Conodonts from the Kechika Formation and Road River Group (Lower to Upper Ordovician) of the Cassiar Terrane, northern British Columbia[1]

Leanne J. Pyle and Christopher R. Barnes

Abstract: This study examines the lower Paleozoic stratigraphy of the Cassiar Terrane from three key sections comprising an east–west transect across the terrane. The Cassiar Terrane, west of the Northern Rocky Mountain Trench, consists of a Neoproterozoic to Triassic succession and is a fragment of the Cordilleran Miogeocline that has been displaced northward. The amount of displacement from its original position remains controversial. Conodonts from the Cassiar Terrane have been previously reported from only a few reconnaissance studies. More than 3000 m of strata have been measured and examined in detail and 85 conodont samples collected. A total of 926 identifiable conodont elements are assigned to 31 species representing 21 genera. The conodonts are mainly representative of the Midcontinent Faunal Realm, but some also represent the Atlantic Realm. Conodonts from the upper Kechika Formation and base of the Road River Group are Early Ordovician (Tremadocian) in age, and those from the upper Road River Group range into the Upper Ordovician (Caradocian). The detailed Ordovician stratigraphy and temporal constraints established by conodont biostratigraphy provide for correlation to coeval facies of ancestral North America. The onset of Road River sedimentation in the mid-Tremadocian is, however, older than that in the Macdonald Platform to the east (early Arenigian). This onset timing may help link the Cassiar Terrane to a specific part of the miogeocline from which it was transported.

Résumé : Cette étude examine la stratigraphie du Paléozoïque inférieur du terrane de Cassiar à partir de trois sections clefs comprenant un transect est-ouest à travers le terrane. Le terrane de Cassiar, à l'ouest du sillon septentrional des Rocheuses, comprend une séquence du néo-Protérozoïque au Trias et représente un fragment du miogéocline de la Cordillère qui a été déplacé vers le nord. La distance de déplacement par rapport à sa position originale demeure controversée. Les Conodontes du terrane de Cassiar n'ont été signalés antérieurement que dans quelques études de reconnaissance. Des strates ont été mesurées et examinées en détail sur plus de 3000 m et 85 échantillons de Conodontes ont été recueillis. Neuf cent vingt-six (926) éléments identifiables de Conodontes ont été assignés à 31 espèces représentant 21 genres. Les Conodontes sont surtout représentatifs du domaine faunique du centre du continent, mais quelques-uns représentent aussi le domaine de l'Atlantique. Les Conodontes de la partie supérieure de la Formation de Kechika et de la base du Groupe de Road River datent de l'Ordovicien précoce (Trémadocien) et ceux de la partie supérieure du Groupe de Road River atteignent l'Ordovicien supérieur (Caradocien). La stratigraphie détaillée de l'Ordovicien et les contraintes temporelles imposées par la biostratigraphie des Conodontes permettent une corrélation à des faciès contemporains dans l'ancienne Amérique du Nord. La sédimentation du Road River au Trémadocien moyen a toutefois débuté plus tard que dans la plate-forme de Macdonald vers l'est (Arénigien précoce). Ce moment du début peut aider à relier le terrane de Cassiar à une partie spécifique du miogéocline d'où il provient.

[Traduit par la Rédaction]

Introduction

The parautochthonous Cassiar Terrane represents a segment of the Cordilleran Miogeocline bounded to the east by the Tintina – Northern Rocky Mountain Trench (NRMT) Fault, which offsets the miogeoclinal strata from those of ancestral North America (Fig. 1). The western boundary of the Cassiar Terrane is the Intermontane Superterrane, which accreted to North America in the Middle Jurassic (Gabrielse and Yorath 1991). Geologic and paleomagnetic measurements indicate the terrane was displaced northward along a dextral strike-slip fault system (Tintina – NRMT Fault) by a minimum of less than 500 km (Price and Carmichael 1986) or up to 900 km (Gabrielse 1985) from the Kakwa Platform (Fig. 1). Maximum estimates based on paleomagnetic data of the Slide Mountain Terrane indicate movement over 2000 km (Richards et al.

Received October 30, 2000. Accepted April 5, 2001. Published on the NRC Research Press Web site at http://cjes.nrc.ca on September 28, 2001.

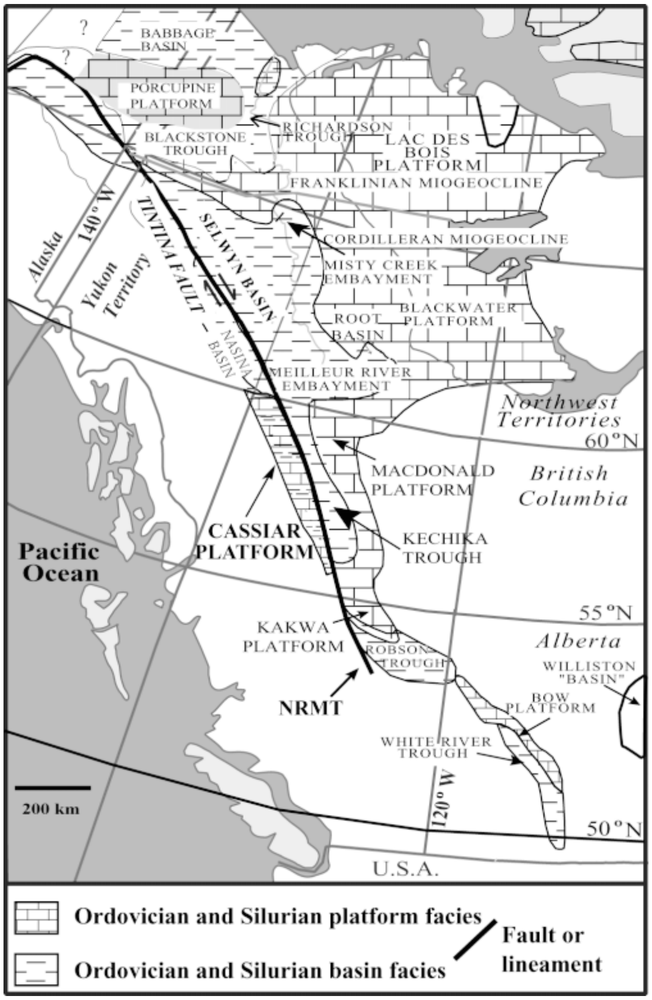
Paper handled by Associate Editor B. Chatterton.

L.J. Pyle[2] and C.R. Barnes. School of Earth and Ocean Sciences, University of Victoria, P.O. Box 3055, Victoria, BC V8W 3P6, Canada.

[1]Lithoprobe Contribution 1199.
[2]Corresponding author (e-mail: leanne@uvic.ca).

 DOI: 10.1139/cjes-38-10-1387

Fig. 1. Map showing lower Paleozoic paleogeography and present position of the Cassiar Terrane (modified from Cecile et al. 1997).



1993) or, based on Cambrian stratigraphy, up to 1700 km as a margin segment from Idaho (Pope and Sears 1997; Fig. 2).

In the Cassiar Terrane, previous work on lower Paleozoic conodonts has been restricted to a few small Cambrian to Devonian collections made in the study area during regional mapping projects. In this study, detailed sampling for conodonts was carried out across an east–west transect of the Cassiar Terrane using three principal stratigraphic sections (Fig. 3). This study is part of a larger project directed at examining the lower Paleozoic stratigraphy and conodonts from Upper Cambrian to Lower Silurian platform to basin facies of the Northern Canadian Cordilleran Miogeocline (Pyle and Barnes 2000, 2001).

A total of 3032 m of strata was measured and described in detail, and 85 conodont samples were collected (4–5 kg each) through the Kechika Formation and Road River Group. The conodont samples were taken from carbonate beds and processed through standard acid-dissolution techniques followed by concentration of conodont elements with heavy liquid (sodium polytungstate) and magnetic separation. The samples yielded 926 identifiable conodont elements, which have colour alteration index (CAI) values ranging from 3 to 5, indicating burial temperatures of 110–200°C to over 300°C. The conodonts have been assigned to 31 species representing 21 genera that are representative mainly of the Midcontinent Realm; however, species characteristic of the Atlantic Realm are also present.

Lithostratigraphy

The lower Paleozoic Kechika Formation and Road River Group have been examined from three key sections: near Moodie Creek; south of Deadwood Lake; and near the township of Cassiar, at the base of Mount McDame (Fig. 3). The stratigraphy of the Kechika Formation and Road River Group is broadly similar to that of the miogeoclinal succession east of the NRMT recently reported by Pyle and Barnes (2000).

Gabrielse (1963, 1979, 1998) described the miogeoclinal succession of the Cassiar Platform, originally referred to as the Pelly–Cassiar Platform (Gabrielse 1967), during regional-scale mapping within the McDame (National Topographic System (NTS) 104 P) and Cry Lake (104 I) map areas. Gabrielse (1963) was the first to describe the Kechika (as a group) at its type locality in the McDame map area. Kechika strata have been reported from the Cry Lake (104 I) and McDame (104 P) map areas west of the NRMT (Gabrielse 1962, 1963). Nelson and Bradford (1989, 1993) mapped part of the geology of the Cassiar Terrane.

In the type area, faunas reported include graptolites, trilobites, brachiopods, bryozoans, and cephalopods, which provide an approximate age from the Late Cambrian to early Late Ordovician (Gabrielse in Glass 1990). In the Cassiar Mountains, Norford (1962) described the overlying Silurian Sandpile Group and its fauna.

The stratigraphy of the three sections, Moodie Creek, Deadwood Lake, and Cassiar – Mount McDame (Fig. 3), has been described in detail by Pyle and Barnes (2000). The contact of the Kechika Formation with the overlying Road River Group is conformable and gradational over less than 1 m at both the Moodie Creek and Deadwood Lake sections (Figs. 4, 5).

At Moodie Creek, the Kechika Formation (1770 m, tectonically thickened) disconformably overlies the Lower Cambrian Rosella Formation and consists of a variety of lithologies. The section is fault repeated such that the maximum thickness in the area is approximately 900 m (Gabrielse 1998). Units are of low metamorphic grade likely due to alkaline sills and dykes in close proximity, described by Pell (1994). Units included pink-brown sericitic, cleaved phyllite, orange-brown massive dolostone with prominent quartz veins, green argillaceous, sheared siltstone and grey weathered, thin- to massive-bedded dolomitic limestone. Conodonts were recovered from the base of the overlying Road River Group, and only the uppermost Kechika Formation is illustrated in Fig. 3. The Road River Group measured from Moodie Creek (88 m) consists of cleaved grey and brown shale and recrystallized silty limestone and dolostone. The overlying dolomitic siltstone and sandstone are assigned to the Sandpile Formation (late Llandovery to early Wenlock; Gabrielse 1998), and the contact appears to be conformable and gradational over a few metres.

At Deadwood Lake, calcareous Road River Group (427.5 m) conformably and gradationally overlies the light

Fig. 2. Map of United States and Canadian Cordillera with Cassiar Platform translated (A) 600 km south in accordance with paleomagnetic data from Butler et al. (1988), and (B) to its proposed site of deposition in accordance with subsequent >2000 km northward translation of Slide Mountain Terrane (Richards et al. 1993; modified from Pope and Sears 1997).

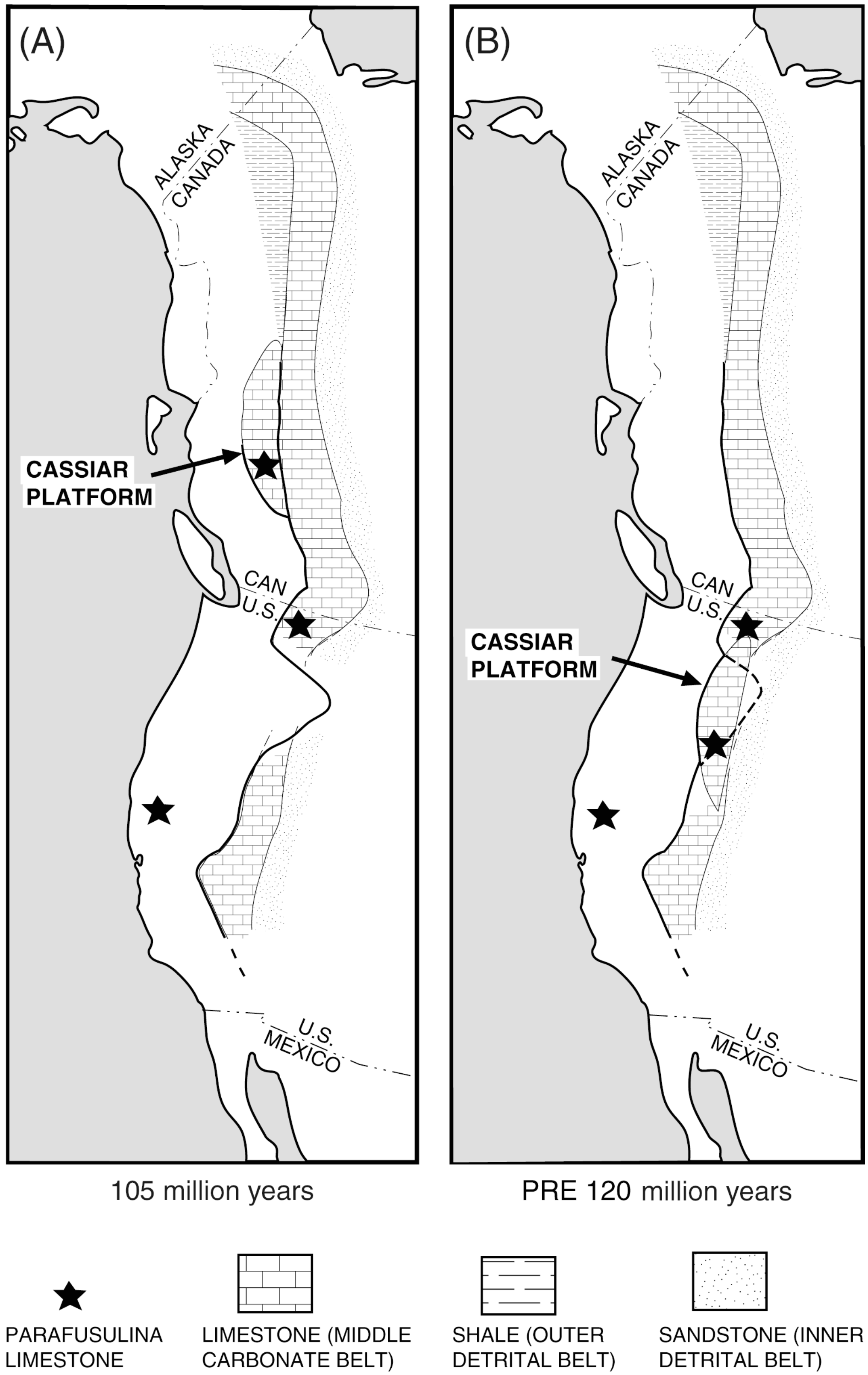
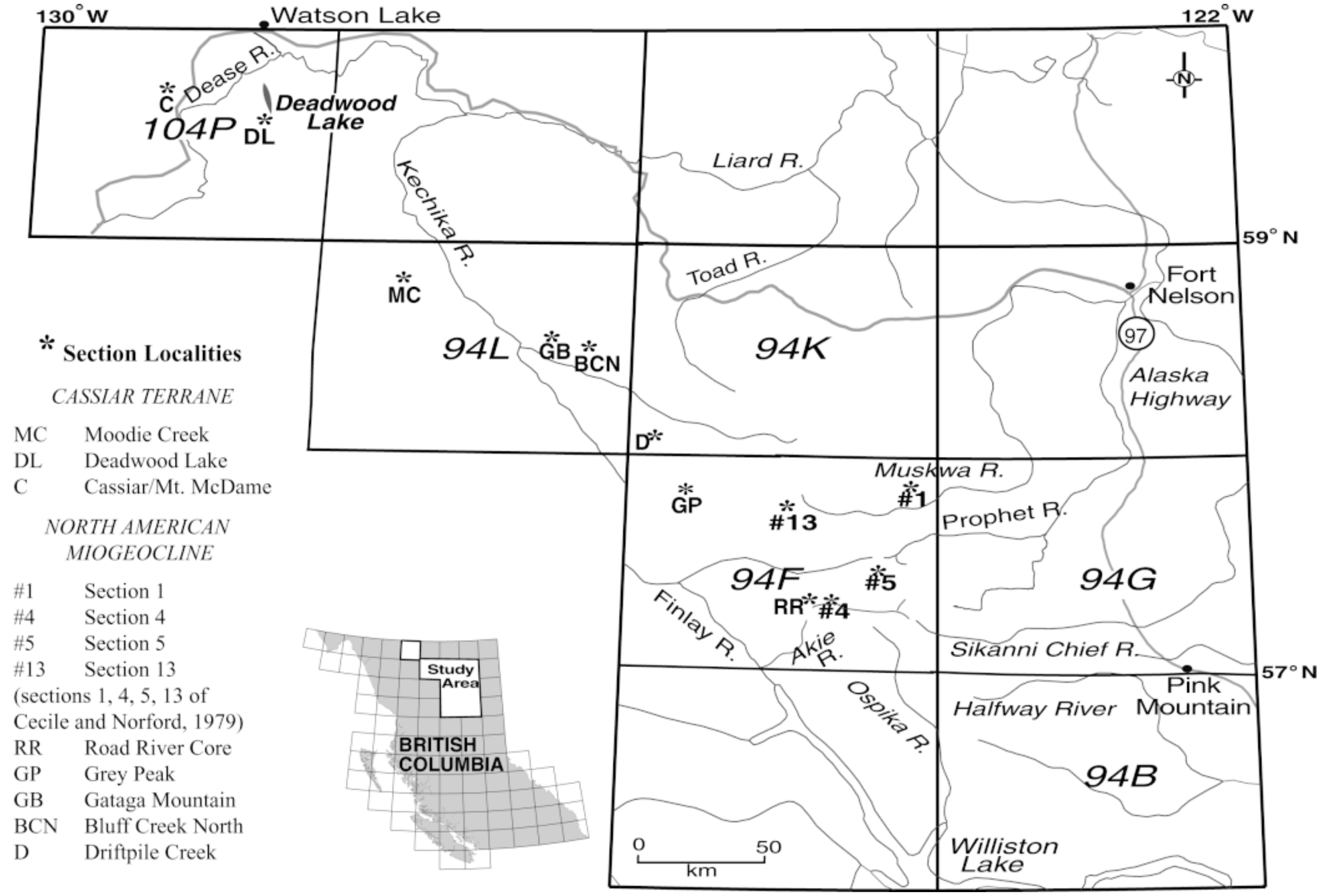


Fig. 3. Map showing geographic localities of Cassiar Terrane sections in Cry Lake (NTS 104 P) and Kechika (NTS 94 L) map areas. Kechika River approximates the Northern Rocky Mountain Trench (NRMT). Cordilleran miogeoclinal section localities east of the NRMT are also shown (NTS map areas 94 F and 94 K).



grey weathering shale and thin-bedded limestone of the Kechika Formation (65.5 m). The Road River Group is divided into four informal units (Pyle and Barnes 2000; Fig. 5). The basal unit (155 m) consists of lenticular limestone and interbedded shale in metre-scale packages, which weather orange-grey. The lenses increase in number and lateral continuity upsection. Unit 2 is a series of grey quartzite beds, quartz veins, interbedded dolostone, and black phyllite (117 m). A third unit (52 m) consists of largely grey, dolomitic siltstone, black shale and phyllite, and minor lime mudstone beds. Unit 4 (144 m) is bedded lime mudstone to grainstone interbedded with black shale, which decreases from 30–50% at the base to less than 5% at the top of the unit. Some beds are undulatory and contain chert nodules. Grainstone becomes abundant near the top of the unit represented in part by phosphatic lags. The unit is disconformably overlain by massive-bedded, light grey dolostone, which Gabrielse (1963) initially called the Sandpile Group and now the Sandpile Formation (Gabrielse 1998).

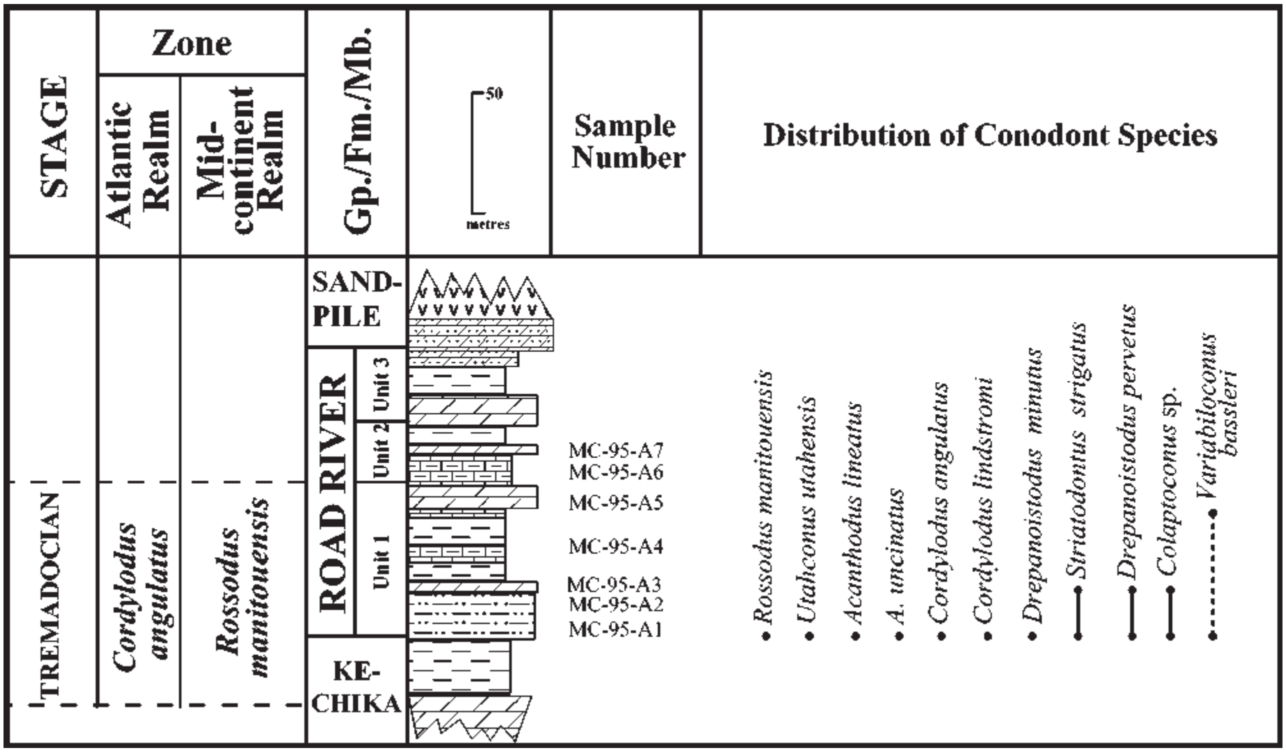
The Road River Group examined in two creeks at the Mount McDame section consists of 120–200 m of blue-black shale and slate interbedded with rare nodular lime mudstone. Volcanics were observed near the top of the black shale units, and the Road River Group is conformably overlain by sandstone of the Ramhorn Formation, as defined by Gabrielse (1998). The conodont samples from this section were barren.

Conodont biostratigraphy

Previously, no detailed biostratigraphic studies have been carried out in the lower Paleozoic strata of the Cassiar Terrane. Pohler and Orchard (1990) reported three species identified from two small collections from the Cassiar Terrane. The conodont fauna from the upper Kechika Formation and Road River Group of the Moodie Creek and Deadwood Lake sections is assigned to 31 species representing 21 genera (Tables 1, 2). Among these, several zonal species are present.

The biostratigraphy of the Kechika Formation and basal formation of the Road River Group, the Ospika Formation, has been established from nine stratigraphic sections east of the NRMT by Pyle and Barnes (2001; Figs. 3, 6). Based on this framework, the conodonts recovered from the Cassiar Terrane establish that the Kechika Formation – Road River Group boundary lies within the *Rossodus manitouensis* Zone (middle Tremadocian). *Rossodus manitouensis* Repetski and Ethington occurs within the uppermost Kechika Formation at the Deadwood Lake section (sample DL-96-2) and within

Fig. 4. Biozonation and stratigraphic distribution of conodont species from the upper part of the Moodie Creek section (58°46′N, 127°33′W; section located 1 km east of Moodie Creek, 7 km south-southeast of Moodie Lakes; 6 km of ridge trending southwest–northeast, then north; section strongly deformed, possible stratigraphic repetition or omission due to faulting in the lower part). Gp., Group; Fm., Formation; Mb., Member.



the base of the Road River Group at the Moodie Creek section (sample MC-95-A1; Figs. 4, 5). At the Deadwood Lake section, the zone is at least 84 m thick.

The fauna from the upper Kechika Formation and basal Road River Group of the Cassiar Terrane (Figs. 4, 5) includes *R. manitouensis*, *Cordylodus angulatus* Pander, and longer ranging species of *Cordylodus*, such as *C. lindstromi* Druce and Jones and *C. caseyi* Druce and Jones, *Utahconus utahensis* Miller, *Acanthodus lineatus* Furnish, *Drepanoistodus pervetus* Nowlan, and *Variabiloconus bassleri* Furnish. New species (formally named by Pyle and Barnes 2001) of Midcontinent Realm affinity that are present at this interval in the Cassiar Terrane and east of the NRMT are *Drepanoistodus minutus*, *Cordylodus delicatus*, and *Striatodontus strigatus*. These data indicate that the Kechika Formation – Road River Group contact is significantly older than that observed east of the NRMT, where the base of the Road River Group is within the *Prioniodus elegans* Zone, early Arenigian.

The Road River Group at the Deadwood Lake section ranges into the *Paroistodus proteus* Zone (late Tremadocian), the base of which occurs at the level of the first appearance of *Paroistodus proteus* (Lindström), as was originally proposed by Lindström (1971). The thickness of the zone was not determined, as *P. proteus* occurs only in sample DL-96-13, 168 m above the base of the Road River Group.

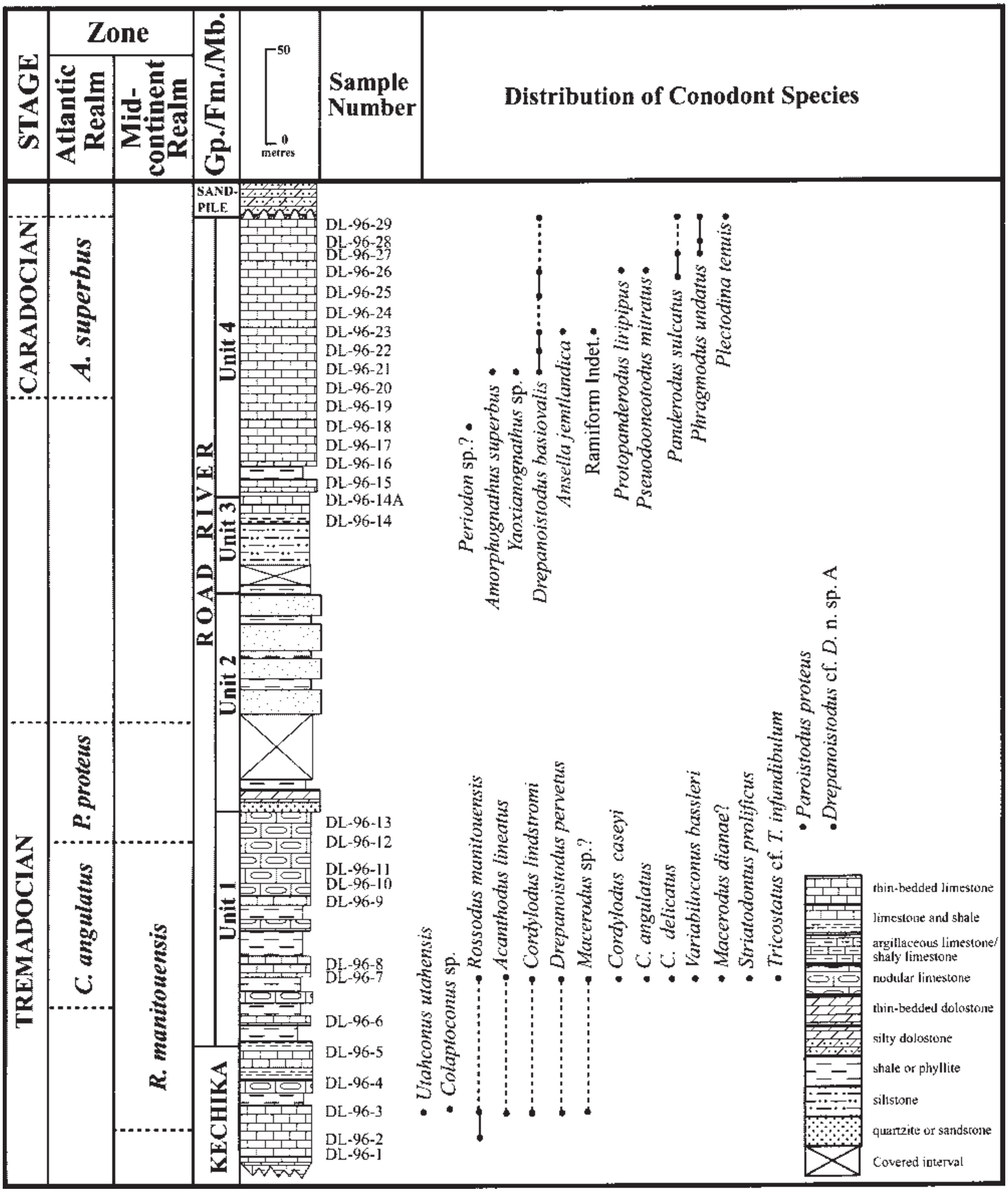
The conodont fauna also indicates that the Road River Group ranges into the middle Caradocian, Upper Ordovician (*Amorphognathus superbus* Zone), at the Deadwood Lake section (59°01′N, 128°23′W), southwest end of Deadwood Lake, Cry Lake map area (Figs. 3, 6). The base of the *A. superbus* Zone is defined as the level of the first appearance of *Amorphognathus superbus* Rhodes (Bergström 1971). The base of the zone is 417.5 m above the base of the measured section and 352 m above the base of the Road River Group (sample DL-96-21). The top and thickness of the zone are not constrained, and it is cut by a disconformity. The zone was originally defined in Baltoscandia by Bergström (1971), who divided it into subzones and discussed its widespread occurrence in Europe and North America and use for intercontinental correlation. Characteristic species that occur in the zone from this study include *Drepanoistodus basiovalis* (Sergeeva), *Ansella jemtlandica* (Löfgren), *Yaoxianognathus* sp., and the long-ranging species *Phragmodus undatus* Branson and Mehl.

Graptolites collected from the top of the Road River Group (sample DL-96-26) comprise an assemblage of three diplograptid taxa, which indicate the *linearis* Zone and a late Caradocian – early Ashgillian age (H. Williams, personal communication, 2000). Macrofossils from the top of the Road River Group at Deadwood Lake were interpreted by G.W. Sinclair (in Gabrielse 1963, pp. 38–39) as Middle or Late Ordovician (Trentonian or Edenian = Caradocian) age, which is in agreement with the conodont and graptolite ages.

Discussion

There is considerable debate about the original position of the Cassiar Terrane along the Cordilleran Miogeocline. A problem in the reconciliation of paleomagnetic and geologic

Fig. 5. Biozonation and stratigraphic distribution of conodont species from the Deadwood Lake section (59°01′N, 128°23′W; located at the southwest end of Deadwood Lake, in creek bed which drains into the southernmost tip of the lake). Abbreviations as in Fig. 4.



data lies in the large-displacement evidence suggested by paleomagnetic measurements within the Cassiar Terrane and the structures responsible for the movement. Dextral motion along the Tintina – NRMT Fault system from the mid-Cretaceous (105 Ma) to early Tertiary ranges from 450 to 900 km. The terrane may have originated a minimum of 450 km south of its present position during the early Paleozoic, on line with the Kakwa Platform (Gabrielse 1985; Price and Carmichael 1986; Cecile and Norford 1993; Fig. 1).

Paleomagnetic data from Permian *Parafusulina*-bearing limestone of the Sylvester Allochthon, which overlies the miogeoclinal succession of the Cassiar Terrane and was

Table 1. Number of conodont elements recovered from Deadwood Lake section, uppermost Kechika Formation and Road River Group.

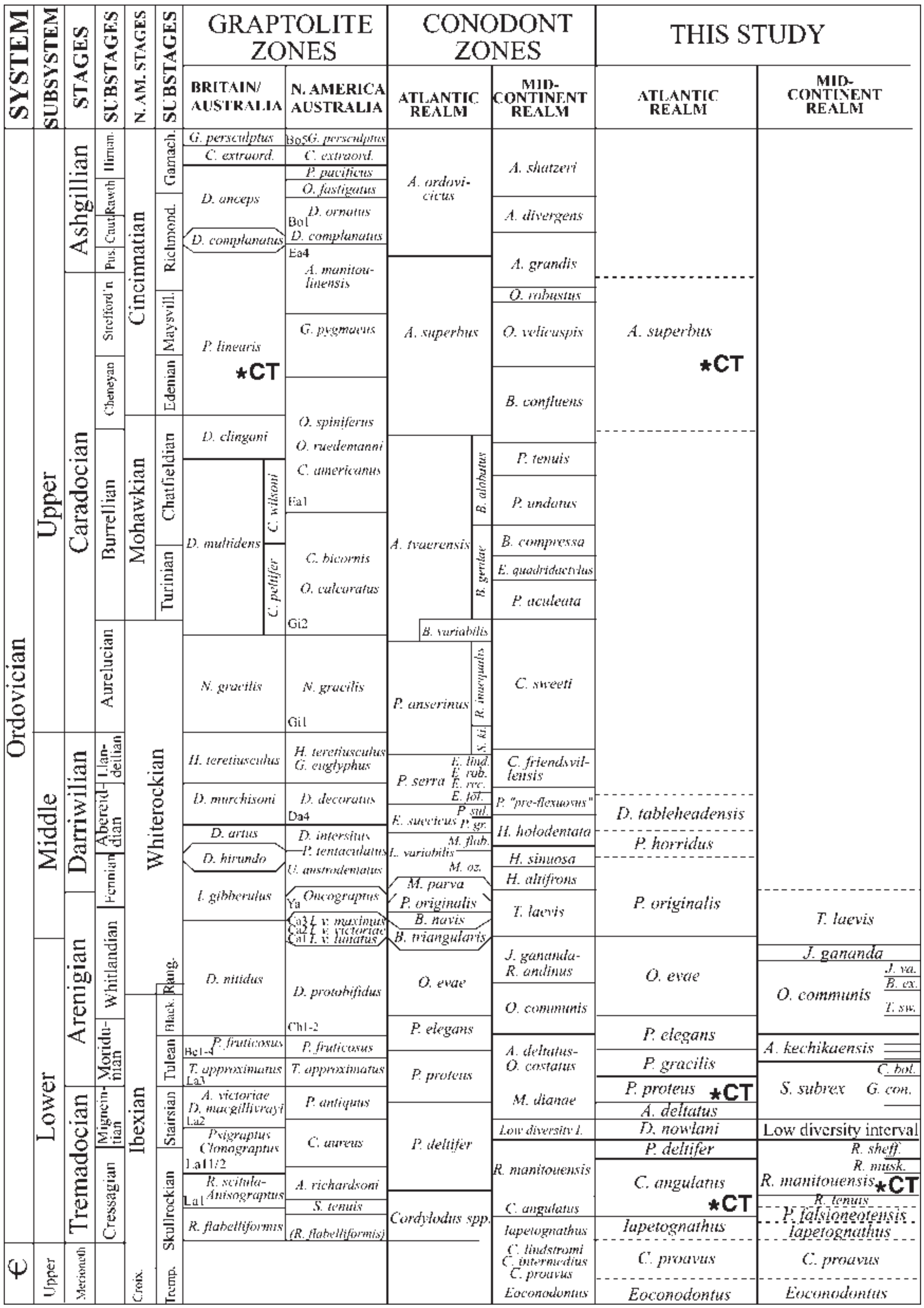
	Kechika Formation		Road River Group											
Distance above base (m):	13	28	97	181	388.5	417.5	427.5	437.5	457.5	467.5	478.5	485.5	494	
Sample No. (DL-96-):	2	3	7	13	18	21	22	23	25	26	27	28	29	Total
Acanthodus lineatus	4	9	168											181
Amorphognathus superbus						63								63
Ansella jemtlandica								1						1
Colaptoconus sp.		7	18											25
Cordylodus angulatus			18											18
Cordylodus caseyi			2											2
Cordylodus delicatus			2											2
Cordylodus lindstromi		3	6											9
Drepanoistodus basiovalis						4	3	1	2	2			3	15
Drepanoistodus pervetus		10	36											46
Drepanoistodus minutus		3	2											5
Drepanoistodus cf. *D.* n.sp. A				8										8
Macerodus dianae?			2											2
Macerodus sp.?		1	12											13
Panderodus sulcatus										1	1		7	9
Paroistodus proteus				7										7
Periodon sp.?					3									3
Phragmodus undatus											9	29	48	86
Plectodina tenuis													13	13
Protopanderodus liripipus										5				5
Pseudooneotodus mitratus										4				4
Ramiform indet.								1						1
Rossodus manitouensis		52	164											216
Striatodontus prolificus			3											3
Tricostatus cf. *T. infundibulum*		2	2											4
Utahconus utahensis		5												5
Variabilioconus bassleri			48											48
Yaoxianognathus sp.					4									4
Total	4	92	483	15	7	67	3	3	2	12	10	29	71	798

Table 2. Number of conodont elements recovered from the Moodie Creek section, Road River Group.

Distance above base (m):	1	13	40	
Sample No.:	MC-95-A1	MC-95-A3	MC-95-A5	Total
Acanthodus lineatus	19			19
Acanthodus uncinatus	7			7
Colaptoconus sp.	5	1		6
Cordylodus angulatus	3			3
Cordylodus lindstromi	2			2
Drepanoistodus minutus	6			6
Drepanoistodus pervetus	14	1		15
Rossodus manitouensis	20			20
Striatodontus strigatus	2		15	17
Utahconus utahensis	11			11
Variabiloconus bassleri	22			22
Total	111	2	15	128

likely accreted by the Middle Jurassic (Gabrielse and Yorath 1991), indicate 700 km northward translation of the Cassiar Terrane since 105 Ma (Butler et al. 1988). In contrast, Richards et al. (1993) interpreted other paleomagnetic data to suggest that part of the Sylvester Allochthon has been translated northward over 2000 km relative to North America between the Early Permian and Jurassic. The movement may have occurred before its emplacement onto the Cassiar Terrane. Pope and Sears (1997) proposed that the terrane originated about 1700 km south of its present position, based on Cambrian stratigraphy and archeocyathid faunas, which restores the Cassiar Terrane to fill a miogeoclinal gap in Idaho (Fig. 2). The main problem in establishing these large displacement estimates is that the dextral faults to accommodate the trans-

Fig. 6. Biostratigraphic correlation chart for the Ordovician system. Conodont and graptolite zones after Goldman and Bergström (1997), Fortey et al. (1995), Harris et al. (1995), and Webby (1995), and time scale after Webby (1998) and Cooper and Nowlan (1999). Abbreviated subzones: *R. musk.*, *Rossodus muskwaensis*; *R. sheff.*, *Rossodus sheffieldensis*; *G. con.*, *Graciloconus concinnus*; *C. bol.*, *Colaptoconus bolites*; *T. sw.*, *Tropodus sweeti*; *B. ex.*, *Bergstroemognathus extensus*; *J. va.*, *Juanognathus variabilis*. Abbreviated stages and substages: Strefford'n, Streffordian; Pus., Pusgillian; Caut, Cautleyan; Rawth, Rawtheyan; Hirnan., Hirnantian; Croix., Croixian; Tremp., Trempealeauan; Black., Blackhillsian; Rang., Rangerian; Maysvill., Maysvillian; Richmond., Richmondian; Gamach., Gamachian. *CT, data from Cassiar Terrane; N. Am., North American.



lation have not been identified, that is, those west of the NRMT Fault between the Intermontane Superterrane and ancestral North America and the southern continuation of the NRMT.

An important aspect in estimating displacements along fault systems is the offset of geologic units. This study, on the basis of the Ordovician stratigraphic succession, confirms that the Kechika Formation and Road River Group are broadly similar to the lithologies of the miogeoclinal succession observed east of the NRMT in northern British Columbia (Macdonald Platform) and may have originally been continuous with the Kakwa Platform to the south (Cecile and Norford 1993). The lack of Ordovician miogeoclinal strata inboard in Idaho makes a lithological match to that part of the miogeocline difficult.

The conodont fauna is largely of Midcontinent Realm affinity but does contain some Atlantic Realm species. The age of the Kechika Formation – Road River Group boundary as established by conodonts suggests an older age (mid-Tremadocian) within the Cassiar succession compared with that east of the NRMT (lower Arenigian).

Although the paleomagnetic data that require large post mid-Cretaceous transport of the terrane are in conflict, the detailed stratigraphy and age constraints on the Ordovician succession are a contribution to the Cassiar Terrane puzzle. Future work to establish a section of the autochthonous miogeocline that has a similar age range for the onset of Road River Group sedimentation may help establish the initial position of the Cassiar Terrane.

Taxonomic remarks

The following taxa require no further taxonomic description or only brief taxonomic remarks. The suprageneric classification of orders of conodonts proposed in Sweet (1988) and modified by Aldridge and Smith (1993) is followed herein. Additional suprageneric ranks of Craniata Linnaeus, Vertebrata Linnaeus, and Gnathostomata Cope have been determined through cladistic analysis by Donoghue et al. (2000). All illustrated specimens are deposited in the National Type Repository in the Geological Survey of Canada (GSC). Several new species that are described in detail in Pyle and Barnes (2001) are present in the Road River Group of the Cassiar Terrane and are included with a brief remark.

Phylum Chordata Bateson, 1886
Class Conodonta Pander, 1856
Genus *Colaptoconus* Kennedy, 1994
Colaptoconus sp.
(Pl. 1, figs. 15, 16)

Remarks
Limited material is assigned to *Colaptoconus* based on the extreme rounded lateral costae and concave posterior cusp face that bears a strong, rounded posterior carina. The symmetrical c element has a rounded, shallow basal cavity and base, which is expanded anteroposteriorly. Anterior cusp face is rounded with a weak carina from tip to base.

Occurrence
Rossodus manitouensis Zone, Kechika Formation and Road River Group.

Material
Thirty-one elements.

Repository
GSC 119654, GSC 119655.

Genus *Cordylodus* Pander 1856
Cordylodus delicatus (Pyle and Barnes 2001)
(Pl. 1, fig. 5)

Remarks
A few specimens of the small, delicate species of *Cordylodus* with extremely wide angle between slender, elongate cusp and first denticle of posterior denticulated process are present in this collection. *Cordylodus delicatus* is similar to *C. primitivus* in its primitive characters, such as a deep basal cavity and simple morphology.

Occurrence
Rossodus manitouensis Zone, Road River Group.

Material
Two elements.

Repository
GSC 119644.

Genus *Drepanoistodus* Lindström 1971
Drepanoistodus minutus (Pyle and Barnes 2001)
(Pl. 1, fig. 10)

Remarks
The small, delicate apparatus is distinguished from other species of *Drepanoistodus* by comprising simple, unornamented coniforms characterized by small size and small base with slender, extremely elongate cusp. The c element bears an erect, long, laterally compressed cusp with sharply rounded anterior and posterior cusp margins. Its base is small and flared equally both posteriorly and anteriorly, and the basal margin is sinuous, arching under anterobasal corner.

Occurrence
Rossodus manitouensis Zone, Kechika Formation and Road River Group.

Material
Eleven elements.

Repository
GSC 119649.

Drepanoistodus cf. *Drepanoistodus* n.sp. A (Pyle and Barnes 2001)
(Pl. 2, figs. 2–5)

Remarks
Elements which are similar to those of *Drepanoistodus* n.sp. A (Pyle and Barnes 2001) occur within the Deadwood Lake section. The a elements are distinct, in which the sharp anterior margin is more developed into a keel that deflects

Plate 1. All specimens are from the Deadwood Lake section except the specimen in fig. 14, which is from the Moodie Creek section. All views are lateral except where noted. **figs. 1, 2.** *Rossodus manitouensis* Repetski and Ethington 1983. (1) a element, posterolateral view, DL-96-7, GSC 119640, ×70. (2) e element, DL-96-7, GSC 119641, ×70. **figs. 3, 4.** *Cordylodus angulatus* Pander 1856. (3) a element, DL-96-7, GSC 119642, ×70. (4) e element, DL-96-7, GSC 119643, ×70. **fig. 5.** *Cordylodus delicatus* Pyle and Barnes 2001, a element, DL-96-7, GSC 119644, ×90. **fig. 6.** *Cordylodus caseyi* Druce and Jones 1971, a element, DL-96-7, GSC 119645, ×125. **fig. 7.** *Cordylodus lindstromi* Druce and Jones 1971, a element, DL-96-3, GSC 119646, ×75. **figs. 8, 9.** *Acanthodus lineatus* (Furnish 1938). (8) a element, DL-96-7, GSC 119647, ×85. (9) e element, DL-96-7, GSC 119648, ×85. **fig. 10.** *Drepanoistodus minutus* Pyle and Barnes 2001, c element, DL-96-7, GSC 119649, ×130. **fig. 11.** *Drepanoistodus pervetus* Nowlan 1985, a element, DL-96-3, GSC 119650, ×85. **figs. 12, 13.** *Tricostatus* cf. *T. infundibulum* Pyle and Barnes 2001. (12) c element, posterior view, DL-96-3, GSC 119651, ×78. (13) a element, posterolateral view, DL-96-7, GSC 119652, ×105. **fig. 14.** *Striatodontus strigatus* Pyle and Barnes 2001, a element, MC-95-A1, GSC 119653, ×43. **figs. 15, 16.** *Colaptoconus* sp. c elements, posterior views, DL-96-3, GSC 119654, GSC 119655, ×125. **figs. 17–21.** *Macerodus* sp.? (17) e element, DL-96-7, GSC 119656, ×80. (18–21) a elements, DL-96-7, GSC 119657 – GSC 119660, ×80. **fig. 22.** *Utahconus utahensis* (Miller 1969). e element, DL-96-3, GSC 119661, ×145. **figs. 23, 24.** *Variabiloconus bassleri* (Furnish 1938). (23) a element, DL-96-7, GSC 119662, ×90. (24) e element, DL-96-7, GSC 119663, ×90. **fig. 25.** *Macerodus dianae* Fåhræus and Nowlan 1978? a element, DL-96-13, GSC 119664, ×80. **fig. 26.** *Striatodontus prolificus* Ji and Barnes 1994, a element, DL-96-7, GSC 119665, ×120.

from the posterior cusp margin to join the base in an anterolateral position. Other a elements do not have such a strong development of anterolateral keel and the base has two carinae, near each basal corner. Base on these elements opens anteriorly. The e element is different from *Drepanoistodus* n.sp. A in being nongeniculate with recurved cusp. Base has inner lateral flare and is not as expanded posteriorly.

Occurrence

Paroistodus proteus Zone, Road River Group.

Material

Six a elements, two e elements.

Repository

GSC 119667 – GSC 119670.

Genus *Macerodus* Fåhræus and Nowlan, 1978
Macerodus dianae Fåhræus and Nowlan, 1978?
(Pl. 1, fig. 25)

Remarks

Two specimens are questionably assigned to *M. dianae* based on the long, compressed cusp with quadrate cross section. However, the compression is uneven and is strongest at the anterobasal corner.

Occurrence

Paroistodus proteus Zone, Road River Group.

Material

Two elements.

Repository

GSC 119664.

Macerodus sp.?
(Pl. 1, figs. 17–21)

Remarks

Elements of two morphotypes (a and e) have elongate, compressed cusps and long, broad, posteriorly extended bases. The a elements have laterally compressed, recurved cusps with sharply rounded anterior and posterior cusp margins. Cusp is slender, about two-thirds width of base, and unornamented. Base is expanded posteriorly. Anterobasal corner is straight in some elements (Pl. 1, fig. 19) as anterior cusp margin meets base at right angle. In other elements, the anterobasal corner is rounded. Basal margin is flat; basal outline oval.

The e element is compressed with long, recurved cusp. Cusp has sharp margins and is unornamented. Base is short and anterobasal corner is rounded and compressed. Base flares open posteriorly and has rounded basal outline.

Discussion

The specimens are tentatively assigned to *Macerodus*, but more material is need to ascertain the relationship. The e element is unlike that in other species of *Macerodus*, but the a elements bear some similarity to *Macerodus* n.sp. B? of Pyle and Barnes (2001).

Occurrence

Rossodus manitouensis Zone, Road River Group.

Material

Thirteen elements.

Repository

GSC 119656 – GSC 119660.

Genus *Pseudooneotodus* Drygant, 1974
Pseudooneotodus mitratus (Moskalenko, 1973)
(Pl. 2, fig. 13)

Remarks

Nowlan and Barnes (1981) described the simple conical elements as having a deep basal cavity and folded lateral faces. They also showed symmetry differences among elements. The few elements recovered from the Road River Group conform to their description.

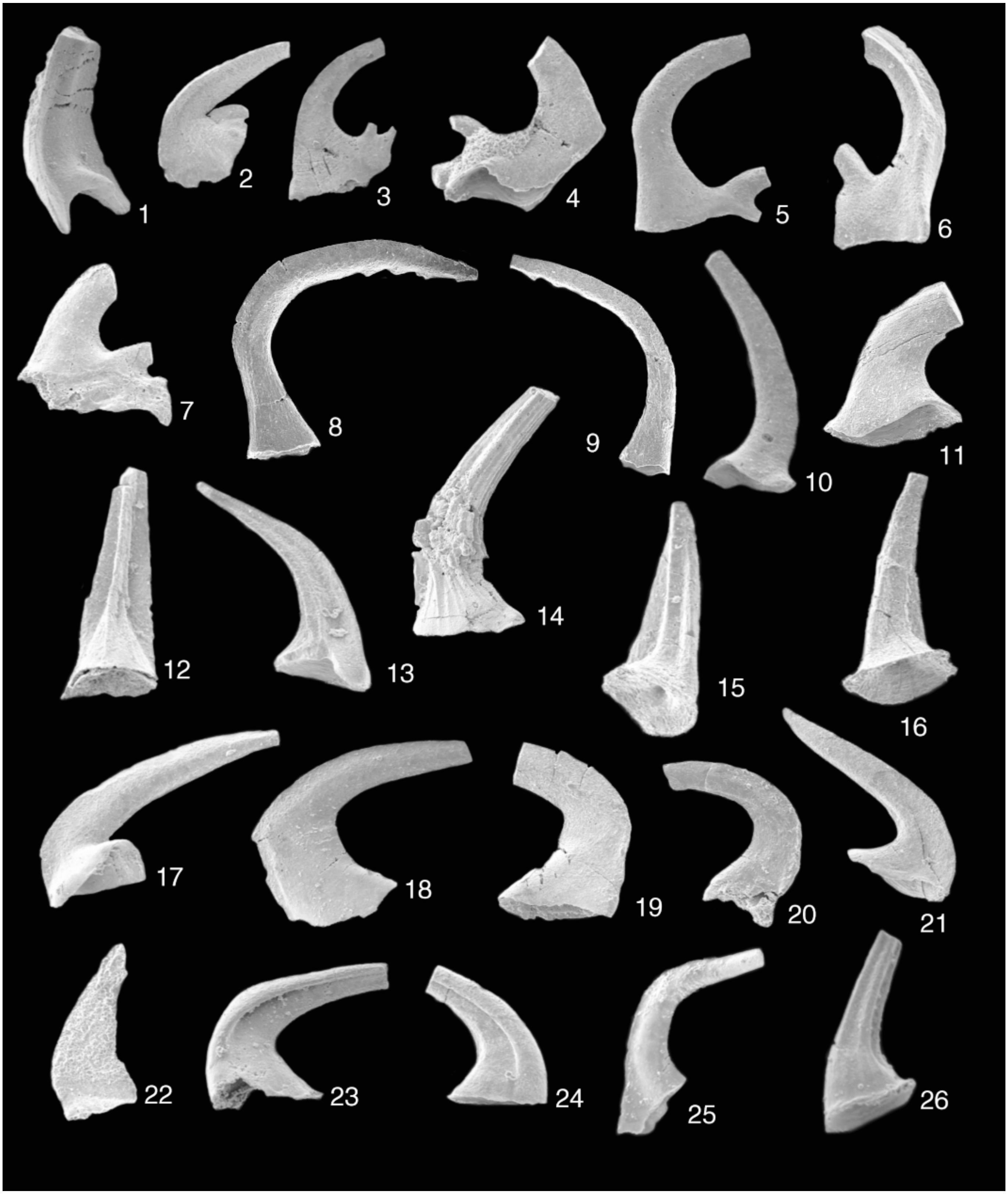

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26

Plate 2. All specimens are from the Deadwood Lake section. All views are lateral except where noted. **fig. 1.** *Paroistodus proteus* (Lindström 1955). S element, DL-96-13, GSC 119666, ×55. **figs. 2–5.** *Drepanoistodus* cf. *D.* n.sp. A. Pyle and Barnes 2001. (2) e element, DL-96-13, GSC 119667, ×53. (3–5) a elements, DL-96-13, GSC 119668 – GSC 119670, ×53. **figs. 6, 7.** *Protopanderodus liripipus* Kennedy, Barnes and Uyeno 1979. (6) c element, DL-96-26, GSC 119671, ×63. (7) a–b element, DL-96-26, GSC 119672, ×63. **fig. 8.** *Periodon* sp.? S element, DL-96-18, GSC 119673, ×80. **fig. 9.** Ramiform indet. posterior view, DL-96-23, GSC 119674, ×150. **figs. 10–12.** *Yaoxianognathus* sp. (10) Sc element, DL-96-21, GSC 119677, ×80. (11, 12) P element, DL-96-21, GSC 119675, ×65. **fig. 13.** *Pseudooneotodus mitratus* (Moskalenko 1973), oral view, DL-96-26, GSC 119676, ×70. **figs. 14, 15.** *Amorphognathus superbus* Rhodes 1953. (14, 15) Pa elements, oral views, DL-96-21, GSC 119678, GSC 119679, ×53. **figs. 16–20.** *Phragmodus undatus* Branson and Mehl 1933. (16) Pb element, DL-96-29, GSC 119679, ×125. (17) Sc element, DL-96-29, GSC 119680, ×70. (18) Sa element, DL-96-29, GSC 119681, ×90. (19) Pa element, DL-96-29, GSC 119682, ×90. (20) M element, DL-96-29, GSC 119683, ×90. **fig. 21.** *Panderodus sulcatus* (Fåhræus 1966). DL-96-29, GSC 119684, ×80. **figs. 22–25.** *Plectodina tenuis* (Branson and Mehl 1933). (22) M element, lateral views, DL-96-29, GSC 119685, ×80. (23, 24) S elements, lateral views, DL-96-29, GSC 119686, GSC 119687, ×80. (25) P element, lateral view, DL-96-29, GSC 119689, ×80.

Occurrence

Phragmodus undatus Zone, Road River Group, Cassiar Terrane.

Material

Four elements.

Repository

GSC 119676.

Genus *Rossodus* Repetski and Ethington, 1983

Rossodus manitouensis Repetski and Ethington, 1983
(Pl. 1, figs. 1, 2)

Remarks

The apparatus of *R. manitouensis* was described adequately by Ji and Barnes (1994) as containing four morphotypes (a, b, c, and e). In the Cassiar collection, two additional nongeniculate compressed elements are recognized, which have a broad, laterally compressed, and flexed cusp.

Occurrence

Rossodus manitouensis Zone, Kechika Formation and Road River Group.

Material

Two hundred and thirty-six elements.

Repository

GSC 119640 and GSC 119641.

Genus *Striatodontus* Ji and Barnes, 1994

Striatodontus strigatus (Pyle and Barnes 2001)
(Pl. 1, fig. 14)

Remarks

The elements are similar in the overall morphology to *Striatodontus prolificus* Ji and Barnes, but are more robust and have more prominent striae covering the elements and deeper longitudinal grooves. They have been assigned to a new species based on the apparatus of at least three morphotypes (a, b, and c elements) of robust but slender cones with slightly expanded bases and cusps, which are covered by fine striae and bear two prominent longitudinal grooves on inner lateral or posterior cusp face.

Occurrence

Rossodus manitouensis Zone, Road River Group.

Material

Seventeen elements.

Repository

GSC 119653.

Genus *Tricostatus* Ji and Barnes, 1994

Tricostatus cf. *T. infundibulum* (Pyle and Barnes 2001)
(Pl. 1, figs. 12, 13)

Remarks

A few samples from the Deadwood Lake section yield specimens that are similar to *T. infundibulum*, a short-ranging species in the mid-Tremadocian Kechika Formation east of the NRMT (*Rossodus manitouensis* Zone), described by Pyle and Barnes (2001). Elements have the inverted funnel-shaped costae on the posterior cusp face, but the base is not as triangular nor as wide as that in *T. infundibulum*.

Occurrence

Rossodus manitouensis Zone, Road River Group.

Material

Four elements.

Repository

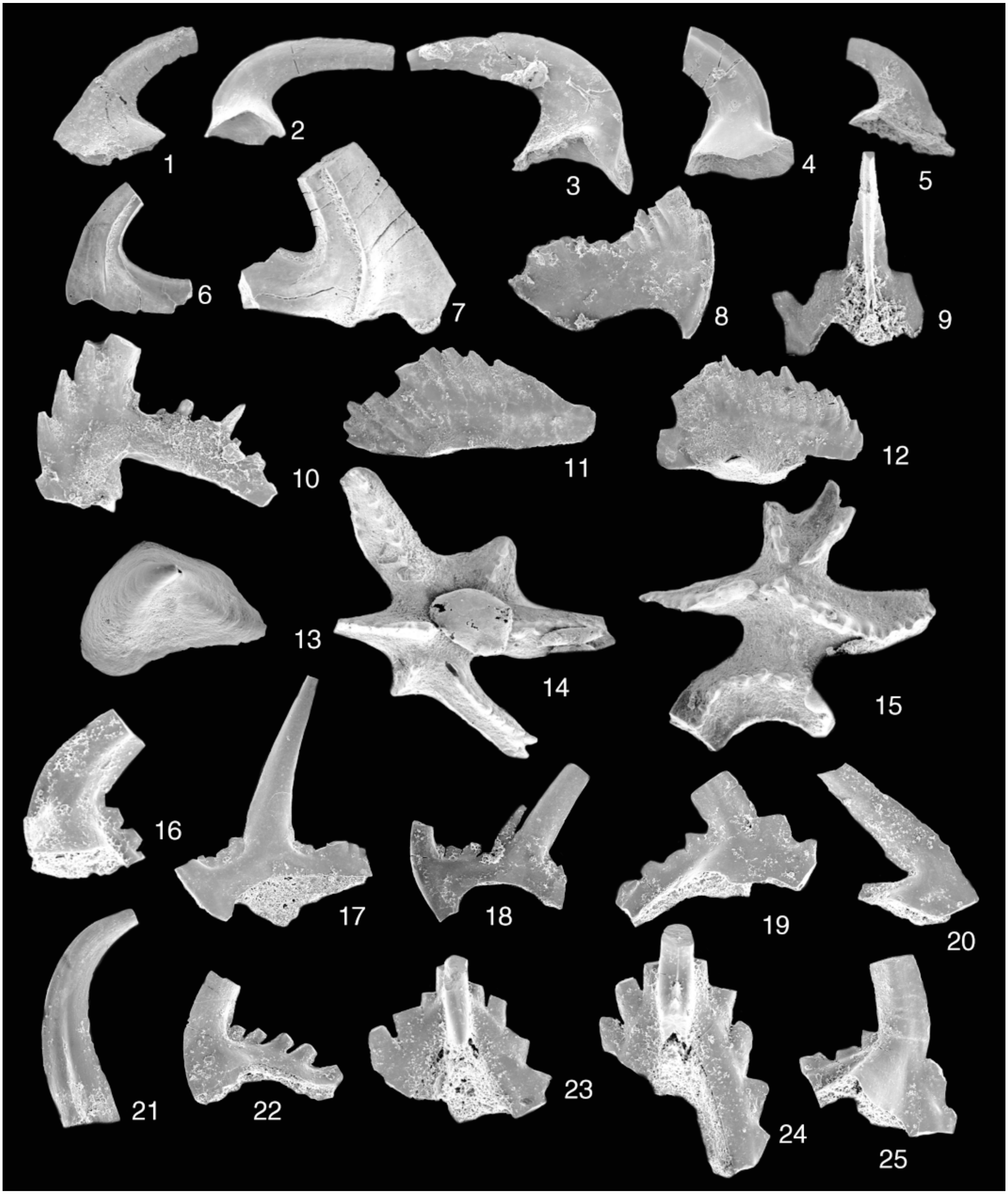
GSC 119651 and GSC 119652.

Genus *Utahconus* Miller, 1980

Utahconus utahensis (Miller 1980)
(Pl. 1, fig. 22)

Remarks

The apparatus of *U utahensis* has previously been described as bimembrate by Miller (1980), who illustrated unicostate (*a*) and bicostate (*e*) elements. Pyle and Barnes (2001) reconstruct a multielement apparatus, which includes six element morphotypes (a, b, c, and three types of e elements) and observed an abundance of compressed e elements in the apparatus, perhaps suggesting there were more pairs of the three types of e elements. The smallest e morphotype is diagnostic and present within the Cassiar collection (Pl. 1, fig. 22). *Utahconus* is the direct ancestor of *Rossodus*.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25

Occurrence
Rossodus manitouensis Zone, Kechika Formation and Road River Group.

Material
Sixteen elements.

Repository
GSC 119661.

Genus *Yaoxianognathus* An in An et al. 1985
Yaoxianognathus sp.
(Pl. 2, figs. 10–12)

Remarks
Only fragmentary specimens have been recovered from the Road River Group, Cassiar Terrane. The P elements are extremely thin and are most similar to *Y. ani* (Zhen et al. 1999) in being unarched with a straight lower margin. However, as elements are broken, it is difficult to determine the prominence of the cusp, number of denticles, and length of anterior process, which are diagnostic characters.

Occurrence
Amorphognathus superbus Zone, Road River Group, Cassiar Terrane.

Material
Four elements.

Repository
GSC 119675 and GSC 119676.

Ramiform indet.
(Pl. 2, fig. 9)

Description
One broken specimen from the Deadwood Lake section is symmetrical ramiform element which has slender, laterally compressed cusp with keeled lateral cusp margins and keeled posterior cusp margin. Two lateral processes are compressed and denticulate.

Occurrence
Amorphognathus superbus Zone, Road River Group.

Material
One element.

Repository
GSC 119674.

Acknowledgments

We gratefully acknowledge primary financial support for the project provided by Lithoprobe Slave – Northern Cordillera Lithospheric Evolution (SNORCLE) Project and the Natural Sciences and Engineering Research Council of Canada and additional support from the Northern Scientific Research Training Program and a Geological Society of America grant. Logistical support for fieldwork was provided by the British Columbia Geological Survey, and discussions on field localities with Hu Gabrielse, JoAnne Nelson, and Brian Norford were appreciated. We thank Henry Williams for graptolite identifications and the reviewers of the manuscript, S.M. Bergström and H. Gabrielse, for their time and helpful suggestions. We also thank Corwin Sullivan and Dianne Pellerin for cheerful and able field assistance and Michelle Landry, Marjorie Deagle, and Emily Delahaye for laboratory assistance and preparation of figures.

References

Aldridge, R.J., and Smith, M.P. 1993. Conodonta. *In* The fossil record 2. *Edited by* M.J. Benton. Chapman and Hall, London, pp. 563–572.

An, T.-x., Du, G.-q., and Gao, Q.-q. 1985. Ordovician conodonts from Hubei, China. Geological Publishing House, Beijing.

Bateson, W. 1886. The ancestry of the chordata. Quarterly Journal of Microscopical Science, **26**: 535–571.

Bergström, S.M. 1971. Conodont biostratigraphy of the Middle and Upper Ordovician of Europe and eastern North America. Geological Society of America Memoir, **127**: 83–161.

Butler, R.F., Harms, T.A., and Gabrielse, H. 1988. Cretaceous remagnetization in the Sylvester allochthon: limits to post-105 Ma northward displacement of north-central British Columbia. Canadian Journal of Earth Sciences, **25**: 1316–1322.

Cecile, M.P., and Norford, B.S. 1979. Basin to platform transition, Lower Paleozoic strata of Ware and Trutch map areas, northeastern British Columbia, Current research, part A, Geological Survey of Canada, Paper 79-1A, pp. 219–226.

Cecile, M.P., and Norford, B.S. 1993. Ordovician and Silurian; Subchapter 4C. *In* Sedimentary cover of the craton in Canada. *Edited by* D.F. Stott and J.D. Aitken. Geological Survey of Canada, Geology of Canada, No. 5, pp. 125–149.

Cecile, M.P., Morrow, D.W., and Williams, G.K. 1997. Early Paleozoic (Cambrian to Early Devonian) tectonic framework, Canadian Cordillera. Bulletin of Canadian Petroleum Geology, **45**: 54–74.

Cooper, R.A., and Nowlan, G.S. 1999. Proposed global stratotype section and point for base of the Ordovician System. Acta Universitatis Carolinae, Geologica, **43**: 61–64.

Donoghue, P.C.J., Forey, P.L., and Aldridge, R.J. 2000. Conodont affinity and chordate phylogeny. Biological Reviews, **75**: 191–251.

Drygant, D.M. 1974. Simple conodonts from the Silurian and lowermost Devonian of the Volyno-Podolian area. Paleontologicheski y Sbornik, **10**: 64–69.

Fåhræus, L.E., and Nowlan, G.S. 1978. Franconian (Late Cambrian) to early Champlainian (Middle Ordovician) conodonts from the Cow Head Group, western Newfoundland. Journal of Paleontology, **52**: 444–471.

Fortey, R.A., Harper, D.A.T., Ingham, J.K., Owen, A.W., and Rushton, A.W.A. 1995. A revision of Ordovician series and stages from the historical type area. Geological Magazine, **132**: 15–30.

Gabrielse, H. 1962. Geology of Cry Lake (104I), British Columbia. Geological Survey of Canada, Preliminary Map 29-1962.

Gabrielse, H. 1963. McDame map area, Cassiar District, British Columbia. Geological Survey of Canada, Memoir 319.

Gabrielse, H. 1967. Tectonic evolution of the northern Canadian Cordillera. Canadian Journal of Earth Sciences, **4**: 271–298.

Gabrielse, H. 1979. Geology of Cry Lake (104 I) map area. Geological Survey of Canada, Open File 610.

Gabrielse, H. 1985. Major dextral transcurrent displacements along the Northern Rocky Mountain Trench and related lineaments in north-central British Columbia. Geological Society of America Bulletin, **96**: 1–14.

Gabrielse, H. 1998. Geology of Cry Lake and Dease Lake map areas, north-central British Columbia. Geological Survey of Canada, Bulletin 504.

Gabrielse, H., and Yorath, C.J. 1991. Tectonic synthesis. *In* Geology of the Cordilleran Orogen in Canada. *Edited by* H. Gabrielse and C.J. Yorath. Geological Survey of Canada, Geology of Canada, No. 4, Chap. 18, pp. 677–705 (Also Geological Society of America, The Geology of North America, Vol. G-2.).

Glass, D.J. 1990. Lexicon of Canadian stratigraphy. Vol. 4. Western Canada, including eastern British Columbia, Alberta, Saskatchewan and southern Manitoba. Canadian Society of Petroleum Geologists, Calgary, Alta.

Goldman, D., and Bergström, S.M. 1997. Late Ordovician graptolites from the North American Midcontinent. Palaeontology, **40**: 965–1010.

Harris, A.G., Dumoulin, J.A., Repetski, J.E., and Carter, C. 1995. Correlation of Ordovician rocks of northern Alaska. *In* Ordovician odyssey: short papers for the seventh international symposium on the Ordovician system. *Edited by* J.D. Cooper, M.L. Droser, and S.C. Finney. Society of Economic Paleontologists and Mineralogists, Las Vegas, Nev., pp. 21–26.

Ji, Z., and Barnes, C.R. 1994. Lower Ordovician conodonts of the St. George Group, Port au Port Peninsula, western Newfoundland, Canada. Palaeontographica Canadiana, **11**: 1–149.

Kennedy, D.J. 1994. *Colaptoconus* (Conodonta), a replacement name for *Glyptoconus* Kennedy 1981, non *Glyptoconus* von Moellendorff 1894. Journal of Paleontology, **68**: 1417.

Lindström, M. 1971. Lower Ordovician conodonts of Europe. *In* Symposium on conodont biostratigraphy. *Edited by* W.C. Sweet and S.M. Bergström. Geological Society of America, Memoir 127, pp. 21–61.

Miller, J.F. 1980. Taxonomic revisions of some Upper Cambrian and Lower Ordovician conodonts with comments on their evolution. University of Kansas Paleontological Contributions, Paper 99, pp. 1–39.

Moskalenko, T.A. 1973. Conodonts of the Middle and Upper Ordovician on the Siberian Platform. Trudy Instituta Geologii i Geofiziki, Akademiya Nauk USSR (Academy of Sciences of the Union of Soviet Socialist Republics Transactions of the Institute of Geology and Geophysics), **137**: 1–143.

Nelson, J.L., and Bradford, J.A. 1989. Geology and mineral deposits of the Cassiar and McDame map areas, British Columbia (104 P/3,5). *In* Geological fieldwork 1988. British Columbia Ministry of Energy, Mines and Petroleum Resources, Paper 1989-1, pp. 323–338.

Nelson, J.L., and Bradford, J.A. 1993. Geology of the Midway–Cassiar area, northern British Columbia (104 O, 104 P). British Columbia Ministry of Energy, Mines and Petroleum Resources, Bulletin 83.

Norford, B.S. 1962. The Silurian fauna of the Sandpile Group of northern British Columbia. Geological Survey of Canada, Bulletin 78.

Nowlan, G.S., and Barnes, C.R. 1981. Late Ordovician conodonts from the Vauréal Formation, Anticosti Island, Quebec. Geological Survey of Canada, Bulletin 329.

Pander, C.H. 1856. Monographie der fossilen Fische des Silurischen Systems der Russisch-Baltischen Gouvernements. St. Petersburg, Russia, 10.

Pell, J. 1994. Carbonatites, nepheline syenites, kimberlites and related rocks in British Columbia. British Columbia Ministry of Energy, Mines and Petroleum Resources, Bulletin 88.

Pohler, S.M.L., and Orchard, M.J. 1990. Ordovician conodont biostratigraphy, western Canadian Cordillera. Geological Survey of Canada, Paper 90-15.

Pope, M.C., and Sears, J.W. 1997. Cassiar platform, north-central British Columbia: a miogeoclinal fragment from Idaho. Geology, **25**: 515–518.

Price, R.A., and Carmichael, D.M. 1986. Geometric test for Late Cretaceous – Paleogene and intracontinental transform faulting in the Canadian Cordillera. Geology, **14**: 468–471.

Pyle, L.J., and Barnes, C.R. 2000. Upper Cambrian to Lower Silurian stratigraphic framework of platform-to-basin facies, northeastern British Columbia. Bulletin of Canadian Petroleum Geology, **48**: 123–149.

Pyle, L.J., and Barnes, C.R. 2001. Taxonomy, evolution, and biostratigraphy of conodonts from the Kechika Formation, Skoki Formation and Road River Group (Upper Cambrian to Lower Silurian), northeastern British Columbia. NRC Monograph Series NRC44461. In press.

Repetski, J.E., and Ethington, R.L. 1983. *Rossodus manitouensis* (Conodonta), a new early Ordovician index fossil. Journal of Paleontology, **57**: 289–301.

Richards, D.R., Butler, R.F., and Harms, T.A. 1993. Paleomagnetism of the late Paleozoic Slide Mountain terrane, northern and central British Columbia. Canadian Journal of Earth Sciences, **30**: 1898–1913.

Sweet, W.C. 1988. The Conodonta: morphology, taxonomy, paleoecology, and evolutionary history of a long-extinct animal phylum. Oxford Monographs on Geology and Geophysics, No. 10, Clarendon Press, Oxford.

Webby, B.D. 1995. Towards an Ordovician time scale. *In* Ordovician odyssey: short papers for the seventh international symposium on the Ordovician system. *Edited by* J.D. Cooper, M.L. Droser, and S.C. Finney. Society of Economic Paleontologists and Mineralogists, Las Vegas, Nev., pp. 5–10.

Webby, B.D. 1998. Steps toward a global standard for Ordovician stratigraphy. Newsletters on Stratigraphy, **36**: 1–33.

Zhen, Y.Y., Webby, B.D., and Barnes, C.R. 1999. Upper Ordovician conodonts from the Bowan Park Succession, central New South Wales, Australia. Geobios, **32**: 73–104.