton yielding several U-Pb zircon dates of circa 134 Ma. Plutonic detritus is identical to the subjacent pluton. The conglomerate passes up section into thin to medium bedded feldspathic sandstone and argillite, which is in turn overlain by a thick succession of amygdaloidal andesite flows.
4. Eastern flank of Mount Ratcliff**.** Boulder conglomerate at this locality, just southeast of the map area, nonconformably overlies an altered granodiorite pluton that yielded a U-Pb age of approximately 155 Ma (van der Heyden, pers. comm., 2002), and contains clasts lithologically identical to the subjacent pluton. The conglomerate is locally overlain by basalt to andesite lava flows, breccias and intercalated volcaniclastic rocks. Laminated siltstone and argillite interbeds indicate stratigraphic facing to the west (Israel and Kennedy, 2003). About 5 kilometres farther north of Mount Ratcliff, a very thick succession (>3 km) of massive, basalt to andesite lava flows, fragmental rocks and bedded argillite-sandstone-siltstone units presumably occur up section from the basal conglomerate.

Several particularly well-exposed sections of the Monarch assemblage demonstrate its lithological variability. Near Mount Creswell (093D/10) approximately 1000 metres of aphanitic andesite and crystal tuff are interstratified with argillite in its uppermost part. The section lacks fossil control, however it is correlated with fossiliferous rocks of the Monarch assemblage based on lithologic content and structural relationships (Sparks and Struik, 2002). Probably the most extensive continuous section recognized, approximately 2500 metres thick, is found west of Kalone Peak, 8 kilometres northwest of the Mount Creswell section. The lower half of this section consists almost exclusively of fine-grained basaltic andesite lava flows with very rare sedimentary intercalations. In contrast, the upper half includes similar flows, but with substantial amounts of interstratified fine to coarse grained volcanic-lithic sandstone, rich in feldspar. The uppermost 500 metres of this section is composed almost entirely of these sandstones, which show grading, convolute laminations, shale rip-up clasts, flame structures, and fossilized wood and plant fragments. The sandstones likely represent proximal facies in a fan-delta system adjacent to an active arc. Black argillite beds up to 15 metres thick are interstratified with sandstones in the upper part of the section west of Kalone Peak. At least 10 distinct argillite units were identified interstratified with the sandstones at the top of this section. The stratigraphically highest argillite is succeeded by approximately 100 metres of amygdaloidal pillow basalt.

The Monarch assemblage mapped in the Bella Coola region is interpreted to be Valanginian (Early Cretaceous) in age, in part, based on sparse ammonite collections made from several localities in 2001 (Struik *et al*., 2002). One argillite bed near the top of the section west of Kalone Peak, studied in 2002, also yielded Valanginian fossils. These biostratigraphic data are the only firm age control at present for the Monarch assemblage, which is widespread in the Bella Coola area. Correlative strata, albeit slightly younger Lower Cretaceous beds, extend southward into Rivers Inlet map area (NTS 092M; Rusmore *et al*., 2000), and farther east into Waddington map area. Lower Cretaceous volcanic rocks have also been mapped to the north in adjoining Whitesail Lake map area (Woodsworth, 1980; van der Heyden, 1989).

UPPER LOWER CRETACEOUS(?) VOLCANIC ROCKS

Bathonian strata are unconformably overlain by a massive volcanic sequence dominated by basaltic lava flows, associated primary and reworked autoclastic breccias. Basaltic flows are dark green to purplish, locally amygdaloidal, and include aphanitic as well as medium-grained, plagioclase-phyric varieties. Rounded to irregular amygdules are filled with quartz and chlorite. Rhyolite tuffs and lesser flows occupy widely separated intervals tens of metres thick within the mafic sequence. This succession forms the distinctive crudely layered, precipitous topography at Stack Peak, Mount Collins, and the Tzeetsaytsul-Thunder massif and, south of the Bella Coola valley, the rugged mountains of Nusatsum, Defiance and Stupendous. It is estimated to be in excess of 1300 metres thick south of the Bella Coola River valley, thinning gradually northward to its apparent terminus immediately south of the Dean River valley.

The unconformity with underlying probable Bathonian strata is marked by either volcanic boulder conglomerate, such as those superbly exposed in the headwall of a southeast-facing cirque at Mount Collins, or a sequence of pyroxene-bearing sandstone and grits containing quartz and mudstone particles found nearby to the south-southwest. The conglomerate is composed of oxidized reddish basaltic clasts that are characterized by a ‘crowded porphyritic’ texture imparted by 1-3 mm plagioclase and subordinate pyroxene grains. Conglomerate is monomictic and clast supported, composed of well-rounded clasts as large as 2 metres in diameter. Locally, volcanic sandstones, siltstones and red mudstones within the conglomerate comprise variegated red-green, parallel-bedded intervals up to

50 metres thick. These fine clastic rocks commonly contain angular pyroxene and plagioclase grains, presumably derived locally from contemporaneous mafic-intermediate lava flows.

On the north flank of Tzeetsaytsul Peak, the basaltic sequence rests on monomictic volcanic boulder conglomerate, which in turn unconformably overlies a dacite flow dome. A Middle Jurassic U-Pb zircon date of 171.6±2.3 Ma from this dome provides a maximum age for the basaltic sequence. A U-Pb date on zircons from welded rhyolite collected high in the basaltic succession exposed at Tzeetsaytsul Peak has provided an inconclusive minimum age of 113 Ma. The implication of this provisional date is that the thick, mafic volcanic sequence may represent a younger, discrete eruptive episode of the Monarch assemblage, possibly as young as Aptian. Alternatively, this succession could conceivably be Middle to Late Jurassic, part of little known and poorly exposed Bathonian stratigraphy documented during this program, or correlative perhaps with the Upper Jurassic (Oxfordian) Hotnarko volcanics recognized by van der Heyden (1991) in Anahim Lake map area (NTS 93C). Distinctive volcanic conglomerates marking the bottom of the mafic lava sections at Tzeetsaytsul Peak and Mount Collins, also crop out along a ridge trending north of Mount Stepp, where they also contain thin, discontinuous interbeds of rhyolitic tuffs and quartz-phyric flows. Quartz rhyolite lava flows from this section have been sampled for U-Pb zircon geochronometry.

EARLY CRETACEOUS DESIRE PLUTONIC SUITE

Metavolcanic rocks interpreted as part of the Monarch assemblage are intruded in several localities by a heterogeneous diorite to granodiorite intrusive complex referred to as the Desire suite. The suite is extensively exposed south and east of Desire Mountain and west of Clayton Falls Creeks from Howe Lake to the southern end of the map area. It is texturally and compositionally diverse, ranging from a fine to medium grained hornblende diorite-quartz diorite to a medium to coarse-grained biotite-hornblende granodiorite. The suite is characterized by numerous metavolcanic pendants, and xenoliths of mafic, commonly, amphibolitic composition. A weak to pronounced foliation is widespread. Internal crosscutting relationships within the suite are complex, with metavolcanic screens intruded by hornblende diorite, which is cut by hornblende-quartz diorite that in turn is cut by hornblende granodiorite to tonalite dikes, and themselves cut by quartz porphyritic felsic dikes.

Rocks assigned to the Desire suite yield a U-Pb age of 119±2 Ma (Gehrels and Boghossian, 2000).

MID-TO LATE CRETACEOUS FOUGNER PLUTONIC SUITE

The Fougner suite is a distinctive, homogeneous hornblende-biotite tonalite to granodiorite that is widely exposed in the western part of the map area, west of Thorsen Creek and the Necleetsconnay River. The suite is named for excellent exposures on Mount Fougner, at the head of Clayton Falls Creek. The Fougner suite is characterized by medium to coarse-grained, equigranular hornblende-biotite tonalite to granodiorite that contains minor (1-2%), yet conspicuous, honey brown sphene. Stretched dioritic xenoliths with a medium grained equigranular texture are widespread. Massive exposures display prominent exfoliation joint sets.

Sub-vertical, high-strain shear zones locally cut and deform plutons of the Fougner suite. Apparent flattening within the shear zones is moderate to intense, evidenced by locally abundant protomylonite and mylonite. Shear fabric is defined by rare attenuated mafic enclaves and fractured, elongate to rotated plagioclase and flattened to smeared biotite and quartz. Shear fabric within tonalite is commonly gradational along shear zone margins into the undeformed pluton. Tonalitic dikes assigned to the Fougner suite also cut the shear zones and, the Mount Fougner pluton clearly plugs a major high-angle shear zone near Clayton Falls Creek. The Fougner suite is thus believed to be syn- to post-kinematic with respect to development of these shear zones.

The age of the Fougner suite is presently unconstrained. Quartz diorite along the south side of the Bella Coola estuary, dated at 119±2 (Gehrels and Boghossian, 2000), was considered to be part of the Fougner suite by Hrudy *et al*. (2002), however, the character and field relationships demonstrate that this pluton belongs to the Desire suite. The Fougner suite intrudes the Desire suite, requiring it to be younger that 119 Ma. Moreover, the Fougner suite is cut by the Four Mile suite, dated at 73 Ma. The syn- to post-kinematic nature of the Fougner suite suggests a mid to Late Cretaceous age.

LATE CRETACEOUS TO EOCENE FOUR MILE PLUTONIC SUITE

Coarse grained, muscovite-biotite granite forming spectacular exfoliated exposures on both sides of the Bella Coola Valley is assigned to the Four Mile suite, named after Four Mile Mountain (Hrudey *et al*., 2002). The Four Mile suite extends to the north and south of the Bella Coola valley, underlying large areas between Mount Creswell and Big Snow Mountain. These plutons are characterized by parallel, steeply dipping joints that lend a sheeted, exfoliated appearance.

The suite consists of homogeneous, coarse-grained, equigranular biotite granite to granodiorite, containing large, fresh books of biotite up to 7 mm in diameter. Muscovite is diagnostic, and comprises up to 8 volume percent. Rare scattered maroon to red, semi-opaque garnet (0.3-1.5 mm) is also diagnostic, but a minor component. The suite is locally inequigranular, containing potassium feldspar phenocrysts. Aplite dikes with pegmatitic segregations containing garnet, muscovite and tourmaline are associated with the suite.

The Four Mile suite intrudes the Monarch assemblage, the Desire and Fougner plutonic suites, and also cuts the northwest-trending shear zones that transect the region. Preliminary U-Pb dates range from circa 51 to 73 Ma. Additional isotopic dating is in progress.

EOCENE NOOSKULLA PLUTONIC SUITE

The Nooskulla suite is named for homogeneous, fine to medium grained hornblende-biotite tonalite occupying ridges projecting outward from Nooskulla Peak, south of the Dean River. This suite differs from tonalite of the compositionally similar Fougner suite in that it is finer grained, does not contain conspicuous sphene, and is post-kinematic with respect to the high-strain shear zones. The tonalite weathers light grey, and has a sheeted appearance due to well developed joints, thus resembling the exfoliated surfaces of plutons from the Four Mile suite. Numerous thin (2-20 cm), randomly oriented aplite dikes, and fewer, mafic dikes cut the suite. Near the pluton margin, the tonalite grades to an inequigranular biotite granodiorite containing coarse grained potassium feldspar phenocrysts.

The Nooskulla suite has a K-Ar date on biotite of circa 47 Ma (Baer, 1973). Additional isotopic dating is in progress.

STRUCTURE

Several deformational events are recorded in Cretaceous stratified rocks in the eastern Bella Coola map area. The oldest structural event recognized is represented by volcanic-plutonic clast conglomerates found in the basal stratigraphy of the Monarch assemblage. These deposits are sufficiently widespread and lithologically diverse (*see* Lower Cretaceous Monarch Assemblage herein; Struik *et al*., 2002) to suggest a regional event involving uplift and erosion of chemically differentiated volcanic terrain(s) and plutonic sources.

An episode of east-west crustal extension is inferred from swarms of north trending diabase dikes, which comprise a late intrusive phase cutting granodiorite plutons that are tentatively assigned to the Stick Pass suite. In the Firvale pluton, which borders the Bella Coola valley east of the Noosgulch River valley, mafic dikes with a consistent northerly trend locally account for up to 70 volume percent of the pluton. A similar relationship between intermediate plutons cut by high volumes of mafic dikes persists elsewhere. For example, in the region east of Stack Peak, southeast of Forward Peak and in an area between Mount Bernhardt and Sakumtha Crag. The continuity of these features from one area to the next, all apparently aligned in the easternmost part of the study area, may indicate this part of the Bella Coola region was the locus of significant east-west extension. Farther east into Tweedsmuir Provincial Park, a pronounced pattern of north-trending lineaments, many of which control the distribution of drainages, may represent the modern surface expression for fault reactivation of older extensional features. The timing of this extensional event is poorly understood; however, it is no older than Early Cretaceous, circa 134 Ma, based on several U-Pb dates from granodioritic plutons of the Stick Pass suite cut by these mafic dike swarms. As the mafic dike swarms occur in proximity to, and are similar in composition with, very thick accumulations of lava flows comprising the upper parts of Thunder-Tzeetsaytsul and Stack-Collins peaks, we speculate that they may be comagmatic and as young as late-Early Cretaceous.

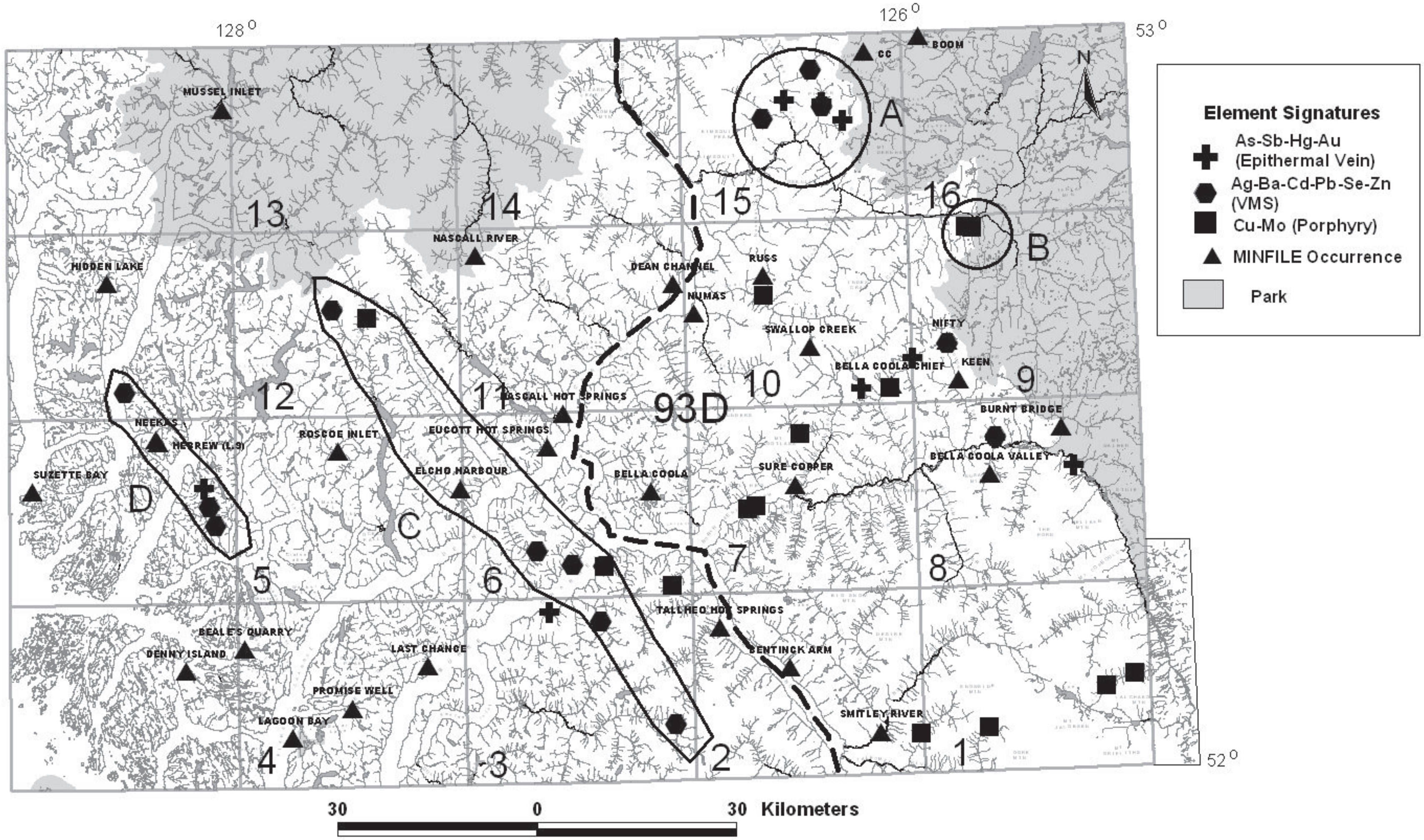
Contractional deformation characterizes a broad region of mainly Lower Cretaceous (Valanginian) Monarch strata in the western part of the study area (Mahoney *et al.,* 2002). In contrast, scant exposures of Jurassic strata lying to the east are comparatively undeformed, and generally form bedded sections disrupted mainly by high-angle faults. The contraction has induced northeast vergent, asymmetric, isoclinal to upright folds and local thrust faults. Although age constraints on the younger limit of this deformational episode are not available, it is believed to coincide with Late Cretaceous contractional deformation in the eastern Waddington fold and thrust belt to the southeast (Rusmore and Woodsworth, 1994; Rusmore *et al*., 2000).

A series of northwest trending, en echelon zones of high strain composed of protomylonite and mylonites developed in Lower Cretaceous volcanic and plutonic rocks overprint contractional features in the western region. Detailed examination of a 750-metre wide ductile shear zone transecting Mount Pootlass, 10 kilometres northwest of the Bella Coola town site, reveals a complex structural history. In summary, high-strain strike-slip shearing that is accompanied by the development of a strong horizontal lineation overprints early asymmetric folds. Across the zone, shear sense changes from dextral in the east to mostly sinistral in the west (L. Kennedy, pers. comm., 2002). The precise age of shear deformation is uncertain, but at present it is bracketed by preliminary U-Pb dates, circa 123 Ma and 73 Ma, on pre- and syn-kinematic intrusions respectively.

MINERAL EXPLORATION TARGETS

The Nifty stratiform base metal sulphide prospect is one of several VMS-like occurrences documented in MINFILE and found in the Noosgulch River valley (Ray *et al*., 1998). Based on mapping reported in Diakow *et al*. (2002; page 133), the stratiform mineralization and silica-bimodal host rocks, particularly apparent at Nifty, were suggested to have formed in Aalenian to Bajocian time (Middle Jurassic); however, several new U-Pb dates from these rocks are somewhat younger, circa 165 Ma (Bathonian; *see* "Younger Middle Jurassic Volcanic Rocks, herein). Prospective Bathonian submarine volcanic and sedimentary strata appear to have limited lateral extent in the field area, exposed intermittently for 11 kilometres adjacent to the western Tweedsmuir Provincial Park boundary between Nifty and the Dean River.

Multi-element stream sediment data generated by a Regional Geochemical Survey (RGS) covering parts of Bella Coola (NTS 93D) and adjoining Laredo Sound (NTS 103A) regions were published in August, 2002 (Lett *et al*., 2002). Preliminary analysis of these data using a statistical



Figu re 3. Ranked multi element geochemical anomalies for epithermal vein, massive sulphide and porphyry signatures (modified after Lett and Fiske, this volume). The dashed line marks the western boundary of geological mapping completed during the Bella Coola TGI.

procedure ranking geochemical anomalies according to groupings of elements commonly associated with epithermal vein, massive sulphide and porphyry mineralization (Lett and Friske, this volume), highlights several areas that warrant follow-up work (Figure 3).

North of the Dean River, in map sheet 93D/15 (A in Figure 3), a number of drainages contain anomalous epithermal vein or VMS signatures. In general within this area, near Pisgah Mountain, intrusive rocks tentatively assigned to the Early Cretaceous Stick Pass suite crop out above treeline. The anomalies, however, are presumably associated with volcanic rocks that may be exposed on vegetated slopes at lower elevation within the various watersheds. The most northerly of the anomalous VMS sites at location A, situated 3 kilometres due west of Sakumtha Crag, is positioned within a drainage containing a large gossan. Although rocks at this locality were not mapped, immediately to the south of Sakumtha Crag, a succession of rhyolite breccias intermixed with reworked pyroclastic debris and mafic flows, believed to be part of the Jurassic Hazelton Group, may be extrapolated to the west into this gossanous zone.

The majority of prospects documented in the MINFILE database in the eastern Bella Coola region are copper-molybdenum prospects associated with various granitoids. They appear to be related to mainly Early Cretaceous and fewer Eocene biotite-hornblende bearing granodiorite and tonalite stocks. At locality B in Figure 3, two high-ranking copper-molybdenum anomalies occur in parallel drainages sourced in granodiorite that is assigned to the Stick Pass suite and cut by an en echelon north-south set of diabase dikes.

West of the Dean Channel, outside of the area mapped during the Bella Coola TGI program, a series of RGS anomalies with a pronounced VMS signature define two parallel belts (areas C and D in Figure 3). These anomalies correspond with tracts of undivided metasedimentary and metavolcanic rocks, informally named the Burke Channel assemblage (Rusmore *et al.,* 2000). Regionally, these metamorphic rocks may be equivalent to those that host numerous Kuroko-type VMS occurrences in the Ecstall Belt (Alldrick, 2001), located about 180 kilometres to the northwest.

CONCLUSIONS

Geologic and geochronologic relationships obtained through regional mapping conducted during the Bella Coola TGI provides an improved geologic framework for the eastern Bella Coola region that aids mineral exploration and broader-based geoscience. Some important results from the program include:

- The best known stratiform massive sulphide-barite mineralization in the region is associated with a previously unknown and poorly exposed Middle Jurassic (Bathonian) bimodal volcanic sequence. Regionally, these rocks are thought to represent a brief subaerial to submarine eruptive event that marks the end of Hazelton island arc construction in Stikinia.
- Lower Cretaceous volcanic rocks informally named the Monarch assemblage and comagmatic plutonic suites occupy a northwest trending belt in the east-central Bella Coola region. The layered rocks consist of marine clastic rocks interlayered with mafic to intermediate and subordinate felsic volcanic rocks which are interpreted as units of island arc volcanoes that formed along the western fringe of Stikinia during Valangianian to possibly Aptian time.
- Multi-element geochemical anomalies, with a massive sulphide signature, cluster in volcanic rocks tentatively assigned to the Monarch assemblage north of the Dean River. Many of the copper showings in the region are spatially associated with dioritic to granodiorite plutons assigned to either Early Cretaceous or Eocene suites. Porphyry-style mineralization in the region lacks the broad colored gossans and alteration associated with large mineralized systems.
- Structural events in the region include Early Cretaceous uplift that resulted in widespread erosion and deposition of conglomerates at the base of the Monarch assemblage. Substantial east-west crustal extension, manifest as north trending swarms of diabase dikes and potentially related eruption of significant volumes of mafic lava flows may record the latest magmatic pulse of the Monarch assemblage. A contractional event imparts northeast vergent folds and thrust faults in Lower Cretaceous strata in the western part of the study area. An episode of high-strain strike-slip shearing overprints the folded rocks within a series of parallel, northwest-trending zones. Plutons that show variable degrees of strain or truncate deformed rocks broadly bracket the timing of ductile deformation between 123 and 73 Ma.

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