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Lower Cretaceous stratigraphy and tectonics of eastern Bella Coola map area, southwest British Columbia[1]

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Abstract: Lower Cretaceous stratigraphic units in the study area consist mainly of flows and fragmental rocks that include basalt and andesite, minor rhyolite and dacite, and epiclastic intervals of sandstone, slate, siltstone, and conglomerate. These rocks are correlated with the Monarch volcanic rocks widespread to the southeast, lie nonconformably on Early Cretaceous plutons, and are interpreted to be deposited onto older plutonic suites. The Cretaceous succession may have formed during east-west crustal extension, and later was tightly to isoclinally and asymmetrically folded to the northeast. The succession appears to have been deposited on an Early Cretaceous topographic high that had sufficient relief to host marine basins and adjacent subaerial hills. The Hazelton Group appears to be absent beneath the Cretaceous succession. Known mineralization (primarily copper) in the Cretaceous volcano-sedimentary rocks is mainly associated with pluton contacts or fault zones. The slate units almost everywhere have minor disseminated pyrite.

Résumé : Dans la région d'étude, les unités stratigraphiques du Crétacé inférieur sont essentiellement formées de coulées et de roches clastiques, parmi lesquelles on reconnaît du basalte et de l'andésite, de faibles quantités de rhyolite et de dacite, ainsi que des intervalles de roches épiclastiques (grès, ardoise, siltstone et conglomérat). Ces roches sont corrélées aux volcanites de Monarch qui sont répandues au sud-est, reposent en discordance d'érosion sur des plutons du Crétacé précoce et , selon nos interprétations, se seraient déposées sur des suites plutoniques plus anciennes. La succession du Crétacé a pu se former pendant une période de distension crustale suivant un axe est-ouest et aurait été ultérieurement déformée en plis serrés à isoclinaux affichant une asymétrie dirigée vers le nord-est. Cette succession semble s'être déposée sur une hauteur topographique du Crétacé précoce qui présentait suffisamment de relief pour contenir des bassins marins encadrés de collines subaériennes. Le Groupe de Hazelton ne semble pas présent sous la succession du Crétacé. Les indices connus de minéralisation (principalement de cuivre) dans les roches volcano-sédimentaires du Crétacé sont en grande partie associés aux contacts de plutons ou à des zones de failles. Presque partout, les unités d'ardoise renferment des quantités mineures de pyrite disséminée.

[1] Contribution of the Bella Coola Targeted Geoscience Initiative Project

INTRODUCTION

Eastern Bella Coola map area (93 D east half) lies along the eastern margin of the Coast Mountains in southwestern British Columbia (Fig. 1, 2) and has seen relatively little geological mapping since the pioneering work of Baer (1973). The bedrock geology of the area is being remapped at 1:50 000 scale over the course of two field seasons as part of the Targeted Geoscience Initiative (TGI) of the Federal Government and allied programs of the British Columbia Ministry of Energy and Mines, and academic research of the universities of British Columbia and Wisconsin at Eau Claire. The aim of the project is two-fold: 1) to improve understanding of the mineral potential of the region in light of the discovery and development of massive-sulphide occurrences hosted by Middle Jurassic and Lower Cretaceous volcano-sedimentary successions in other parts of western British Columbia, and; 2) to improve the quality of our understanding of the geology and evolution of the central Coast Mountains. Also during the summer of 2001, as a separate, but complementary, TGI project, the Geological Survey of Canada and British Columbia Geological Survey conducted a regional geochemical survey of silt in streams throughout the Bella Coola map area (Jackamin et al., 2002).

This report describes some of the preliminary results of the first field season of the bedrock-mapping project. Further results from the Bella Coola TGI project on Jurassic stratigraphy, plutonic evolution and structural analysis are contained in Diakow et al. (2002), Hrudey et al. (2002), Mahoney et al. (2002), and Israel and Kennedy (2002).

GENERAL GEOLOGY

Eastern Bella Coola map area lies in the eastern Coast Mountains within a transition between the Coast Mountains batholith complex to the west and volcanic rocks of the Intermontane Belt to the east (Fig. 2). In addition, it appears to occupy a transitional position between the Triassic and Cretaceous sedimentary and igneous suites of the southeastern Coast Mountains and the Jurassic and distinctive Late Cretaceous igneous suites on the eastern flank of the Coast Mountains farther northwest. A preliminary geological sketch map of the northern part of the area is shown in Figure 3; place names are shown in Figure 4.

The oldest known rocks in the map area outcrop extensively within a southwest-trending tract along the eastern margin of the map area. They comprise an assemblage of volcanic and lesser sedimentary rocks of probable Middle

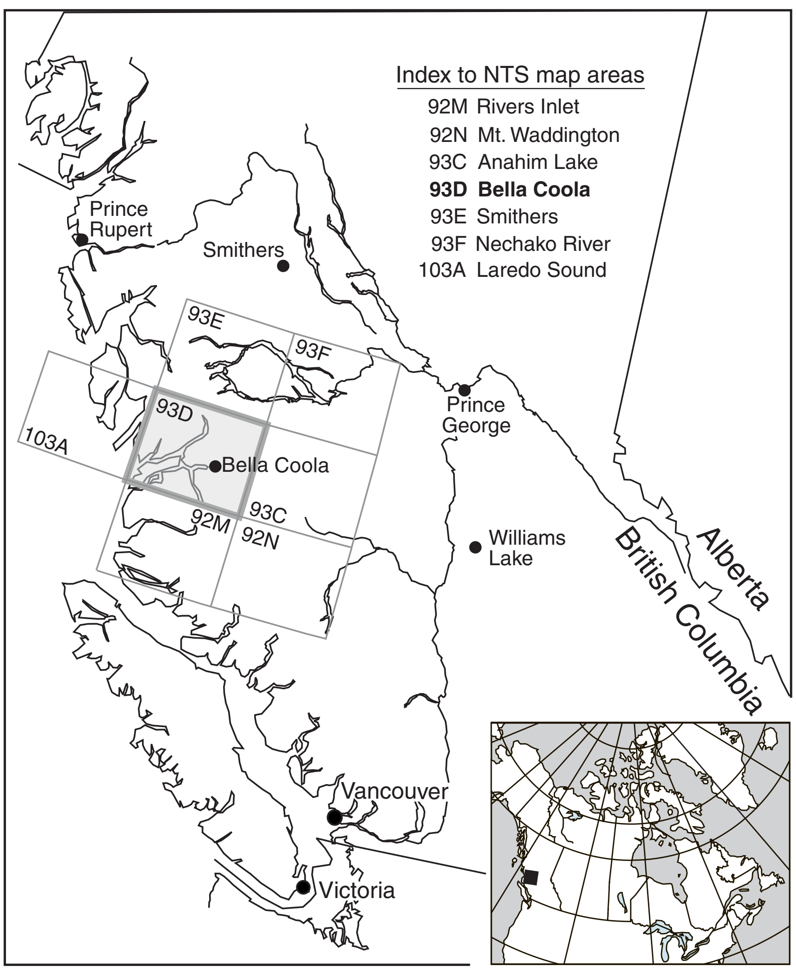

Figure 1.

Location of the eastern Bella Coola Targeted Geoscience Initiative (TGI) Project in the south-central Coast Mountains of British Columbia.

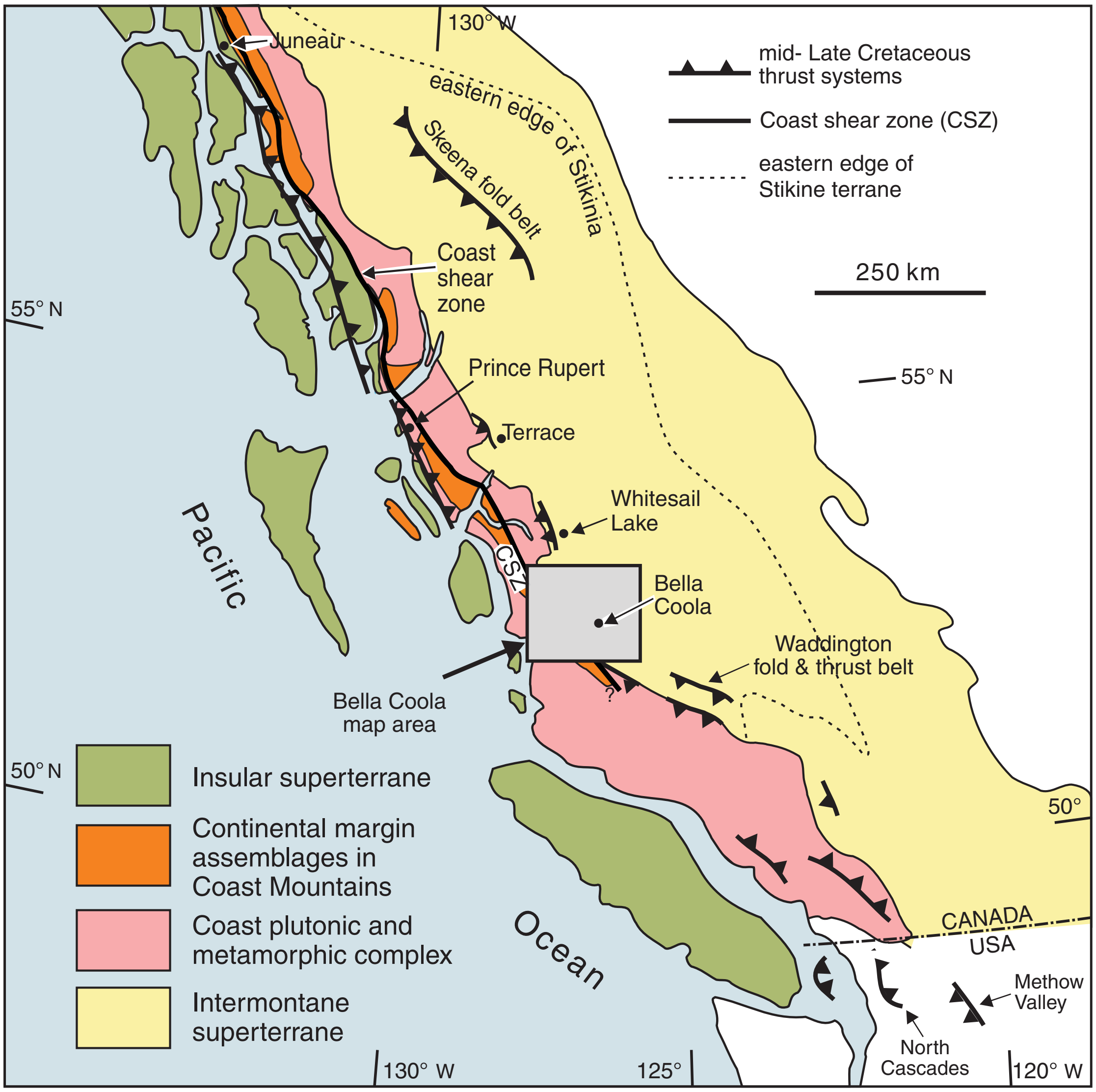

Figure 2. *Simplified terrane map of western British Columbia and southeastern Alaska, showing location of Bella Coola map area.*

Jurassic age. At the latitude of the Bella Coola area, they comprise the western fringe of the Stikine terrane, an upper Paleozoic to Middle Jurassic suite of island-arc-related volcano-sedimentary assemblages (Fig. 2, 3). These layered rocks are tentatively correlated regionally with the Smithers Formation of the Hazelton Group (Diakow et al., 2002). Middle and Late Jurassic plutonic rocks, known in the southernmost Whitesail Lake map area (NTS 93 E; Woodsworth, 1980), are suspected to extend southward into the Bella Coola map area where they form several northwest-elongated dioritic stocks (Hrudey et al., 2002). Volcanic rocks assigned to the Hazelton Group are intruded by various plutons, most likely of Cretaceous and Tertiary ages (Hrudey et al., 2002).

West of the tract of Jurassic volcanic rocks is a thick, deformed assemblage composed of volcanic, sedimentary, and fine-grained intrusive rocks of Cretaceous age. This Cretaceous volcano-sedimentary assemblage is the subject of this report. Spatially associated plutonic rocks presumed to be genetically related to this assemblage are discussed by Hrudey et al. (2002). The Lower Cretaceous sequence of rocks appears to have been generated during a time of east-west crustal extension(locally greater than 40%), uplift, erosion and magmatism. The Cretaceous stratified and intrusive rocks have been deformed in at least two episodes of tectonism, and subsequently offset by north-trending, steeply dipping faults (Mahoney et al., 2002). The first deformational episode induced northeast-verging to upright, tight to isoclinal folds and possible thrust faults that may correlate with the Waddington fold and thrust belt to the southeast (Rusmore and Woodsworth, 1994; Schiarizza et al., 1997; Rusmore et al., 2000). The second episode induced wide northwest-trending pure-shear zones, possibly combined with minor components of simple shear. North-trending faults

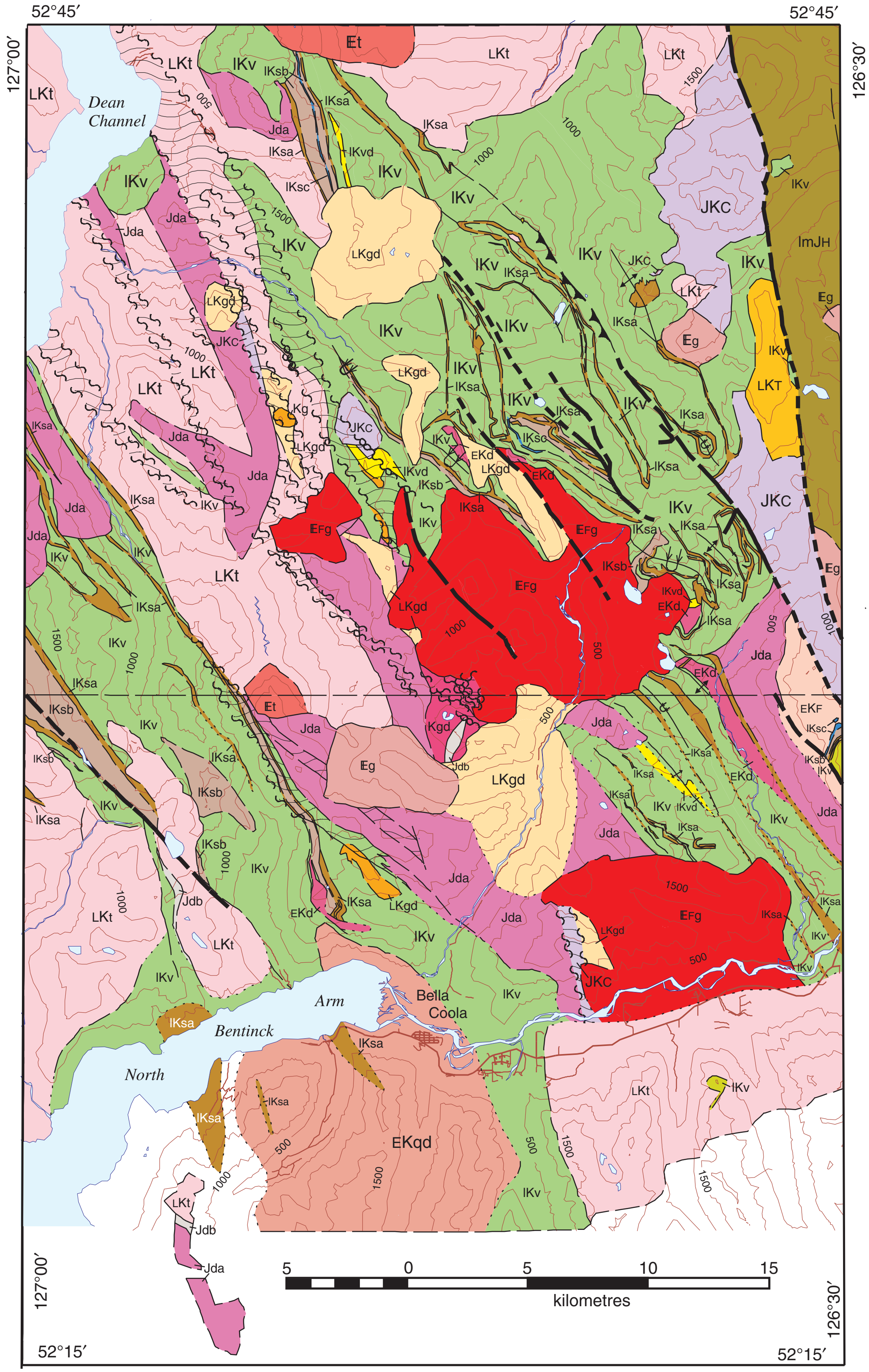

Figure 3. Geological map and legend for NTS map areas 93 D/10 and part of 93 D/07. Contour interval is 500 m.

containing gouge, phyllonite, and variously oriented slickensided surfaces crosscut the folds and shear zones and parallel a dense set of topographic lineaments.

CRETACEOUS STRATIFIED ROCKS

Lower Cretaceous volcaniclastic, volcanic, sedimentary, and intrusive rocks underlie much of eastern Bella Coola map area between Noosgulch River and Dean Channel. These rocks are intruded by Tertiary, and possibly Late Cretaceous, igneous rocks (Hrudey et al., 2002). No Upper Cretaceous or Tertiary stratified rocks have been found or inferred in the area.

Lower Cretaceous stratified rocks appear to form a single tectonostratigraphic sequence consisting of interlayered dacite to andesite, sandstone, siltstone, slate, and minor conglomerate. The volcanic rocks locally grade into subvolcanic diorite, and the entire sequence is cut by fine-grained and aphanitic andesite, rhyolite, and granodiorite dykes and sills.

LEGEND FOR FIGURE 3

STRATIFIED ROCKS

LOWER CRETACEOUS

Monarch sequence (lKva - lKvd)

lKv — *Andesite:* mostly fragmental breccia, lapilli and ash tuff, agglomerate, granule conglomerate, sandstone, and greywacke; pyroclastic rocks are dominated by heterolithic intermediate and locally abundant felsic pyroclasts; some flows, aphanitic to plagioclase±rare augite-phyric, locally calcite-chlorite-quartz-amygdaloidal, flow breccia, dykes, small microdiorite stocks; olive to olive-grey, locally maroon

lKvd — *Rhyolite, dacite:* fine grained tuff, sedimentary rocks

lKsa — *Slate, argillite, siltstone, sandstone:* rusty argillite, laminated siltstone, feldspathic sandstone (arkose), minor granule-pebble conglomerate

lKsb — *Sandstone:* feldspathic arkose, argillite

lKsc — *Conglomerate:* rounded granule to cobble, feldspathic, granitic, and volcanic clasts

MIDDLE JURASSIC

mJH — *Hazelton Group:* andesite, basaltic andesite; massive flows, aphanitic to plagioclase±augite-phyric lava, locally coarsely plagioclase-phyric, locally amygdaloidal, fragmentals, dykes, small microdiorite stocks, flow breccia, minor slate and volcaniclastic rock; olive-grey to dark grey, locally maroon

INTRUSIVE ROCKS

(?) EOCENE

EFg — *Four Mile suite:* granite; biotite and muscovite±garnet; medium grained, equigranular; pink, weathers white

Eg — *Granite, granodiorite:* biotite; medium grained, equigranular; weathers yellow

Et — *Tonalite:* biotite; medium grained; white; sheet jointed

(?) CRETACEOUS

Kgd — *Granodiorite:* biotite, hornblende; medium to fine grained, equigranular; grey

Kg — *Granite and granodiorite:* biotite, hornblende; medium to fine grained, equigranular; grey

(?) LATE CRETACEOUS

LKgd — *Granodiorite:* biotite, hornblende; medium grained, equigranular; light grey

LKt — *Tonalite:* biotite, hornblende; medium to coarse grained, equigranular; grey;llocally sheet jointed

LKT — *Talcheazoone pluton:* quartz diorite: biotite, hornblende, medium grained; white; foliated; pendants of amphibolite

(?) EARLY CRETACEOUS

EKqd — *Quartz diorite:* biotite, hornblende; medium grained, equigranular; grey; sheet jointed; ca. 119 Ma

EKd — *Microdiorite:* hornblende, some gabbro and amphibolite, locally subvolcanic to Monarch sequence andesite; equigranular; light grey to grey

EKF — *Firvale suite:* granodiorite: chlorite-epidote-altered hornblende, rare hornblende-quartz monzonite; medium grained, equigranular; off-white to greenish; ca. 134 Ma

JURASSIC AND (?) CRETACEOUS

JKC — *Crag Creek intrusive complex:* ±pyroxene, hornblende diorite, minor quartz diorite and gabbro invaded by hornblende granodiorite to monzogranite and younger rhyolite, plagioclase-phyric and aphanitic andesite and basalt; subvertical and locally sheeted dykes

(?) JURASSIC

Jda — *Diorite:* hornblende, ±biotite; medium grained, equigranular; foliated

Jdb — *Hornblende diorite, gabbro, hornblendite:* heterogeneous, pegmatitic; medium and coarse grained; locally foliated

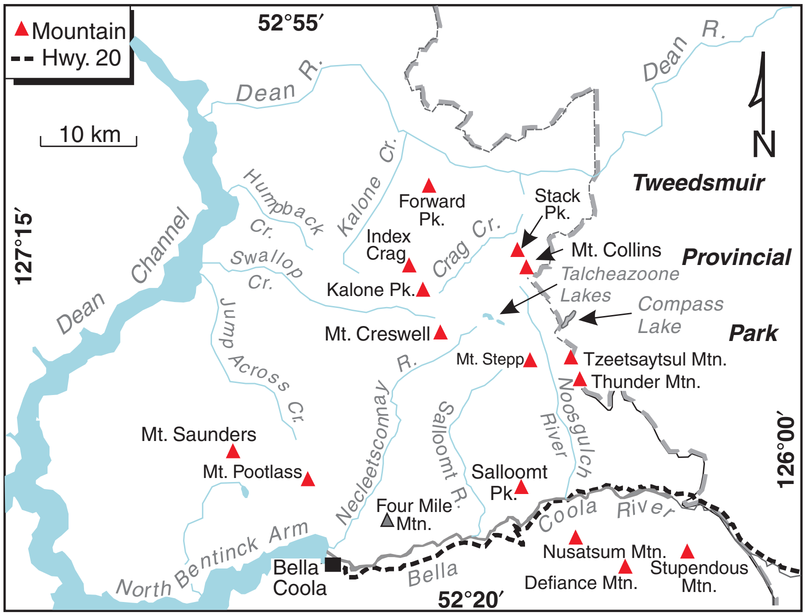

Figure 4.

Northern part of Bella Coola (east half) map area showing locations of geographical features referred to in the text.

The stratified rocks are lithologically and age-correlative with rocks of the 'Monarch volcanics' to the south and southeast (Tipper, 1969; van der Heyden, 1990, 1991; Rusmore et al., 2000) and rocks of the southern Coast Mountains assigned to the Gambier Group by Woodsworth (1979, 1980).

A generalized stratigraphic sequence for the Cretaceous rocks, from uppermost exposures downwards, consists of:

1. >1000 m of thick units of interbedded olive to olive-grey aphanitic and plagioclase-phyric andesite flows and fragmental rocks;
2. Two, possibly three, 5 to 35 m thick units of dark grey slate, 'siltstone', sandstone and limey sandstone within a 500 to 1000 m section of predominately interbedded olive to olive grey, andesitic fragmental rocks and lesser flow sequence;
3. 10 to 30 m thick local arkosic sandstone and pebble to cobble conglomerate derived from plutonic and andesitic sources;
4. A 5 to 20 m thick unit of slate, 'siltstone', and sandstone within a 400 to 800 m thick sequence of brownish- to olive-weathering, olive to olive-grey andesitic fragmental rocks, volcaniclastic rocks and lesser flows.

The top of the sequence is unconstrained and the bottom is locally a nonconformity below the conglomerate unit, or an intrusive contact with (?)Cretaceous and (?)Tertiary plutons. Because of the repetition of various rock types within the sequence, and the complexity induced by the asymmetric, very tight to isoclinal folding, in this preliminary report we describe the rocks by their type and not by position within the stratigraphic succession.

Sedimentary and volcaniclastic rocks

Conglomerate

Polymictic conglomerate has been found in three widely separated localities in the mapped area. Conglomerate beds are from 3 to 15 m thick, and exhibit some similarities, although each has its own distinct features. Conglomerate units at the two northerly locations occur within a sedimentary and volcanic succession and have gradational contacts above and below. Conglomerate at the southernmost locality forms the nonconformable base of a succession resting directly on a biotite hornblende granodiorite.

The northern locality, northwest of Kalone Creek, has rounded elongate to subspherical andesite, sandstone, mudstone, rhyolite, and minor tonalite clasts (1–30 cm) in a mudstone and arkose matrix. Conglomerate layers and lenses are interbedded with arkose and mudstone layers. The conglomerate-bearing sequence is underlain by arkose beds and overlain by slate.

At the central locality, south of Swallop Creek, rounded spherical to sub-elliptic andesite, rhyolite, dacite, tonalite, and quartz diorite clasts (1–35 cm) are supported by an arkosic sandstone matrix (Fig. 5). It is 50 to 70 m thick and overlies thin, graded beds of arkose, granule conglomerate, and siltstone overlying fragmental olive andesite. It is in turn overlain by agglomeratic to massive aphanitic to plagioclase-phyric olive-grey andesite.

At the southern locality, north of Salloomt Peak, the conglomerate is composed of rounded to subrounded, spherical, granodiorite to quartz diorite and minor andesite clasts (1–18 cm) in a quartz-feldspar-rich matrix. It is clast supported and rests in gradational nonconformity on granodiorite regolith and its underlying granodiorite. The conglomerate is gradationally overlain by arkosic sandstone and muddy sandstone. The conglomerate and arkose are approximately 100 m thick.

Figure 5. Tonalite, rhyolite and andesite clasts floating in arkose matrix in the conglomerate unit south of Swallop Creek.

Poorly preserved fossil bivalves collected from the muddy sandstone during the course of this study (GSC Locs. C-211801, C-306164, and C-306170) include trigoniids and possible ostreids assigned a general Middle Jurassic–Cretaceous age. Fossils collected previously from this locality (GSC Loc. 65044) were provisionally identified by J.A. Jeletzky (*in* Baer, 1973) as the brachiopod *Rhynchonella* and the bivalve *Lima*, and subsequently assigned a possible Early to Middle Jurassic age. Given that the underlying granodiorite has been dated at ca. 134 Ma using U-Pb from zircons (van der Heyden, 1991), we assume that all these fossils likely represent Early Cretaceous, rather than Jurassic, forms. Fossil faunas are indicative of a shallow-marine, inner-shelf depositional environment, indicating that deposition of the conglomerate occurred in very shallow water.

Slate, siltstone and sandstone

Slate units consist mainly of dark-grey- and rusty-weathering black shale, argillite, slate, and lesser phyllite. They commonly contain minor amounts of disseminated fine-grained pyrite and pyrrhotite. In less deformed rocks they have yielded fossil assemblages dominated by ammonites and subordinate bivalves and plant debris (mainly wood fragments or plant stems). The slate units are locally interbedded with plagioclase-rich sandstone, andesite tuff, limey greywacke, and minor limestone. In places the slate unit contains dark grey limestone nodules and lenses in the thin, fine-grained tuff and greywacke beds. Generally, the contacts with bounding andesite flows, tuff, greywacke, and siltstone are sharp or gradational over a metre. The slate units are generally from 3 to 150 m thick, tightly folded, and locally structurally thinned and thickened.

Siltstone and sandstone are generally interbedded (1–30 cm), commonly graded, and locally have load casts and flame structures; very rarely they are crossbedded or rippled. They are locally convoluted in irregular, asymmetric isoclinal folds that appear to represent synsedimentary deformation. The siltstone is generally grey to dark grey and the andesitic sandstone is olive in colour, weathering olive-grey to grey. These rocks occur as units 5 to 30 m thick bounded by, or included in, the slate units, and as 10 to 100 m units low in the Lower Cretaceous sequence where they commonly bound or underlie one of the upper slate units. Grains in the sandstone consist primarily of plagioclase, minor quartz, and amphibole or pyroxene. They are locally arkosic, and in some places quartzite found with andesite or slate units may be of sedimentary origin. The matrix is mostly silt with subordinate calcite cement.

The slate, siltstone and sandstone unit has been dated by fossils found mainly in the slate and locally in the sandstone. Fossil collections (GSC Locs. C-306160 and C-306165) contain abundant ammonites and lesser bivalves as well as plant matter, including common conifer stems and wood fragments, and rare fronds. Ammonites include forms assignable to the genera *Dichotomites* and ?*Polyptychites* and indicate a Valanginian, probably Late Valanginian age. Diversity and abundance of molluscan assemblages suggest a relatively shallow, marine depositional setting, possibly an outer-shelf environment. The abundance of plant matter in the collections also supports a relatively shallow-water interpretation, suggesting proximity to the paleoshoreline.

Volcanic and intrusive rocks

Volcanic and subvolcanic rocks are the most abundant of the rocks interpreted to be of Cretaceous age. Andesitic fragmental rocks predominate with less voluminous flows of andesite and basalt, and minor dacite and rhyolite. They are most voluminous in the upper part of the interpreted Cretaceous section. Subvolcanic rocks consist mainly of diorite plugs that grade into andesite crystal tuff and flows, and a variety of dykes and sills that vary in composition from andesite to rhyolite.

The various andesite flows, fragmental rocks and intrusive phases are locally mineralized. Most of the mineralization is pyrite, which forms nodules or disseminations and, in some places, minor chalcopyrite partially altered to malachite. A single boulder containing a vein with native copper was found in a moraine in the cirque east of Kalone Peak.

Andesite fragmental rocks

Olive-weathering, olive-grey andesitic tuff, agglomerate and breccia form a large part of the Lower Cretaceous unit. In some places the andesite is mostly dark olive-grey to grey and may be more basaltic, and is easily mistaken for volcanic rocks of the Jurassic Hazelton Group. In a few places the fragmental andesite is maroon. Generally the fragmental andesite is medium to coarse grained and locally is an ash tuff. Plagioclase is the predominate phenocryst in the fragments, occurring as stubby prisms or acicular felted masses; hornblende and augite are rare.

The agglomerate and breccia are generally monomictic, and, in places, the fragments are maroon, grey, and olive aphanitic to coarsely plagioclase-phyric (Fig. 6). Fragment shapes vary from well rounded and sub-spherical to highly

Figure 6. Texture of coarse-grained Lower Cretaceous andesite fragmental rocks. Mechanical pencil (circled) for scale (width of photo is about 80 cm).

Figure 7. Flattened agglomeratic fragments in andesite north of Swallop Creek and west of Index Crag.

Figure 8. Example of lapilli tuff of the Monarch sequence.

angular and irregular. In some places the fragments are densely packed with very little interstitial matrix and well rounded, suggesting they are reworked. In contrast, some areas have a few fragments floating in a predominantly aphanitic matrix. North of Swallop Creek the agglomerate is lenticular and the clasts and matrix are flattened parallel to bedding (Fig. 7).

The tuffs commonly consist of rock and crystal fragments in poorly sorted massive beds and locally as well sorted, graded, thick- and thin-bedded sequences. Variations include plagioclase-crystal tuff, welded tuff, lapilli tuff (Fig. 8), and ash tuff. In many places the andesite tuff fragments consist of subangular to subrounded rhyolite and dacite. Conglomerate and sandstone of andesitic composition appear to be a reworked subaqueous facies of the tuff.

Andesite flows

Andesite flows are mostly olive to dark olive-grey weathering, olive-grey to dark grey aphanitic to plagioclase-phyric. Flow breccia forms local pods and lenses within the massive sequences. Pillow lava has been reported from the north shore of Burke Channel (G. Gehrels, pers. comm., 2001) and is also known from the Monarch volcanics south of the mapped area (Rusmore et al., 2000). Contacts between flows are generally sharp with rare interflow breccia or disruption.

Andesite dykes and sills

Andesite dykes and sills are generally olive to olive-grey weathering, olive-grey to dark grey, aphanitic to hornblende-plagioclase-phyric. The plagioclase (<1.6 mm) is generally prismatic to acicular glomerophyric to felted. The hornblende (<6 mm) is present only locally and is acicular and scattered evenly throughout the andesite.

The dykes are generally vertical, trend northerly, are 5 to 150 cm thick, and have chilled margins in most localities. They are prominent in many interpreted Early Cretaceous and older mafic- to intermediate-composition plutons and form bulbous masses in some plutons. The dykes are themselves intruded locally, forming sheeted complexes. Sills, characterized by chilled margins and homogeneous, densely packed plagioclase-phyric texture, occur throughout the stratified Cretaceous volcanic and sedimentary rocks.

Most of the andesite dykes and sills of east Bella Coola map area are interpreted to have fed flows, fragmental volcanic, and volcaniclastic rocks that have been mapped as Monarch volcanics. They also define a wide-spread extensional complex with at least 10 to 50% upper level east-west crustal extension. In combination with diorite, granodiorite, and rhyolite dykes, they locally form intrusive complexes informally called the ‘Crag Creek intrusive complex’ (Hrudey et al., 2002). Until these dykes are isotopically dated (underway), the timing and magmatic relationships remain hypothetical.

Rhyolite dykes and sills

Scattered white, mainly aphanitic to sugary, rhyolite forms 50 to 150 cm wide dykes and sills that commonly exceed 0.5 to 1 km in length. Locally, near the margins, the dykes are flow banded, implying viscous flow. The dykes and sills vary in width along strike and are generally subparallel to bedding. They cut all andesite dykes, sills, extrusive, and sedimentary rocks of the Lower Cretaceous succession.

Subvolcanic diorite

Microdiorite to fine-grained diorite bodies locally lie within, and are commonly difficult to distinguish from, some extrusive rocks comprising the Lower Cretaceous sequence. In places, they grade into crystal-tuff beds, but elsewhere they crosscut andesite flows and fragmental rocks. The diorite consists primarily of hornblende (20–35%, 0.5–2 mm) and plagioclase (50–70%, 0.5–1.5 mm) and, in some places, the mafic mineral may be mostly augite.

These diorite bodies are difficult to trace and look very similar to coarser grained larger bodies that can be mapped throughout eastern Bella Coola map area. The microdiorite is interpreted as subvolcanic to parts of the Cretaceous volcanic sequence. Macroscopically it cannot be distinguished from similar rocks east of the Noosgulch River, which are spatially associated with thick accumulations of mafic flows assigned to the Hazelton Group.

DISCUSSION AND CONCLUSIONS

The volcanic and sedimentary rocks of the interpreted Lower Cretaceous sequence mapped in the eastern Bella Coola area appear to represent a segment of a regionally more-extensive volcano-sedimentary arc succession. In the northern Bella Coola map area, the eastern margin of this succession is, in part, a steeply dipping fault that separates the Lower Cretaceous succession from Middle Jurassic volcanic rocks of the Hazelton Group farther east. The western margin may be the Coast shear zone (Rusmore et al., 2001), or may be disrupted by Miocene and Pliocene uplift of the Coast batholithic complex.

Because the Lower Cretaceous volcano-sedimentary sequence mapped in the northern part of eastern Bella Coola map area is dominated by volcanic rocks, but also contains a high proportion of sedimentary rocks, we temporarily refer to it, for convenience of discussion, as the Monarch sequence.

As described by van der Heyden (1991) for the area near Salloomt Peak, the base of the Monarch sequence is locally a well exposed nonconformity deposited on an Early Cretaceous granodiorite (134 Ma) that he called the Firvale pluton (Hrudey et al., 2002). We discovered further examples of conglomerate within the lower parts of the Monarch sequence of eastern Bella Coola map area that may represent erosion from the same uplift event as described by van der Heyden. These conglomerate units record erosion from tonalite, quartz diorite, andesite, dacite, and rhyolite sources. Those source rocks are Early Cretaceous or older, and were presumably exposed aerially during the Early Cretaceous , as interpreted from the fossil ages. Because the conglomerate units occur within the Monarch sequence, parts of that sequence must have been deposited concurrently with subaerial exposure of adjacent areas like the Firvale pluton near Salloomt Peak. This association of highland and basins implies significant local topography during the Early Cretaceous, an interpretation supported by the large size of clasts in the Swallop and Kalone Creek occurrences. The fossil assemblage of the Monarch sequence represents a shallow-marine environment, so the subaerially exposed topography may have resembled oceanic islands or parts of a coastal environment, perhaps like the present-day coastlines of Vancouver Island or the Gulf Islands of the Georgia Strait in southern British Columbia.

The Kalone and Swallop Creek conglomerate units contain a large percentage of volcanic clasts, suggesting provenance from a Lower Cretaceous terrane composed largely of volcanic rocks. Across a narrow north-south zone in the eastern part of the map area, the Monarch sequence abruptly changes eastward to silica-bimodal rocks assigned to the Jurassic Hazelton Group. The Hazelton Group has not been recognized west of this zone. Several possibilities exist for their apparent absence; they may be present locally but not readily distinguished from lithologically similar volcanic rocks comprising the Monarch sequence, or they may have been deposited and subsequently eroded prior to deposition of the Monarch sequence.

Hazelton Group rocks, like the Monarch sequence, are also in contact with the Firvale pluton. Unlike the Monarch sequence, which rests nonconformably on the Firvale pluton, the Hazelton Group may be intruded by the pluton. Because the break between the Hazelton and Monarch is abrupt, a northerly trending uplift is interpreted to exist just to the west of the present exposures of the Hazelton Group (Diakow et al., 2002). The uplift corresponds with a north-south belt exposing a suite of intrusive rocks informally named the Crag Creek intrusive complex (Hrudey et al., 2002; Mahoney et al., 2002). This complex is defined by a high concentration of locally sheeted, northerly trending basalt and andesite dykes that cut granodiorite and older dioritic phases. The Crag Creek complex is interpreted as an extensional complex, broadly synchronous with emplacement of the Firvale pluton that formed an exposed highland in the east.

Regionally, the Monarch sequence appears to continue for several tens of kilometres north into Whitesail Lake map area (93 E) and south into the Rivers Inlet (92 M) and Mount Waddington (92 N) map areas. In Whitesail Lake map area, the sequence is not well studied, but is dominated by andesite to rhyodacite tuff, breccia, and flows (Woodsworth, 1979) that appear to rest nonconformably on Late Jurassic plutons (van der Heyden, 1989). Based on lithological similarities, Woodsworth (1980) correlated these rocks with the Lower Cretaceous Gambier Group exposed near Vancouver. A U-Pb (zircon) date of about 136 Ma (van der Heyden, 1989) and a K-Ar (hornblende) date of 124 ± 4 Ma (Woodsworth, *in* Stevens et al., 1982) confirm an Early Cretaceous age for the volcanic rocks.

In northeastern Rivers Inlet map area, Rusmore et al. (2000) included these rocks in the informally named 'Monarch volcanics' of van der Heyden (1990, 1991) and correlated them with the informally named Lower Cretaceous 'Ottarasko volcanics' in the Mount Waddington map area (Rusmore and Woodsworth, 1994; Mustard and van der Heyden, 1997). They interpreted these suites as the younger parts of a Late Jurassic–Early Cretaceous volcanic arc that formed on the western edge of Stikine terrane; *see* van der Heyden (1989), Umhoefer et al. (1994) and Rusmore et al. (2000) for further discussions of regional correlations and tectonic implications.

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