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An intercalibrated biostratigraphy of the Upper Triassic of Black Bear Ridge, Williston Lake, northeast British Columbia[1]

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Abstract Black Bear Ridge on Williston Lake is one of several important North American reference sections for intercalibrating the ranges of Upper Triassic ammonoids, conodonts, bivalves, ichthyoliths, and brachiopods. The section (Ludington and Pardonet formations) spans the uppermost Carnian through Hettangian of the Lower Jurassic. The co-occurrence of several fossil groups facilitates an integrated biozonation of the interval. Fossil fauna and biofacies serve to identify significant biological and sedimentary events in the history of the Late Triassic. Conodont and ichthyolith faunal change is gradual through the Carnian–Norian boundary, whereas conodont and ammonoid changes are dramatic across the Lower–Middle Norian boundary. Major transgressions are recognized in both the Lower and Middle Norian, and are marked by a conodont (Norigondolella) and ichthyolith (Birgeria) biofacies.

Résumé La crête Black Bear sur le lac Williston est l'une de plusieurs sections de référence importantes en Amérique du Nord qui permettent de faire la datation corrélative des aires de distribution des ammonoïdés, des conodontes, des bivalves, des ichtyolithes et des brachiopodes. La section (formations de Ludington et de Pardonet) s'étend du Carnien sommital à l'Hettangien du Jurassique inférieur. La présence simultanée de plusieurs groupes fossiles facilite la biozonation intégrée de l'intervalle. La faune fossile et les biofaciès contribuent à mettre en évidence les événements biologiques et sédimentaires importants de l'histoire du Trias tardif. Les changements fauniques observés chez les conodontes et les ichtyolithes sont graduels sur l'ensemble de la frontière du Carnien et du Norien, alors que les changements chez les conodontes et les ammonoïdés sont spectaculaires sur la frontière du Norien moyen et du Norien inférieur. On a mis en évidence des transgressions importantes dans le Norien inférieur et moyen; celles-ci sont marquées par un biofaciès de conodontes (Norigondolella) et d'ichtyolithes (Birgeria).

[1] Contribution to the Foreland NAPMAT Project

INTRODUCTION

This article briefly summarizes the biostratigraphy of one of several important Triassic outcrops on the shores of Williston Lake in northeast British Columbia. This region has produced much of the data on which North American Upper Triassic biochronology is based (e.g. *see* Tozer, 1967, 1994; Orchard and Tozer, 1997; Orchard, 1983, 1991b). Considerable progress has been possible since the Peace River was dammed in 1967 and its valley was flooded to form Williston Lake. New Triassic outcrops along the perimeter of the lake were first noted by Tozer in 1979, and in subsequent years (chiefly 1980–1983) Tozer and Orchard examined most of these and made large collections of ammonoids and conodonts. This work continued sporadically through the 1990s and was supplemented by stratigraphic studies by Gibson (e.g. 1992) and Zonneveld et al. (1997), and paleontological work by M.J. Johns (ichthyoliths, Johns et al., 1997), C. McRoberts (bivalves), and M. Sandy (brachiopods). G. Muttoni also undertook a magnetostratigraphic study but found the Triassic signal overprinted (Muttoni et al., in press).

The Black Bear Ridge section lies on the north shore of Williston Lake (Fig. 1), 4 km northeast of the mouth of Nabesche River (NTS Map 94 B/3; zone 10, UTM 497670E, 6215500N). The section begins within the Upper Carnian Ludington Formation, extends through the largely Norian Pardonet Formation, and ends in the Lower Jurassic Fernie Formation. The entire Pardonet Formation is exposed, with the exception of a small covered interval. The steeply dipping beds are locally disturbed, but there is no major structural complexity.

STRATIGRAPHY

The Black Bear Ridge section has been described by Gibson in a number of field guides (e.g. Gibson, 1992), not all of which have been published; the following stratigraphic summary draws freely on these guides.

The Ludington Formation consists predominantly of siltstone and dolostone with minor limestone, often ribbon-like in its bed-form. White-mineral-filled vugs, a fine-scale lamination, and occasional slump structures can be observed. The depositional environment envisaged for the Ludington Formation is one of relatively deep water in the distal shelf or slope of western Pangaea far offshore and to the west of the shallow-water equivalents represented by the Charlie Lake and Baldonnel formations.

At Black Bear Ridge, the Ludington Formation is overlain by the Pardonet Formation. Gibson drew the base of the Pardonet Formation between his units 3 and 4 (Fig. 2), the former being chiefly dolostone and the latter including bioclastic and brachiopod-coquinid limestone layers containing rare ammonoids, halobiids, and the calcite spheres or 'pseudo-oolites' that are characteristic of the Pardonet Formation elsewhere. The rich brachiopod beds would appear to represent condensed horizons based on the abundance of rhynchonellids, but whether they represent a short-lived shallower water (regressive) phase, or a shell bed redeposited in deeper water is unclear. Both Unit 4 and Unit 5 also consist of interbedded limestone and dolostone displaying in part a wavy, ribbon-like character and represent a transitional facies to typical Pardonet Formation. Unit 5 is also characterized by cherty lenses concentrated in the lower part and by large

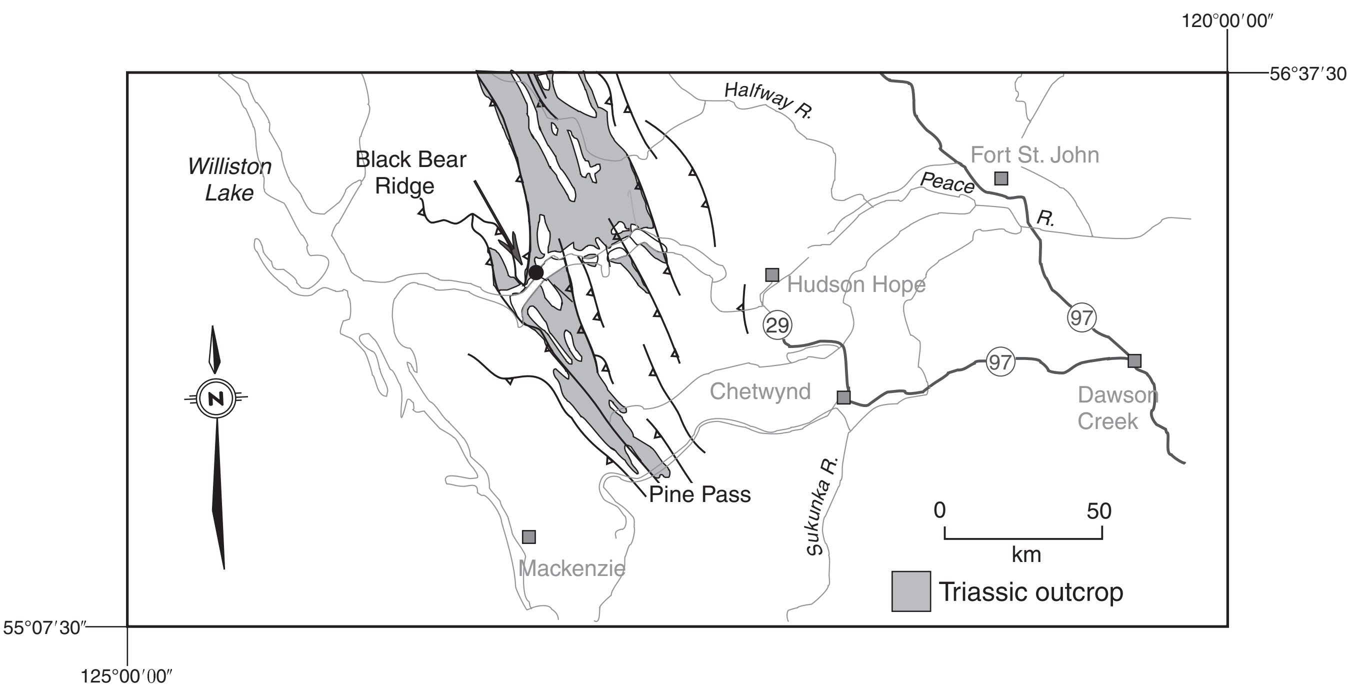

Figure 1. *Location of the Black Bear Ridge section on Williston Lake in northeast British Columbia.*

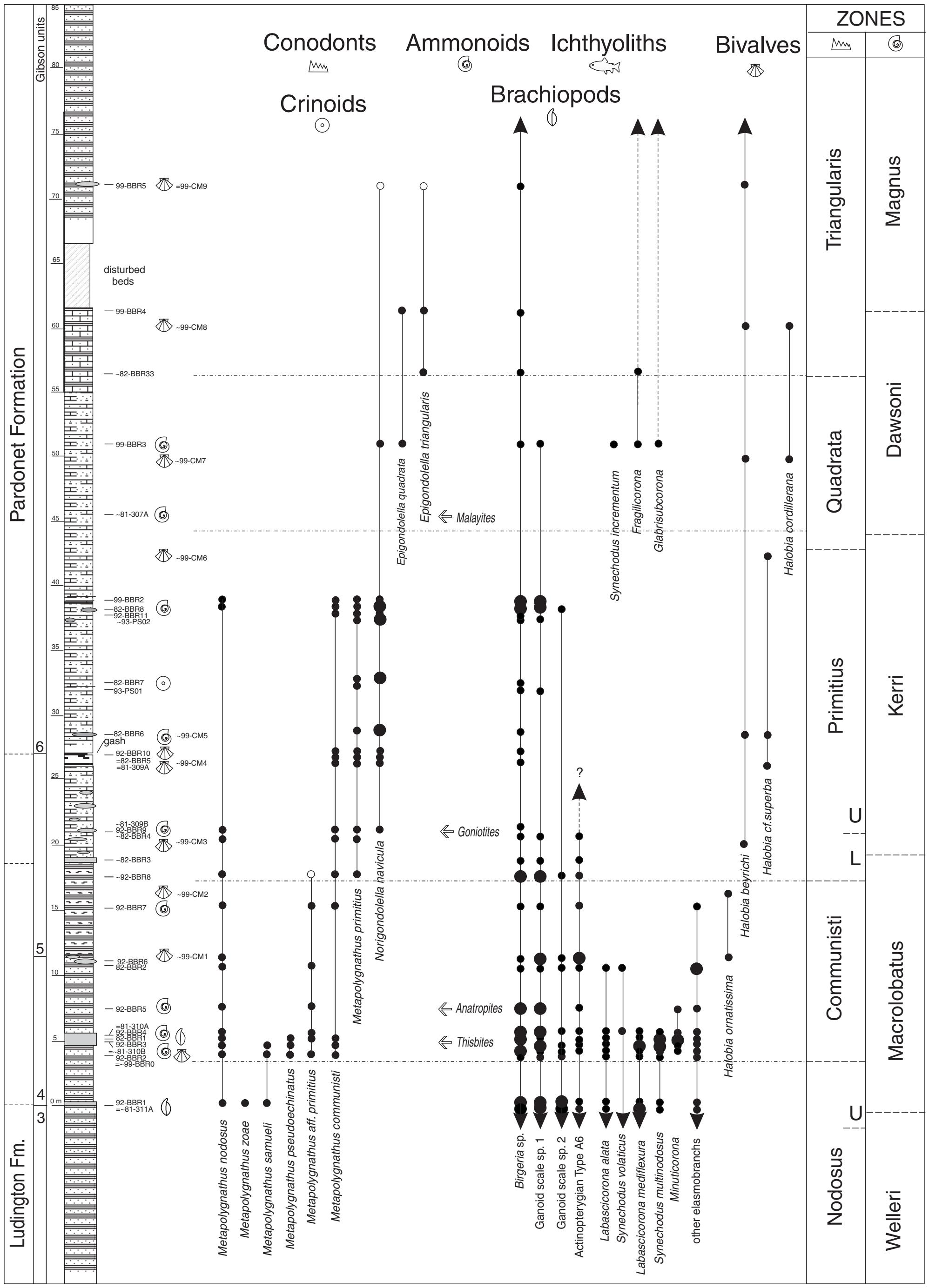

Figure 2. *Schematic section of the Upper Carnian-Lower Norian part of the Black Bear Ridge section showing occurrence and distribution of conodonts, ammonoids, bivalves, and ichthyoliths within the Ludington and lower Pardonet formations. Also shown are units differentiated by Gibson (1992). On the left are shown numbered samples which were taken for conodonts and/or ammonoids, and bivalves (CM). Ichytholith fauna was recovered from the former. The position of brachiopod fauna is indicated in the lowest part of the section.* See *text for lithological descriptions.*

diagenetic limestone concretions in the upper part. The base of the Pardonet Formation could reasonably be drawn between these two parts (Fig. 2).

The Pardonet Formation typically consists of carbonaceous silty limestone, calcareous and dolomitic siltstone and shale, and dense coquinid beds of bivalve shells. Limestone concretions occur throughout much of the formation and often contain ammonoids and scattered ichthyosaur bones. The Pardonet Formation is rich in organic carbonaceous matter and has a strong fetid sulphurous odour. Its deposition is thought to have followed a major transgression and lithological and faunal attributes suggest a relatively deep-water, restricted, anoxic, basin environment below storm wave-base. The base of Unit 6 of Gibson (Fig. 2) is marked by a recessive 30 cm black shale that forms a distinctive 'gash' in the section. Below this level, to the east, the outcrop is relatively smooth and polished by glacial erosion, whereas above the gash the beds display the typical attributes of the Pardonet Formation. Formerly, the base of the Pardonet Formation was drawn between units 5 and 6, but lithological and faunal characteristics are essentially the same across the marker bed.

Notable features of the lower Pardonet Formation include numerous ammonoid-belemnoid (including *Aulacoceras*) beds and concretions associated with ichthyosaur bones and horizons rich in pseudo-oolites that occur between about 10–20 m above the 'Pardonet gash'. These fossil beds are recrystallized and macrofossil extraction is difficult. Overlying beds are silty and sparsely fossiliferous. Richly fossiliferous limestone beds are common again just below (east of) a covered beach interval (Fig. 2). West of the beach, stratigraphically higher strata contain many rich fossil horizons yielding excellent ammonoid faunas and a succession of bivalve coquinas preserved in fine to coarse, wavy, crenulated beds. The distinctive *Monotis* beds constitute in excess of 30 m of section and are chiefly monotonous and variably calcareous dolostone, siltstone, and shale. Much of these strata are fossiliferous, but the best preservation is in rare limestone concretions. The uppermost *Monotis* beds contain small patches of phosphatic chert pebbles. Two thin (up to 7 cm) fibrous calcite ('beef') marker beds occur: one lies within the lower *Eomonotis* beds, and the second occurs about 1 m above the *Monotis* beds. The base of the Fernie Formation, and the Jurassic, is uncertain: Gibson drew it immediately above the *Monotis* beds, but it might occur anywhere within the 7.5 m between that level and the first Hettangian ammonites (*see* Tozer, 1982).

Gibson measured a total of about 212 m for the Black Bear Ridge section, with the Pardonet Formation attaining a thickness of about 182 m and the Ludington about 30 m. Cumulative thicknesses in Figures 2 and 3 were compiled over several visits and regard datum as the base of the Ludington–Pardonet transitional facies: the summed measurements do not exceed 170 m. The discrepancy might be caused by shifting beach outcrops between successive visits, but reliable datums are the main brachiopod bed near the base of the section, the 'gash' within the lower section, and the base and top of the *Monotis* beds in the upper (western) section.

CONODONTS

M.J. Orchard

Conodont faunas have been collected from throughout the Black Bear Ridge section and provide a rather complete framework for Late Carnian through Late Norian time. The lowest conodont faunas come from the 'transitional facies' characterized by shell beds that are at first bioclastic, but later coquinid in nature. The lowest fauna (Fig. 2, 92BBR-1) contains predominantly unornamented to weakly nodose metapolygnathids assigned to the *Metapolygnathus* ex gr. *nodosus* Hayashi. More ornate forms correspond to *Metapolygnathus samueli* Orchard and rarely *M. zoae* Orchard. This association identifies the Upper Nodosus Zone of Orchard (1991a). Several samples taken across 1 m of shell beds containing brachiopods and rare halobiids and ammonoids reveal a major diversification of the conodont fauna characterized as the base of the Communisti Zone (Fig. 2, 92BBR-2). *Metapolygnathus communisti* Hayashi appears concurrently with a variety of *M. pseudoechinatus* Kozur morphotypes, regarded as a proxy for the Communisti Zone in western Canada. Both *Metapolygnathus* ex gr. *nodosus* and *M. samueli* occur at this level, but amongst the former considerable variety leads to the recognition of several morphotypes, one of which is here called *M.* aff. *primitius* (Mosher). Unlike the index of the succeeding zone, this distinctly nodose form lacks the consistent node differentiation and low posterior platform of *M. primitius* as shown by Orchard (1991a, Pl. 3, F) but the trend toward that species is clear.

Above the brachiopod beds (Fig. 2, 92BBR-5, 6, 7), the sharp-noded species disappear, and most collections are dominated by *Metapolygnathus* ex gr. *nodosus* through to near the top of the siliceous facies (lower Unit 5 sensu Gibson). At this level (92BBR-8), a major faunal shift is evident and *M. primitius* becomes the dominant metapolygnathid. A little higher (92BBR-9), within the typical concretionary facies of the Pardonet Formation, *Norigondolella navicula* (Mosher) appears. This datum marks the base of the 'Upper' Primitius Zone in the Williston Lake exposures (Orchard, 1983), but the taxon is rare at first and occurs sporadically through the Primitius Zone, as it does elsewhere (Carter and Orchard, 2000; Orchard et al., 2000). Peak abundance of *Norigondolella navicula* occurs only in higher collections from the *Aulacoceras-bearing* pseudo-oolite beds collections near the top of the Primitius Zone (Fig. 2). Overlying strata is characterized by siltier and less fossiliferous beds, but single-conodont collections nevertheless document the succeeding Lower Norian Quadrata and Triangularis zones (99BBR-3, 4).

Richly fossiliferous limestone beds reappear in the Middle Norian (Fig. 3). The Multidentata Zone is succeeded by the Spiculata, Postera, and Serrulata zones in succession (Orchard, 1991b). The first two imply levels corresponding to the Rutherfordi and Columbianus 1 ammonoid zones, although neither macrofauna is certainly identified at Black Bear Ridge. The Postera Zone, which occurs through 10+ m of section with ammonoids of Columbianus Subzone 2, is

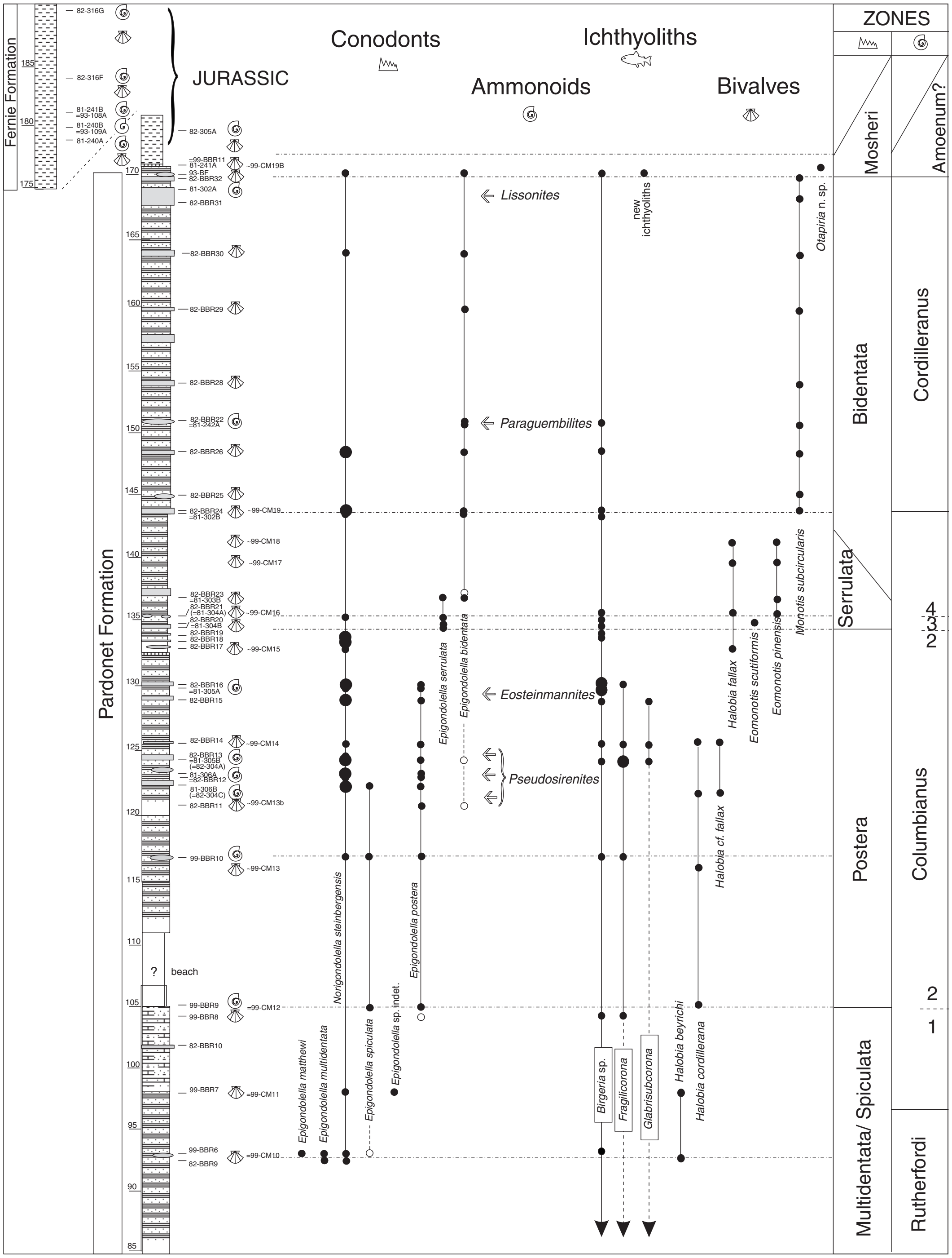

Figure 3. *Schematic section of the Middle-Upper Norian and younger part of the Black Bear Ridge section showing occurrence and distribution of conodonts, ammonoids, bivalves, and ichthyoliths within the upper Pardonet and lowest Fernie formations. On the left are shown numbered samples which were taken for conodonts and/or ammonoids, and bivalves (CM). Ichytholith fauna was recovered from the former.* See *text for lithological descriptions.*

characterized by abundant specimens of *Norigondolella steinbergensis* (Mosher), the second such 'flood' of the genus in the Black Bear Ridge section. Conodonts of the Serrulata Zone are associated with the overlying species of *Eomonotis* bivalves.

Upper Norian *Monotis* coquina and associated strata extend through some 33 m of section at Black Bear Ridge (Fig. 3). The Bidentata Zone fauna occurs both with *Monotis* bivalves and more abundantly in limestone concretions with the ammonoid *Paraguembilites*. Variation in the conodont faunas are noted: abundant *Norigondolella steinbergensis* are found in the lower part of the *Monotis* coquina, but indices of *Epigondolella* dominate the limier ammonoid beds. The stratigraphically highest conodonts occur in a small limestone concretion sitting directly above the youngest bedding surface of *Monotis*. These are examples of *Epigondolella* ex gr. *bidentata* Mosher, including a few large elements resembling the younger *E. mosheri* Kozur and Mostler (Orchard, 1994). This species is known overlying *Monotis* strata at a single locality elsewhere on Williston Lake (Ne Parle Pas Point), that is in the '*Rhacophyllites* beds' assigned to the Rhaetian Amoenum Zone. The data is sparse but provides an indication of Rhaetian strata.

AMMONOIDS

E.T. Tozer

Well preserved and locally abundant ammonoids occur in the Middle and Upper Norian, and in the overlying Lower Jurassic strata at the Black Bear Ridge section. Ammonoids also occur in Upper Carnian and Lower Norian, but they are rare or the specimens are difficult to separate from the matrix. Many of these ammonoid faunas are reported by Tozer (1994, p. 344–5, indicated below as * ; *see also* Tozer, 1982). The notable features of the ammonoid succession are the several levels of the Columbianus Subzone 2 fauna, and the superimposition of two *Eomonotis* faunas and two subzones of the Upper Norian Cordilleranus Zone. The Lower Jurassic (Hettangian) succession is also unique (currently under study by R. Hall, U. of Calgary). Available data are summarized in ascending stratigraphic order below with both field numbers (*see* Fig. 1) and GSC locality numbers indicated. These data enable the other faunal elements to be calibrated with the standard Triassic ammonoid biochronology.

99-BBR0 = GSC loc. C-304377. Ammonoid indet.

81-310A = GSC loc. 98555. Ammonoids indet.

82-BBR1 = GSC loc. C-101002. *Thisbites* sp.

92-BBR5 = GSC loc. C-201931. *Anatropites* sp.

81-309B = GSC loc. 98554. *Gonionotites* sp.

81-307A = GSC loc. 98553. cf. *Malayites dawsoni* McLearn. Approximates 82-305B = 98872.

81-306B = *GSC loc. 98552. *Pseudosirenites pardoneti* (McLearn), *Mesohimavitites columbianus* (McLearn), *Distichites canadensis* McLearn, *Leiodistichites ursidens* Tozer, *Helicites decorus* McLearn. Repeated as 82-304C = 98770.

81-306A = *GSC loc. 98551. *Pseudosirenites pardoneti* (McLearn), *Himavitites multiauritus* McLearn, *Distichites canadensis* McLearn, *Helicites decorus* McLearn, *Episculites teres* (McLearn).

81-305B = *GSC loc. 98550. *Pseudosirenites pardoneti* (McLearn), *P. pressus* (McLearn), *Distichites canadensis* McLearn, *Leiodistichites ursidens* Tozer, *Helicites decorus* McLearn. Repeated as 82-304A = 98868.

81-305A = *GSC loc. 98549. *Eosteinmannites orientalis* Tozer, *Himavitites appinatus* Tozer, *Helicites decorus* McLearn, *Parajuvavites canadensis* Tozer. Repeated as 82-303A = 98867.

81-304B = GSC loc. 98548. *Eomonotis scutiformis*

81-304A = GSC loc. 98547. *Eomonotis pinensis*

81-303B = GSC loc. 98546. *Eomonotis pinensis*

81-242A = *GSC loc. 98534. *Paraguembilites ludingtoni* Tozer, *Monotis* sp. Repeated as 82-301A = 98865.

81-302A = *GSC loc. 98545. *Lissonites* sp. indet., *Monotis* sp.

81-305A = GSC loc. 98871. *Primapsiloceras*? sp.

81-240A = GSC loc. 98531. *Psiloceras calliphyllum* (Neumayr), phylloceratids (Tozer, 1982).

81-240B = GSC loc. 98532; 93-109A = GSC loc. C-209258. *Curviceras* sp.

81-241B = GSC loc. 98533; 93-108A = GSC loc. C-209257. *Caloceras* sp.

82-316F = GSC loc. 98894. *Schlotheimia* sp.

82-316G = GSC loc. 98895. *Pseudaetomoceras* sp.

In addition to these levels, Tozer collected faunas of both the *Juvavites magnus* Subzone 2 and Columbianus 3 from talus on the west slope of Black Bear Ridge prior to dam construction and flooding. These are respectively:

64-137D = *GSC loc. 64636. *Dimorphotoceras caurinum* (McLearn), D. ursinum Tozer, *Juvavites concretus* McLearn.

64-138C = *GSC loc. 64638. *Paragymnites symmetricus* (Mojsisovics), *Steinmannites* sp. indet.

McLearn (1960) also collected several rich examples of the Columbianus Subzone 2 fauna (*GSC locs. 9741, 9744, 9745; *see* Tozer, 1994, p. 295-6).

BIVALVES

C.A. McRoberts, J.S. Shaner

The continuous sequence of the Pardonet Formation and its transitional facies at Black Bear Ridge provides documentation of a *Halobia* and *Monotis* succession unparalleled throughout the North American Cordillera. Biostratigraphic resolution is best in the lower and uppermost parts of the Pardonet Formation in which diagnostic halobiid and monotid species occur. In particular the succession of *Halobia ornatissima* Smith overlain by *H. beyrichi* (Mojsisovics) indicates the traditional Carnian/Norian stage boundary which, based on *Halobia* species, lies between beds 99CM-2 and -3 (Fig. 2). *Halobia beyrichi* (*H. alaskana* Smith is considered a junior synonym) is known to occur throughout the Cordilleran terranes from Alaska to Nevada. It is well represented from Vancouver Island and the Queen Charlotte Islands of British Columbia (Tozer, 1967; Carter et al., 1989; and undescribed GSC collections), southeast Alaska (Muffler, 1967), as well as from the Wallowa Terrane in Oregon (McRoberts, 1993), and the Shoshone Mountains of Nevada where it occurs with the ammonoid *Stikinoceras kerri* (Silberling, 1959; Silberling and Tozer, 1968; Kristan-Tollmann and Tollmann, 1983). In the Tethys realm and the western Pacific regions, the place of *H. beyrichi* is replaced by *H. stryiaca (Mojsisovics), a key zonal fossil of the earliest Norian which is conspicuously absent from North America (e.g. Gruber, 1976).*

In the higher parts of the Pardonet Formation, *H. cordillerana* Smith together with *H. beyrichi* indicates the probable occurrence of the Dawsoni and Magnus zones. *Halobia cordillerana* is known from throughout the Cordillera with significant occurrences in Nevada (*H. hochstetteri* Mojsisovics listed by Kristan-Tollmann and Tollmann (1983) from the Luning Formation is here treated as a synonym for *H. cordillerana*), California, possibly northeast Oregon, and southern, eastern, and arctic Alaska (*see* McRoberts, 1997). In British Columbia, this species was known as *Halobia parcalis* McLearn, which is now considered a junior synonym.

The bivalve succession in the Middle Norian Columbianus Zone and the Upper Norian Cordilleranus Zone is demonstrated in the succession of *Eomonotis* and *Monotis* species. *Eomonotis pinensis* (Westermann) is the more common Middle Norian species (Fig. 3, 99CM-17, -18), but earlier collections made by E.T. Tozer (*see* above) also included a lower horizon with *E. scutiformis* (Fig. 3, 81-304B); both species apparently occur within the upper range of *Halobia fallax* Mojsisovics. *Eomonotis* is well known from numerous middle Norian localities elsewhere in northeastern British Columbia (e.g. Westermann, 1962) as well as in several allochthonous terranes such as the Nixon Fork and Alexander terranes of central and southern Alaska (*see* Silberling et al., 1997). In all of these localities it occurs in the upper part of the Middle Norian Columbianus Zone where is often associated with the ammonoid *Himavitites* (*see* for example Tozer, 1979; Silberling et al., 1997).

At Black Bear Ridge, the *Eomontis pinensis* beds are overlain by beds dominated by Upper Norian *Monotis subcircularis* Gabb, perhaps one of the most abundant of monotids in the North American Cordillera and eastern Asia (*see* for example Tozer, 1982; Silberling et al., 1997). The first appearance of *Monotis subcircularis* is taken as the base of the Cordilleranus Zone. Overlying the uppermost *Monotis subcircularis* bed occur a probably new and undescribed species of *Otapiria*. While several species of *Otapiria* are well known from the Norian and Rhaetian of the circum-Pacific (e.g. New Zealand, Japan, and Russia) and Tethys (e.g. Austria) they become increasingly common in Lower Jurassic strata. The specimens recovered from Black Bear Ridge are Rhaetian or Hettangian.

The transitional beds from the Pardonet Formation to the Jurassic Fernie Formation contain abundant specimens belonging to at least two pectinacean genera, *Entolium* and *Agerchlamys*. Similar pectinacean specimens occur from approximately the same stratigraphic horizon elsewhere in northeastern British Columbia (e.g. Ne Parl Pas Point, Pine Pass; Tozer, 1982), where some appear to be Triassic. A complete taxonomic assessment of these 'Pecten Beds' awaits further study.

ICHTHYOLITHS

M.J. Johns

Samples from the Nodosus and Communisti conodont zones include the most abundant and diverse ichthyoliths in the Black Bear Ridge section. The deepest level, corresponding to the Upper Nodosus conodont Zone (Fig. 2, 81-311A), contains abundant actinopterygian (bony fish) teeth and ganoid scales in addition to abundant *Labascicorona mediflexura* Johns and a variety of other elasmobranch (shark) scales and teeth (see Johns et al., 1997, p. 111). The next higher ichthyolith rich level occurs in the Communisti Zone (Fig. 2, 81-310B, 82BBR-1, 92BBR-3, 4, 5) and is marked by a peak abundance of the elasmobranch tooth *Synechodus multinodosus* and scale *Minuticorona* in addition to other ichthyoliths (see Johns et al., 1997, p. 111, 112). This interval represents the type locality for the *S. multinodosus* concurrent-range ichthyolith Zone (Johns et al., 1997, p. 13). Actinopterygian teeth and ganoid scales are also abundant in these samples. Just above this level there is a change in the distribution of ichthyoliths. In sample 92BBR-5, *Birgeria* sp., Type A6, and ganoid scale sp. 1 are abundant but there are only a few small elasmobranch scales.

Sample 82BBR-2 contains an odd diversity and abundance of ichthyoliths including: 1) some elasmobranch scales commonly observed from older Liard Formation rocks in the Halfway River map area that do not occur in the Nodosus and Communisti zones (see Johns et al., 1997, p. 112 and compare to p. 100-107); 2) other actinopterygian and elasmobranch ichthyoliths that are commonly found in the Communisti Zone (Fig. 2); and 3) an absence of diagnostic taxa of the *S. multinodosus* Johns ichthyolith Zone (including *S. multinodosus*, *Minuticorona*, and

Labascicorona alata). Just above this level (Fig. 2; 92BBR-6), no elasmobranch teeth or scales were recovered and actinopterygian scales and teeth were common to abundant in the sample. In sample 92-BBR7 (Fig. 2), some new ichthyoliths, also observed in samples from the Trutch map area, share similarities to other ichthyoliths from the uppermost upper Baldonnel Formation. This level appears to mark the last true occurrence of transitional facies, Ludington, and older elasmobranchs at Black Bear Ridge.

Above in 92BBR-8 (Fig. 2), *Birgeria* and ganoid scale sp. 1 are very abundant and specimen recrystallization is common. A similar abundant bony fish scale bed near the base of the Pardonet Formation has been observed at Pink Mountain in the Trutch map area. For about 20 additional metres of strata, fish diversity remains low (Fig. 2). Near the top of the Upper Primitius Zone (Fig. 2, 82BBR-8) there is another peak abundance of *Birgeria* sp. and ganoid scale sp. 1 in addition to a rare occurrence of ganoid scale sp. 2 (Fig. 2).

Higher strata in the Pardonet Formation (Fig. 2, 99BBR-3, 82BBR-33) contain the first known and common occurrences at Black Bear Ridge of typical Norian elasmobranch ichthyoliths including *Synechodus incrementum* Johns, and form species of *Fragilicorona*, and *Glabrisubcorona*. Norian ichthyoliths generally occur in low abundance and diversity, and are long-ranging. At a few levels they are common to very abundant, including the level mentioned above in the Quadrata conodont Zone and another two levels (Fig. 2; 81-305B and 82BBR-16/81-305A) in the Postera conodont Zone. Such ichthyolith-abundant beds can be traced through large areas of the Western Canada embayment and may be the result of certain sedimentary or environment conditions (*see* Johns et al., 1999, p. 97). Similar beds occur in the Primitius and Multidentata conodont zones. Upper Norian strata at Black Bear Ridge mainly contain the long-ranging actinopterygian, *Birgeria* sp. Some new ichthyoliths were found in the (?)Rhaetian (93-BF, Fig. 2).

BRACHIOPODS

M.R. Sandy

Low diversity brachiopod faunas are known from a number of localities on Williston Lake, and the Upper Carnian fauna at Black Bear Ridge has counterparts at both Brown Hill and at Pardonet Hill. The brachiopods are generally very well preserved in carbonates, often ‘popping out’ of the sediment; only the high level of induration of some of the carbonate layers prevents their easy removal from matrix for study. The Black Bear Ridge brachiopod fauna is concentrated in several coquinid layers within a 60 cm bed and is composed of monospecific rhynchonellids referred to *Piarorhynchia winnemae* (Smith).

Although the brachiopods have yet to be subjected to detailed taxonomic investigation, the species has been interpreted as quite varied morphologically. Other authors have considered that varieties or subspecies may be present. Ager and Westermann (1963, plates 71–73) recorded two species, *P. winnemae* and *P. hamiltonensis*, from the Carnian of Caribou Ridge in the Mount Laurier area of northeastern British Columbia; these are thought to be probable synonyms. Their material was composed of smaller specimens compared with that of Smith (1927), who first recorded the species from the Hosselkus Limestone of Brock Mountain in Shasta County, California. The material from the rhynchonellid horizons at Williston Lake show both small and larger forms, and some of these resemble other species that Smith identified; it seems likely that these are also synonyms of *P. winnemae*. There have been no other records of the taxa in North America to date.

Although first described from the Jurassic, *Piarorhynchia* is known to range into the Triassic. The genus has been identified from the latest Triassic of southern Europe, and Dagys (1974) recorded the range as Carnian - Rhaetian. Ager and Westermann (1963) regarded the British Columbian occurrences of *Piarorhynchia winnemae* as Lower Carnian although this was not substantiated. The occurrences at Black Bear Ridge and elsewhere on Williston Lake are high in the Carnian.

INTERCALIBRATION AND SUMMARY

An integrated biostratigraphic summary of the Black Bear Ridge section is summarized below in point form emphasizing the essential features of the succession.

1. At datum (Fig. 2), relatively low-diversity Upper Nodosus Zone conodonts occur at the base of the Ludington-Pardonet transitional facies, characterized by a brachiopod-bearing bioclastic limestone. Ichthyoliths are diverse and include the elasmobranch *Synechodus multinodosus* and a peak abundance of ganoid scale sp. 2.
2. At approximately 5 m, Communisti Zone conodonts appear with rare Macrolobatus Zone ammonoids in coquinas of *Piarorhynchia winnemae* brachiopods. This level marks the peak abundance of *Synechodus multinodosus* and *Minuticorona* ichthyoliths. *Halobia ornatissima* ranges within the upper part of the Communisti Zone, where several changes in ichthyolith fauna are noted.
3. At approximately 18 m, Primitius Zone conodonts appear above the commonly cherty beds and at the base of the concretionary beds of the Pardonet Formation. Associated ichthyoliths are abundant, low-diversity actinopterytgian teeth and ganoid scales, with most of the older elasmobranch teeth and scales having disappeared. This datum represents a probable sequence boundary. A little higher *Halobia beyrichi* appears.
4. From approximately 28 m to approximately 38 m, there is a peak abundance of *Norigondolella navicula* within the Primitius Zone. This interval includes rich ammonoid and belemnoid beds that also contain ‘pseudo-oolites’. Extremely abundant actinopterygian ichthyoliths occur at

38 m. Dawsoni Zone ammonoids and *Halobia cf. superba* are identified within these strata, which are thought to represent a time of maximum flooding.

5. From approximately 52 m through approximately 92 m, monotonous, generally unfossiliferous strata bear uncommon levels of Lower Norian Quadrata and Triangularis Zone conodonts, and the bivalve *Halobia cordillerana*. New elasmobranchs — *Synechodus incrementum, Fragilicorona*, and *Glabrisubcorona* — occur within the Quadrata Zone. Fossiliferous strata become more common in Middle Norian Multidentata and Spiculata zones, which include the last *Halobia beyrichi*. This entire interval probably documents a regressive-transgressive cycle.

6. At approximately 105 m to approximately 130 m, diverse ammonoids of Columbianus Subzone 2, Postera Zone conodonts, the bivalves *Halobia cordillerana* and *H.* cf. *fallax*, and abundant ichthyoliths of the *Synechodus incrementum* Zone occur in limestone nodules. From approximately 122 m through the end of the Postera Zone, a peak abundance of *Norigondolella steinbergensis* is interpreted as second major transgressive event in the Norian.

7. Between approximately 135 m and approximately 143 m, a succession of *Eomonotis scutiformis* followed by *E. pinensis* occurs within the range of *Halobia fallax*. Serrulata Zone conodonts (but no *Norigondolella*) are associated.

8. Above approximately 143 m, Upper Norian *Monotis* coquina and Bidentata Zone conodonts occur together throughout a succession that includes two ammonoid faunas characterized by *Paraguembilites ludingtoni* and *Lissonites* sp. These represent the Cordilleranus subzones 1 and 2. *Norigondolella* is very common in the lower 5 m of the *Monotis* beds, implying a sudden change in the environment.

9. Above approximately 170 m, a very thin Rhaetian succession is tentatively identified on the basis of *Otapiria* sp. and possible Mosheri Zone conodonts that abruptly overlie *Monotis* coquinid beds. A sedimentary break or substantial slowdown in sedimentation is assumed at about this level based on the small thickness of strata and the presence of occasional pebble lag. Other bivalves of the overlying ‘Pecten Beds’ include *Entolium* and *Agerchlamys* and may be of latest Triassic or earliest Jurassic age. New ichthyoliths occur at this level.

10. At least six levels of Lower Jurassic ammonites were collected from within the basal Fernie Formation during preliminary investigations. Subsequent work has located 30 separate horizons of ammonites over 22 m of Fernie Formation, and indications are that at least parts of the Lower, Middle, and Upper Hettangian are represented (R. Hall, pers. comm.).

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