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Atlin TGI, Part V: Carbonate and Siliceous Rocks of the Cache Creek Terrane, Southern Sentinel Mountain, NTS 104N/5E and 6W

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KEYWORDS: Cache Creek terrane, Atlin, Sentinel Mountain, basalt, carbonate, chert, radiolaria, fusulinid, biostratigraphy.

INTRODUCTION

Cache Creek terrane is a subduction-generated accreted terrane within the Canadian Cordillera (Struik *et al.*, 2001). It is characterized by an oceanic-rocks including Lower Mississippian to upper Middle Permian shallow-marine carbonates containing Tethyan-type fusulinid-bearing limestone, often occurring as huge tectonic slabs.Lower Mississippian to Middle Jurassic radiolarian chert, argillite, greywacke, basic volcanic rocks and ultramafic rocks are other major constituents (Monger *et al.*, 1991). Tethyan fusulinids imply paleobiogeographic allochthoneity to North America (Monger and Ross, 1971; Carter *et al.*, 1991; Orchard *et al.*, 2001). Cache Creek terrane is, therefore, a key terrane which contains remnants of the Mississippian to Jurassic, long-lived Panthalassan Ocean, and contains a record of much of the late Mesozoic tectonic evolution of the Canadian Cordillera (Mihalynuk *et al.*, 1994).

The most extensive and best exposures of Cache Creek terrane occur within a wedge-shaped region centered on the Atlin area (Figure 1; Monger *et al.*, 1991). As in the other major exposure areas, such as near Pavillion (Figure 1), Cache Creek terrane near Atlin comprises a highly complicated structural aggregate of the Lower Mississippian to Upper Triassic oceanic rocks. During the Atlin Targeted Geoscience Initiative (TGI) fieldwork in 2003 (Mihalynuk and Lowe, 2002), Mesozoic and Paleozoic oceanic rocks of Cache Creek terrane were investigated (Figure 1) within the area wouthwest of Sentinel Mountain.We discuss the stratigraphic relationship of the deep-marine siliceous rock facies to the shallow-marine carbonates, historically referred to as the Kedahda and Horsefeed formations, respectively (Monger, 1975), and how that bears on the evolution of the Cache Creek as a whole.

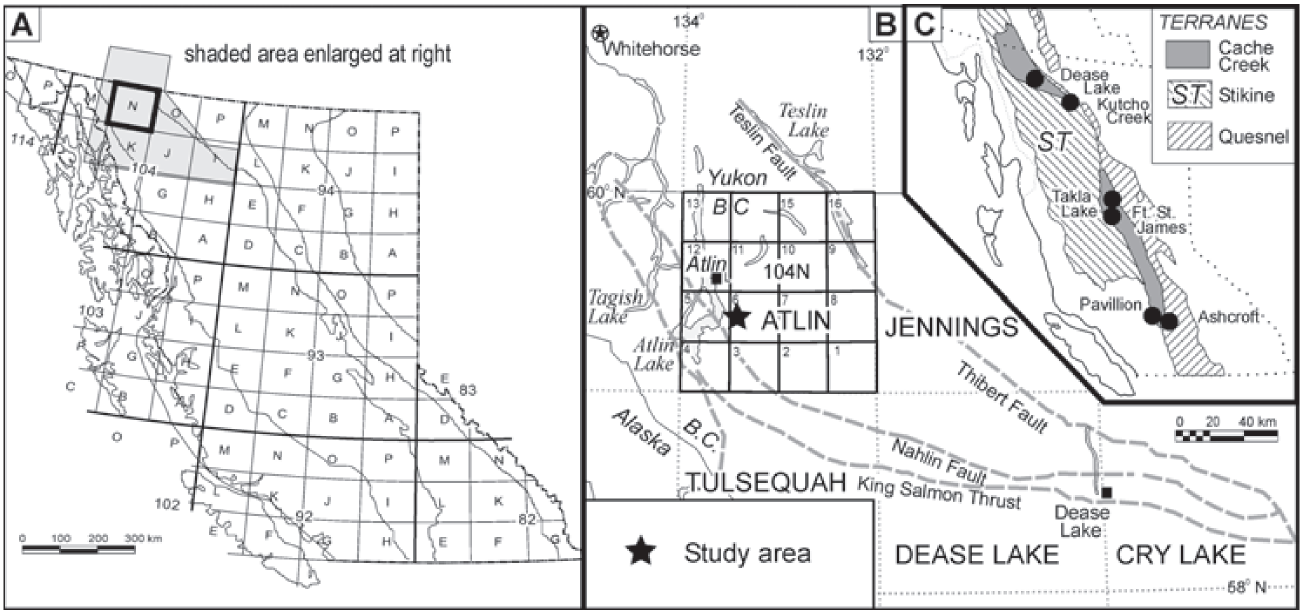

Figure 1. The location of Atlin TGI transect mapping in northwestern British Columbia (A), and location of our study area, on the southern flank of Sentinel Mountain (B).

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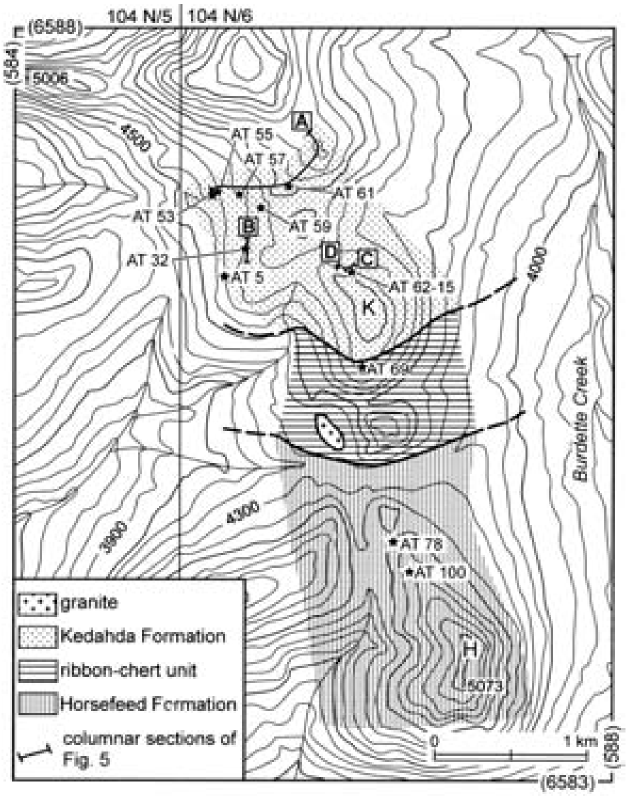

Figure 2. Geology of southern Sentinel Mountain area . Localities of outcrop photos 1, 2, 3, 5, and 7, and columnar section included on Figure 3 are indicated.

KEDAHDA AND HORSEFEED OCEANIC ROCKS

Rocks of the Kedahda Formation crop out along the gently rolling hills and peaks located approximately 2 km southwest of the head of Burdette Creek (Figure 2). To the north, are are mafic volcanic rocks and to the south are Triassic radiolarian-bearing ribbon chert (Photo 1). The structural relationship between the chert and volcanic rocks remains unresolved. However, we suggest that there is a gently to moderately north-dipping thrust fault contact with chert placed atop volcanic rocks.

The Kedahda Formation in the study area is composed predominantly of chert with subordinate basaltic flow rocks, tuffaceous rocks, argillite, and greywacke. It is herein subdivided into the lower, middle, and upper members (Figure 3). The lower member is characterized by basaltic flows and subordinate volcaniclastic rocks, chert, and carbonate. It is overlain by the middle member of massive chert and related siliceous and tuffaceous rocks. These, in turn, areoverlain by the upper member composed of argillacoeus rocks and greywacke (Figure 3). The thickness is difficult to ascertain, but is estimated to be 500 metres, or more.

Photo 1. The small peak, denoted as K in Figure 2, is almost entirely underlain by massive Kedahda Formation chert . View is to the southeast.

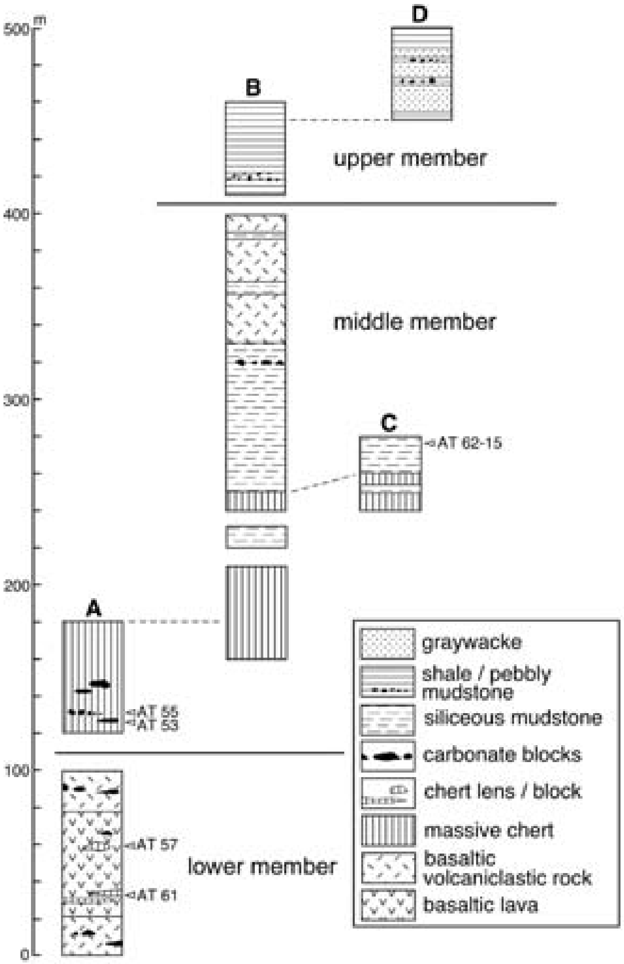

Figure 3. Measured columnar sections illustrating lithostratigraphy of Kedahda Formation, southern Sentinel Mountain area. Localities of these columnar sections are illustrated on Figure 2.

Basaltic flow rocks of the lower member are distributed mainly in the northern part of the outcrop area. They are locally pillowed and are intercalated with lenses of chert (Photo 2-1) and isolated blocks of limestone and chert (Photo 2-2). Volcaniclastic rock underlie the flows, and range in thickness from several tens of centimetres to a few metres, or more. The limestone and chert blocks vary in size, ranging from a few centimeters to several metres. The blocks are irregularly pod-shaped, and are in sharp contact with their enclosing host rocks. Limestone blocks also occur within the basaltic volcaniclastic rocks, and locally yield gastropod and bivalve debris of a shallow-marine affinity. We interpret that the intercalated chert formed during a short cessasion in the submarine eruption of basalt flows. Some of the chert and limestone blocks are believed to have been incorporated in the basalt lavas during downslope-flow, and some are probably mixed with volcanics during gravitational displacement of both units.

The lower portion of the middle member consists of massive chert, which grade up-section into siliceous mudstone (Figure 3). The massive chert lacks clayey partings and is characterized by the absence of ribbon-bedding (Photo 2-3). It is grey to dark grey, dense and hard, with a splintery conchoidal fracture. A lack of preserved radiolaria is probably due to recrystallization which is supported by petrographic analysis. Massive chert contains scattered, silica-filled, rod-shaped particles; possibly siliceous sponge spicules. I does not contain coarse terrigenous clastic grains. The siliceous mudstone can look similar to the massive chert: devoid of a distinct bedding fabric (Photo 2-4), dark grey, hard and dense. However, it is differentiated on the basis of having more argillaceous and fissile properties, particularly at higher stratigraphic levels. Lower siliceous mudstone yields radiolaria of probable middle to upper Early Permian age (AT 62-15 in Figures 2 and 3).

The massive chert and siliceous mudstone contain isolated blocks of carbonate (Figure 3). Carbonate blocks vary in size, ranging from several centimetres to several metres across (Photo 3), but are most commonly a few tens of centimetres. The blocks are lenticular, bulbous, and tabular in shape. Their outer surfaces arecommonly knobby and ragged, probably due to pressure solution. Carbonate blocks are composed predominantly of siliceous, dark grey micrite (Photo 3-1) containing scattered crinoid debris and poorly preserved fusulinids. Dolomite and dolomitic limestone, silicified micrite with chert nodules, and limestone conglomerate (Photo 3-2) are subordinate. All types of carbonates are massive and crystalline and devoid of well-defined bedding.

The tuffaceous shale of the upper part of the middle member, is pale to greyish green, fine-grained and highly fissile (Photo 2-5). Locally it contains dark green, lithic fragments presumably of intermediate to acidic volcanic rocks. These fragments are flattened to forma a fabic parallel with a spaced cleavage. The tuffaceous shale also contains isolated siliceous limestone blocks.

The lower part of the upper Kedahda Formation is primarily dark grey shale with minor siltstone and pebbly mudstone (Figure 3). The shale is slightly siliceous, highly fissile, and locally cleaved. The pebbly mudstone occurs intermittently as thin beds, less than 1 m thick. Subrounded pebble to granules dominated by limestone, chert, and greywacke are chaotically scattered within the argillaceous matrix of the pebbly mudstone. The siltstone is massive and devoid of distinctly sedimentary structures.

The upper part of the upper member consists of the greywacke with minor dark grey shale and pebbly mudstone (Figure 3). The greywacke occurs as massive beds, up to 10 metres thick. The rocks are fine-grained and sorted, but distinct sedimentary structures were not identified in outcrop.

Less extensive, but significant, is the ribbon-bedded chert which crops out south of the Kedahda massive chert (Figure 2). The ribbon-bedded chert appears to crop out only in the limited area south of the Kedahda Formation (Figure 2). Stratigraphic continuity of the ribbon-bedded chert and Kedahda Formation massive chert is not recognized. The ribbon-chert is distinguished from the Kedahda massive chert mainly by a difference in bedding style. It is characterized by a distinct, rhythmic layering of highly siliceous beds and fissile, less siliceous and clayey partings (Photo 2-6). Highly siliceous beds are grey and pale greenish grey, and beds are usually several centimeters thick. Numerous radiolarian remains are discerned in outcrop and in thin section. Tight folding is common. These properties differ from those of the massive Kedahda Formation chert.

Radiolaria tentatively identified as Middle to Upper Triassic age were extracted from the ribbon-bedded chert (AT 69 in Figure 2). In contrast with middle to upper Lower Permian age of radiolaria within massive chert. Although both chert types have previously been included within the Kedahda Formation by Monger (1975), the clear lithologic and age characteristic suggest that the ribbon-bedded chert should be designated as a distinct stratigraphic unit.

HORSEFEED FORMATION

Horsefeed Formation carbonates crop out extensively in southwestern Sentinel Mountain area (Monger, 1975). We examined the Horsefeed Formation carbonates exposed on the north-trending ridge, west of Burdette Creek (Photos 4-1 and 5-1). Here, the Horsefeed Formation is bounded by Middle to Upper Triassic radiolarian ribbon chert to the north of an east-northeast- trending fault zone (Photo 6). The southern extent of the Horsefeed Formation is covered by dense vegetation .

The Horsefeed Formation comprises a thick succession of primarily siliceous, locally dolomitized, dark grey limestone. Much of the limestone is massive, lacking distinct bedding, presumably due to a continuous and uniform accumulation of carbonate sediment. Depositional surfaces, represented by parallel alignment of skeletal debris, are present at only a few localities.

Although much of the Horsefeed limestone is massive, a small amount of bedded limestone crops out (Photo 5-2). Bedding is defined by highly carbonaceous marl intercalated withsiliceous limestone beds. Siliceous limestone

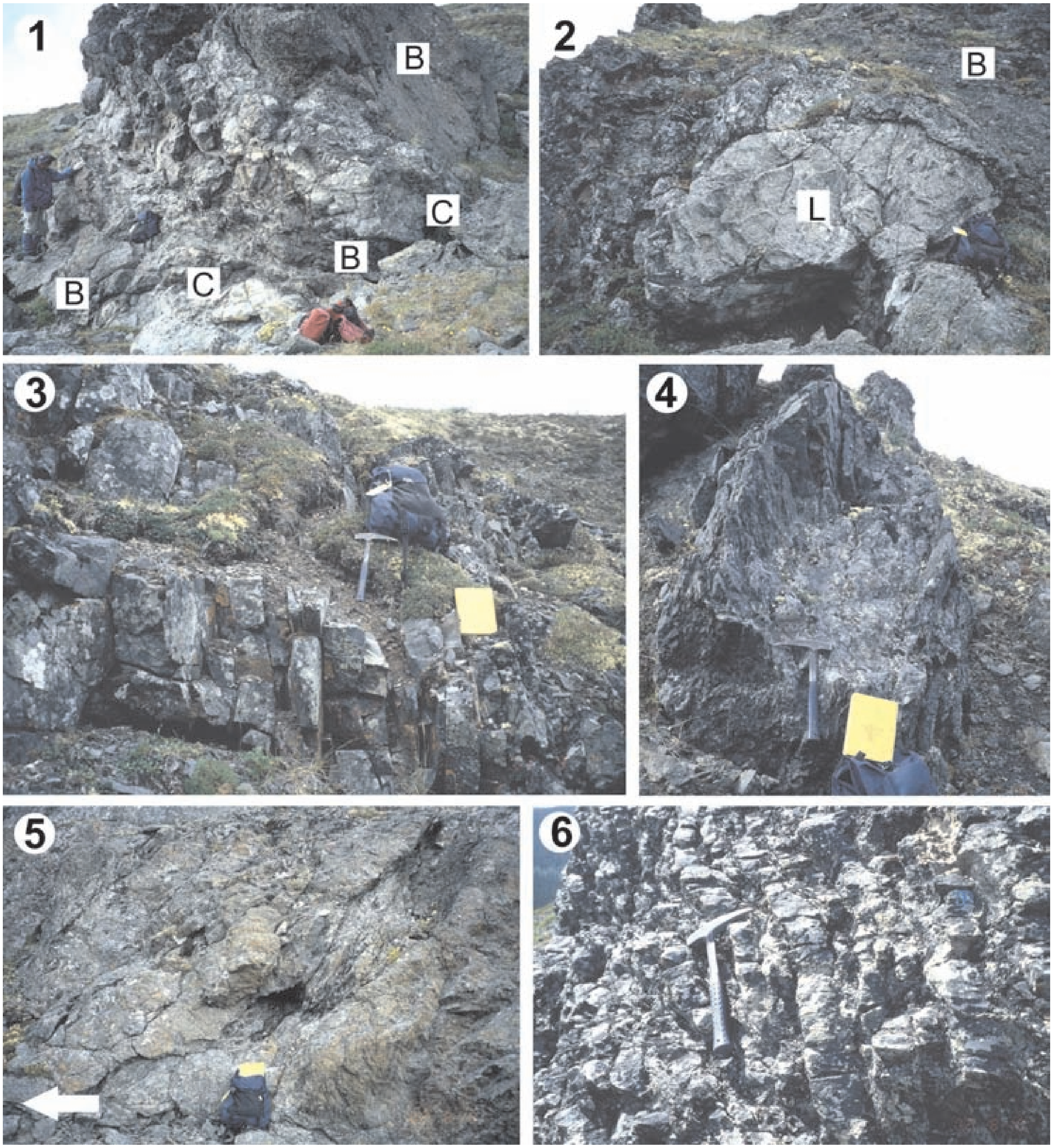

Photo 2. Kedahda Formation basaltic rocks and ribbon-bedded chert. Localities are indicated on Figure 2.
1. Lenticular beds of chert (C), intercalated in basaltic flow rocks (B) with minor volcaniclastic rocks. Locality AT 61. *See* Figure 3 for approximate stratigraphic level.
2. Isolated block of siliceous limestone (L) wholly embedded in a basaltic lava (B), which also contains small blocks of chert and limestone breccia. Locality AT 57. *See* Figure 3 for approximate stratigraphic level.
3. Dark grey, massive chert, entirely devoid of bedding surfaces, cut by nearly vertical joints. Locality AT 5.
4. Fissile and fractured, siliceous mudstone having locally crowded, pebble-sized limestone debris. Locality AT 32.
5. Penetratively and pervasively cleaved, pale green, tuffaceous shale of Kedahda Formation. The scaley cleavage is anastomosing and moderately inclined to northwest. Arrow at lower left indicates north. Locity AT 59.
6. Weakly contorted, ribbon-bedded, radiolarian chert with clayey partings. Locality AT 69.

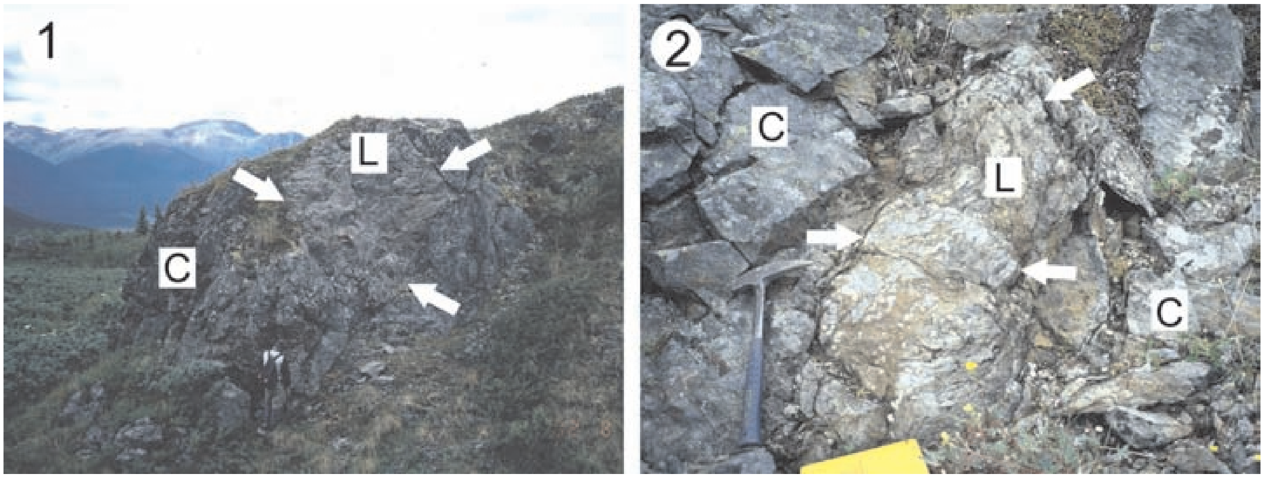

Photo 3. Various-sized, displaced limestone blocks (L) embedded in massive chert (C) of the Kedahda Formation. Arrows denote lithologically sharp, ragged and knobby boundary surface between limestone blocks and massive chert. All localities are shown on Figure 2. *See* Figure 3 for approximate stratigraphic levels.

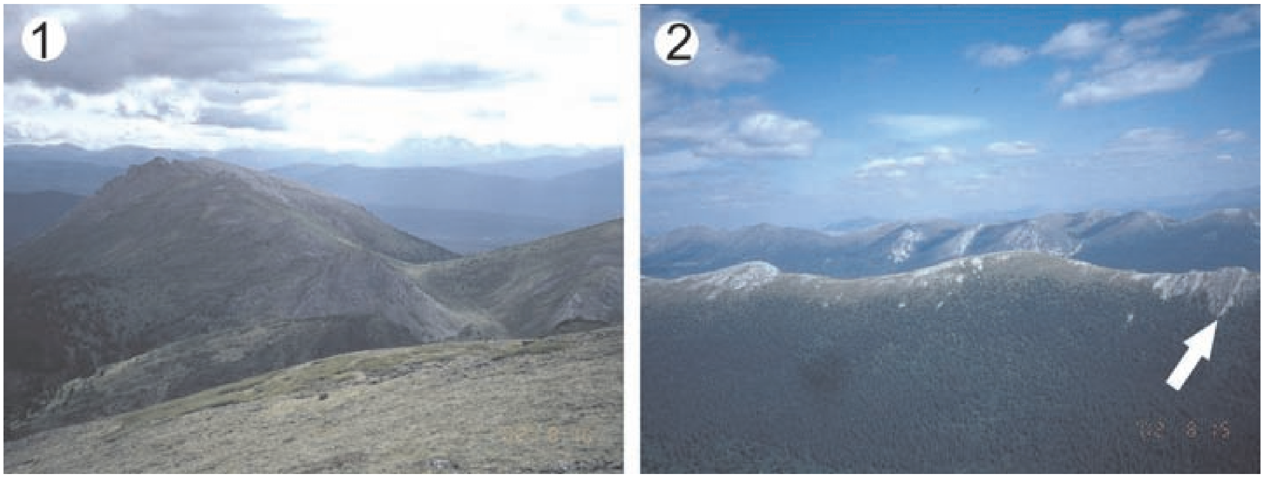

Photo 4. Horsefeed Formation limestone.

1. North-northwest-trending ridge underlain mostly by massive limestone of the Horsefeed Formation.View to south from small peak underlain by Kedahda Formation siliceous rocks. Densely-vegetated, western slope of Burdette Creek is at left edge of view.
2. Horsefeed Formation limestone exposed on north-trending ridge. View is to east across Burdette Creek. Note moderately north-dipping, thick limestone beds, indicated by arrow. Beyond this ridge is the southern part of Laurie Range, which is underlain by Horsefeed Formation limestone.

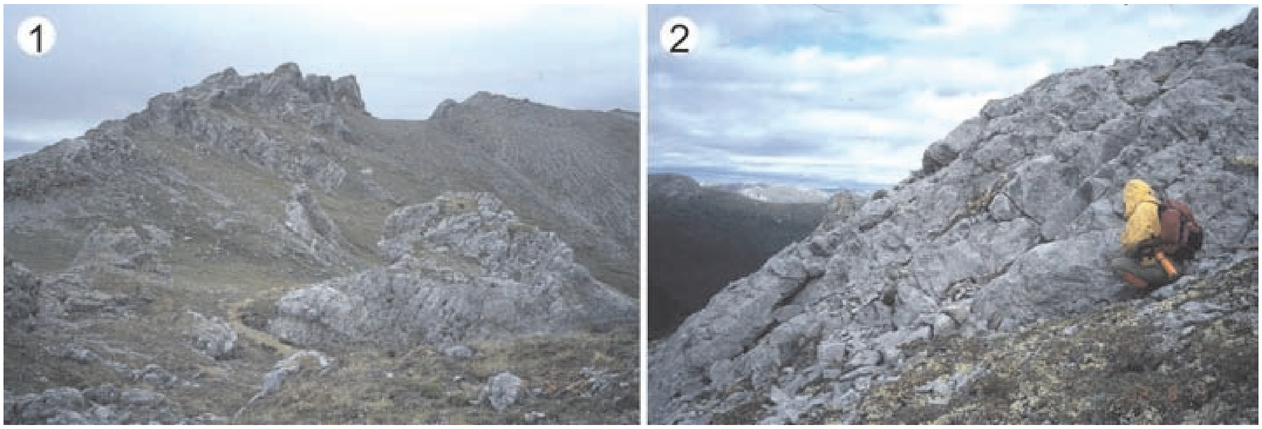

Photo 5. Vews of Horsefeed Formation limestone in southern Sentinel Mountain area.

1. View of strongly fractured, massive limestone exposed at peak, denoted as H in Figure 2.
2. Style of bedded limestone with intercalation of thin, highly carbonaceous marl layers. Locality AT 100 in Figure 2.

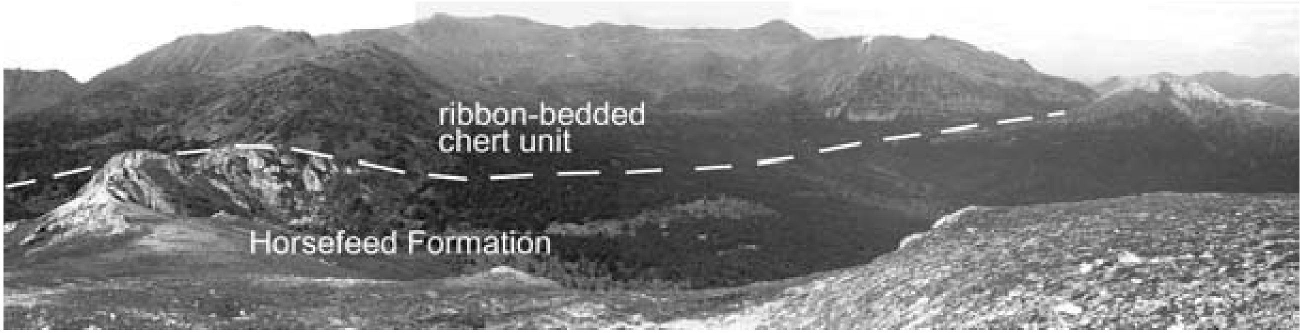

Photo 6. Panoramic view of fault boundary, indicated by dashed line, between Triassic radiolarian-bearing ribbon-chert unit and Horsefeed Formation carbonate rocks. Fault boundary trends east-northeast. Thickly vegetated, upper reaches of Burdette Creek at center of view.

beds are usually a few tens to several tens of centimetres thick, dominate the marl beds, which are commonly less than 5 centimeters thick. Siliceous limestone is dark grey to black; probably rich in carbonaceous matter. Carbonaceous marl is dark grey, occasionally jet black, weakly fissile, and smells putrid when broken. Bedding surfaces are gently undulated and knobby, due to stylolitization. The rocks trend approximately southwest, with moderate northwest dips. This structural trend extends outside of the study area, to the east (Photo 4-2).

All Horsefeed limestone contains shallow-marine bioclasts. Boundstone is not observed. Fossils preserved are fusulinids, crinoids, gastropods, bivalves, ostracods, and dasycladacean algae; all are indicative of carbonate accumulation in shallow water. These skeletal debris are in many cases supported by a micritic matrix, but in places the rock is grain supported (Photo 7).

Although fusulinids were found at many localities throughout the outcrop area, their preservation is poor. Preliminary identifications support an upper Lower Permian (upper Artinskian) age for the highly carbonaceous limestone (AT 100 in Figure 2). On the basis of the upper Artinskian fusulinids, plus the lower Lower and upper Middle Permian fusulinids previously reported by Monger (1975), the Horsefeed Formation in the Sentinel Mountain probably rangesin age from Lower to Middle Permian.

DISCUSSION

REVISION OF KEDAHDA FORMATION STRATIGRAPHY AND ITS SEDIMENTOLOGICAL IMPLICATION

Kedahda succession of the Sentinel Mountain area probably represents stratigraphy formed in a deep marine environment. We consider that the stratigraphic change from massive chert to greywacke, records a lateral shift from a deep-marine basin ideal for the chert accumulation, to a hemipelagic environment, then to a trench-environment, where land-derived clastic sediments and intermediate volcaniclastic debris were deposited.

Kedahda massive chert is interpreted to be a deep-water siliceous facies, characterized by an abundance of siliceous sponge spicules, which accumulated in a pelagic setting in an open-ocean. This would place it far beyond the reach of terrigenous clastics.The argillaceous character of the siliceous mudstone is interpreted to represent accumulation in a hemipelagic setting. Deposition of the tuffaceous shale suggests a nearby volcanic source; however, the siliceous rocks suggest sedimentation in a pelagic to hemipelagic setting, succeeded by a deep-marine environment. The Lower Permian, radiolarian-bearing greywacke is possibly a distal trench-fill sediment.

HORSEFEED AND KEDAHDA FACIES INTERPRETATION

Horsefeed Formation rocks are shallow-marine bioclastic carbonate sediments. Carbonaceous and siliceous properties, and predominance of the micritic matrix, imply deposition in a slightly stagnant, lagoonal setting within the deep subtidal zone. An absence of terrigenous materials in the Horsefeed Formation suggests deposition on a topographic high in an open-ocean setting. According to Monger *et al*. (1991), the Horsefeed Formation carbonates formed a cap upon a basaltic seamount, or an oceanic plateau.

Massive chert of the Kedahda Formation is similar to the Bashkirian to Moscovian chert of the Pope succession within the Cache Creek Complex of the Mt. Pope area near Fort St. James, central British Columbia (Sano and Struik, 1997; Orchard *et al*., 1998) as both contain siliceous sponge spicules and displaced shallow-marine carbonates. Although they differ in age, the Kedahda and Pope cherts are commonly interpreted as siliceous facies formed in a deep-water setting, where shallow-marine carbonates could have been introduced by density flows (olistostromes), most probably sourced from the nearby Horsefeed and Pope buildups, respectively.

Following the sedimentary model of Monger *et al*, (1991) and Sano and Rui (2001), we consider that the Kedahda massive chert accumulated on the lower flank of a seamount, or an oceanic plateau, the top of which was capped by the Horsefeed carbonate buildup. We infer that

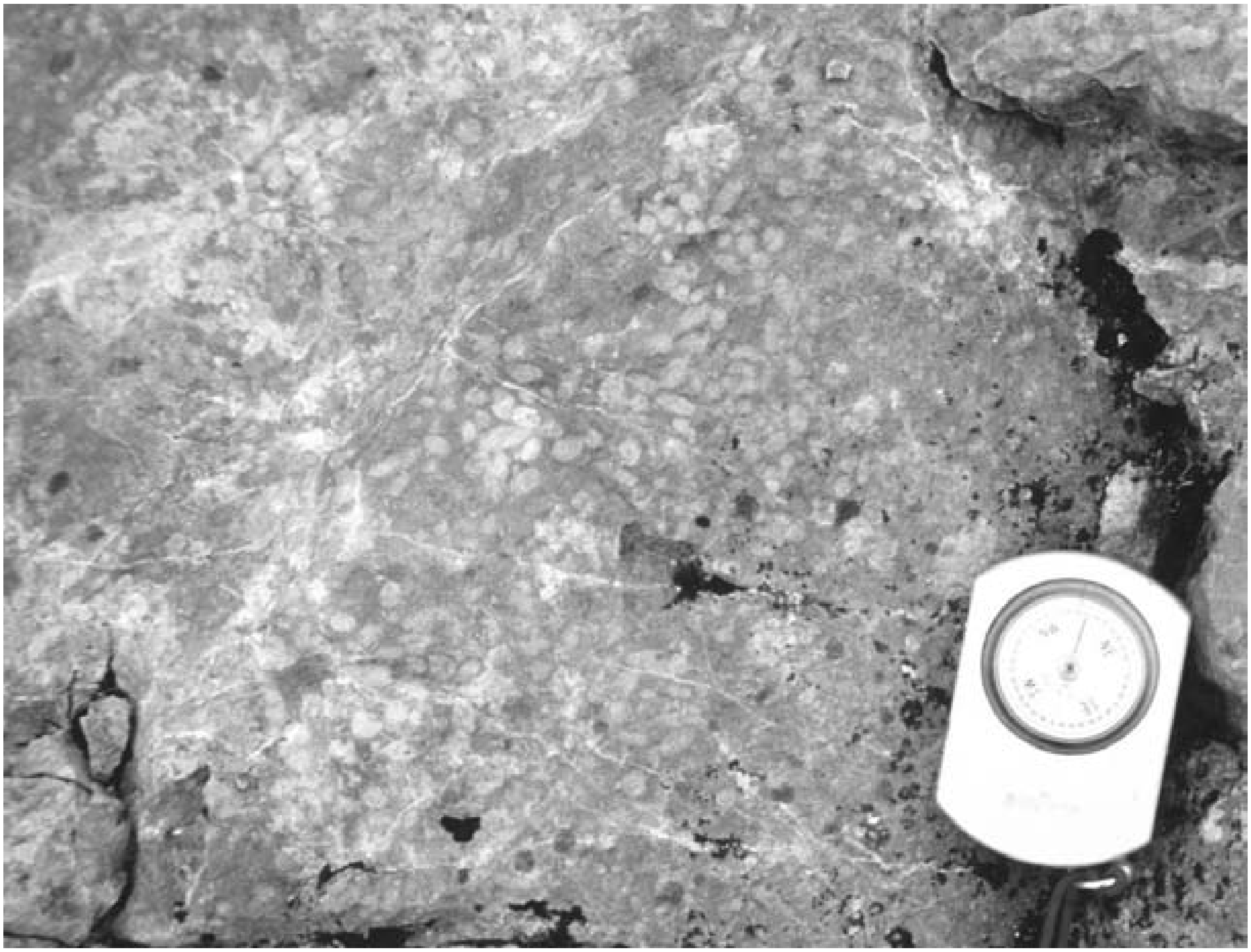

Photo 7. Local, dense accumulation of fusulinids in dark grey, micritic limestone. Location AT 78 in Figure 2.

their deposition was nearly synchronous; Horsefeed shallow-marine and Kedahda deep-marine facies pass laterally into each other, linked by olistostromal carbonate blocks and debris. Analogous facies occur in the Upper Carboniferous to Middle Permian spicular chert of the Akiyoshi terrane (Uchiyama *et al*., 1986; Sano and Kanmera, 1988), a subduction-generated Permian accretionary complex in southwest Japan. It is characterized by remnants of a Lower Carboniferous to Middle Permian shallow-marine carbonate buildup atop a seamount (Kanmera and Nishi, 1983; Kanmera *et al*., 1990).

Siliceous sponge spicules, instead of radiolaria, are the common biogenic component of the Carboniferous to Permian Kedahda, Pope, and Akiyoshi cherts. It is uncertain what this similarity implies. It is probably a facies controlled rather than age-related. Sano and Kanmera (1988) suggest that the Akiyoshi spicular chert exhibits proximal facies with respect to the carbonate capped seamount, whereas time-equivalent radiolarian chert is a distal facies without olostostromal carbonate.

SUMMARY

The Kedahda and Horsefeed oceanic rocks of Cache Creek terrane were investigated within the southern part of the Sentinel Mountain area, southeast of Atlin Lake, BC. Kedahda Formation consists of basaltic lavas and volcaniclastic rocks, massive chert, siliceous mudstone, tuffaceous shale, dark grey shale and pebbly mudstone, and greywacke, in ascending order. Isolated blocks and resedimented debris of shallow-marine carbonate occur at several levels embedded in the siliceous and argillaceous rocks. The succession is interpreted as oceanic stratigraphy formed by a shift from accumulation of the massive chert in an open-ocean realm, through hemipelagites in a possible trench setting. The massive chert yields Middle to Upper Permian radiolaria. Horsefeed Formation is composed entirely of locally dolomitized, but mostly siliceous, dark grey and carbonaceous, bioclastic limestone. It is mainly thick- bedded with thin, highly carbonaceous marl beds, and contains fusulinids, bivalves gastropods, and crinoids, all having a shallow-marine affinity. The fusulinids are preliminarily dated as the upper Lower Permian (Artinskian).

We interpret the Kedahda and Horsefeed oceanic rocks as having been deposited beside or atop a basaltic seamount, or oceanic plateau in an open-ocean realm. The Horsefeed shallow-marine facies and Kedahda deep-water facies pass laterally into each other, linked by olistostromal, shallow-marine carbonates.

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