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LOWER VISÉAN AMMONOIDS FROM THE LOWER MOUNT HEAD FORMATION, EAST-CENTRAL BRITISH COLUMBIA

D.M. Work, W.W. Nassichuk, and B.C. Richards

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Cover Illustration
Holotype of *Goniocycloides ochakensis* Work and Nassichuk, n. sp. x3.5. Photo courtesy of Brian F. Glensiter.

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PREFACE

Correlation of sedimentary strata is based to a great extent on precise paleontological information. Foraminifers and conodonts have provided a sound basis for dating Carboniferous rocks in many places in North America, but correlation to standard successions in Europe has been difficult before now because many faunal elements within these groups have long ranges in time and show a rather distinctive provincialism.

This bulletin describes all the available Lower Carboniferous ammonoids from the Mount Head Formation in east-central British Columbia. Using modern techniques to ensure precise definition of genera and accurate identification of species, this study is an important contribution to ammonoid taxonomy and clearly demonstrates their usefulness in intercontinental correlation. Further, studies of this kind provide data necessary for an understanding of the geological history of the Western Canada Sedimentary Basin and thereby contribute to the exploration for mineral and energy resources in Canada.

M.D. Everell
Assistant Deputy Minister
Earth Sciences Sector

PRÉFACE

La corrélation entre les strates sédimentaires est basée en grande partie sur des données paléontologiques précises. Les foraminifères et les conodontes ont permis de déterminer avec précision l'âge des roches du Carbonifère rencontrées dans de nombreuses régions en Amérique du Nord. Cependant, il a été difficile jusqu'ici d'établir des corrélations avec les séquences européennes de référence, car de nombreux éléments fauniques présents dans ces groupes s'échelonnent sur de longues périodes de temps et sont confinés dans une région relativement distincte.

Le présent bulletin décrit l'ensemble des ammonoïdés du Carbonifère inférieur observés dans la Formation de Mount Head, dans le centre est de la Colombie-Britannique. Cette étude, qui a bénéficié de techniques de pointe permettant de définir les genres et d'identifier les espèces avec exactitude, constitue une contribution importante à la taxonomie des ammonoïdés et montre de toute évidence l'utilité de ces fossiles à l'établissement de corrélations intercontinentales. En outre, de telles études fournissent des données indispensables à la bonne compréhension de l'histoire géologique du Bassin sédimentaire de l'Ouest du Canada et, par conséquent, sont un outil précieux pour l'exploration des minéraux et des ressources énergétiques du Canada.

M.D. Everell
Sous-ministre adjoint
Secteur des sciences de la Terra

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LOWER VISÉAN AMMONOIDS FROM THE LOWER MOUNT HEAD FORMATION, EAST-CENTRAL BRITISH COLUMBIA

ABSTRACT

Lower Viséan (upper middle Osagean) ammonoids from microbial carbonate mud mounds in the lower member of the Mount Head Formation in the Monkman Pass map area of east-central British Columbia, include *Merocanites rileyi* n. sp., *Imitoceras tardum* n. sp., *Irinoceras bamberi* n. sp., *Goniocycloides ochakensis* n. gen. et sp., *Polaricyclus canadensis* n. sp., *Eurites kusinae* n. sp., *Dzhaprakoceras belcourtense* n. sp., *D. crassum* n. sp. and *Furnishoceras heterolobatum* n. gen. et sp. The ammonoids generally resemble faunas from the *Fascipericyclus–Ammonellipsites* Zone, particularly those from the Tournaisian–Viséan boundary beds in the Chadian of the United Kingdom. To some extent however, the age of the ammonoid beds in British Columbia is refined or constrained by other associated faunal groups. The ammonoids are directly associated with upper *Scaliognathus anchoralis–Doliognathus latus* Zone conodonts that indicate correlation with the upper part of the middle Osagean Burlington Formation in the Mississippi Valley. Further, the ammonoid beds are underlain and overlain by strata containing representatives of the definitive Viséan foraminifer *Eoparastaffella* with a subangular to angular outer periphery – that is, morphotype 2.

The lower member, a coeval correlative of the Wileman Member of the Mount Head Formation of southwestern Alberta, was deposited on the northwest-trending Sukunka Uplift, of block-fault origin. Recessive carbonates and siliciclastics of the lower member generally overlie the upper Tournaisian to lower Viséan Turner Valley Formation conformably, and are abruptly overlain by the lower Viséan Baril Member of the Mount Head Formation.

The microbial carbonate mounds occur as isolated deposits between 2 and 8 m thick and as complexes of small buildups developed in shallow-neritic settings. Enclosing facies in the lower member are of peritidal-marsh to neritic-shelf origin.

RÉSUMÉ

Les ammonoïdés du Viséen inférieur (sommet de l'Osagéen moyen) contenus dans les monticules microbiens de boux calcaire du membre inférieur de la Formation de Mount Head, dans la région cartographique du col Monkman, dans le centre est de la Colombie-Britannique, sont les suivants : *Merocanites rileyi* n. sp., *Imitoceras tardum* n. sp., *Irinoceras bamberi* n. sp., *Goniocycloides ochakensis* n. gen. et sp., *Polaricyclus canadensis* n. sp., *Eurites kusinae* n. sp., *Dzhaprakoceras belcourtense* n. sp., *D. crassum* n. sp. et *Furnishoceras heterolobatum* n. gen. et sp. Les ammonoïdés ressemblent en général aux éléments fauniques de la Zone à *Fascipericyclus–Ammonellipsites*, particulièrement ceux des couches se trouvant à la limite du Tournaisien et du Viséen dans le Chadien au Royaume-Uni. Cependant, en Colombie-Britannique, l'âge des couches renfermant des ammonoïdés peut, dans une certaine mesure, être affiné ou défini à l'aide d'autres groupes fauniques associés. Ainsi, les ammonoïdés sont directement liés aux conodontes de la partie supérieure de la Zone à *Scaliognathus anchoralis–Doliognathus latus* et, de ce fait, ils montrent une corrélation avec la partie supérieure de la Formation de Burlington (Osagéen moyen) observée dans la vallée du Mississippi. En outre, les couches contenant des ammonoïdés recouvrent ou sont recouvertes par des strates renfermant des éléments représentatifs du foraminifère viséen définitif *Eoparastaffella*, dont la périphérie externe est subanguleuse à anguleuse, c'est-à-dire de type morphologique 2.

Le membre inférieur, corrélatif contemporain du Membre de Wileman de la Formation de Mount Head, dans le sud-ouest de l'Alberta, s'est accumulé sur le soulèvement de Sukunka de direction nord-ouest, lequel a été formé à la faveur d'un morcellement par failles. Des roches carbonatées et silicoclastiques récessives du membre inférieur reposent généralement en concordance sur la Formation de Turner Valley, qui

s'échelonne du Tournaisien supérieur au Viséen inférieur; elles sont brusquement recouvertes par le Membre de Baril (Viséen inférieur) de la Formation de Mount Head.

Les monticules calcaires microbiens sont présents sous forme de dépôts isolés de 2 à 8 m d'épaisseur et sous forme de complexes de petites accumulations qui se sont déposées dans des milieux épinéritiques. Dans le membre inférieur, les faciès encaissants sont originaires de milieux allant d'un marais péritidal à une plate-forme néritique.

INTRODUCTION

Lower Carboniferous ammonoids of early Viséan (late middle Osagean) age are abundant and diverse in microbial carbonate mounds in the lower member of the Mount Head Formation (Rundle Group) in the overthrust belt of the Rocky Mountain Front Ranges in east-central British Columbia (Fig. 1). More than 1500 silicified ammonoids assigned to *Merocanites*, *Imitoceras*, *Irinoceras*, *Goniocycloides*, *Polaricyclus*, *Eurites*, *Dzhaprakoceras* and *Furnishoceras* were recovered from limestone collected from the lower member in the general vicinity of Ochak Mountain (Fig. 1–3) in the Monkman Pass map area (NTS 93-I). This constitutes the largest and most diverse assemblage of lower Viséan ammonoids ever recovered in North America.

The purpose of this report is to describe the ammonoids, explain their biostratigraphic significance and also to review the stratigraphy and depositional setting of the lower member of the Mount Head Formation in east-central British Columbia. Work and Nassichuk are responsible for systematic paleontology and ammonoid biostratigraphy, and Richards is responsible for sections dealing with the stratigraphy, sedimentology and paleotectonic setting of the lower member.

The lower Viséan ammonoids of the lower member were first discovered at the head of an unnamed tributary of Belcourt Creek (Fig. 1, loc. 10) by E.W. Bamber in 1970 while he was working with a Geological Survey of Canada field party mapping the Monkman Pass map area (NTS 93-I). Ammonoids were also recovered nearby, on the

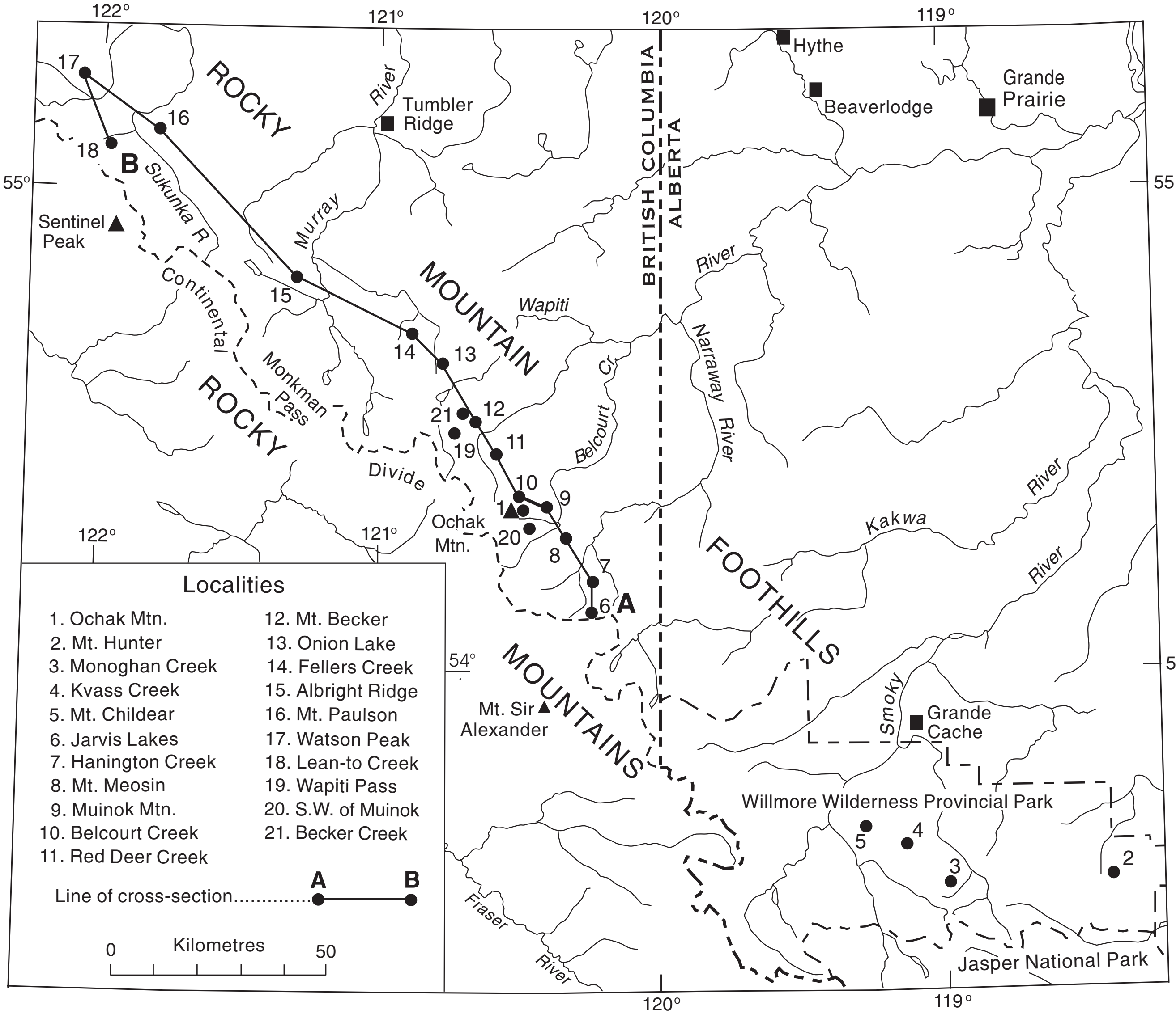


Figure 1. Map of east-central British Columbia and west-central Alberta showing Mount Head ammonoid localities, line of cross-section A–B (Fig. 5), and location of sections discussed in text.

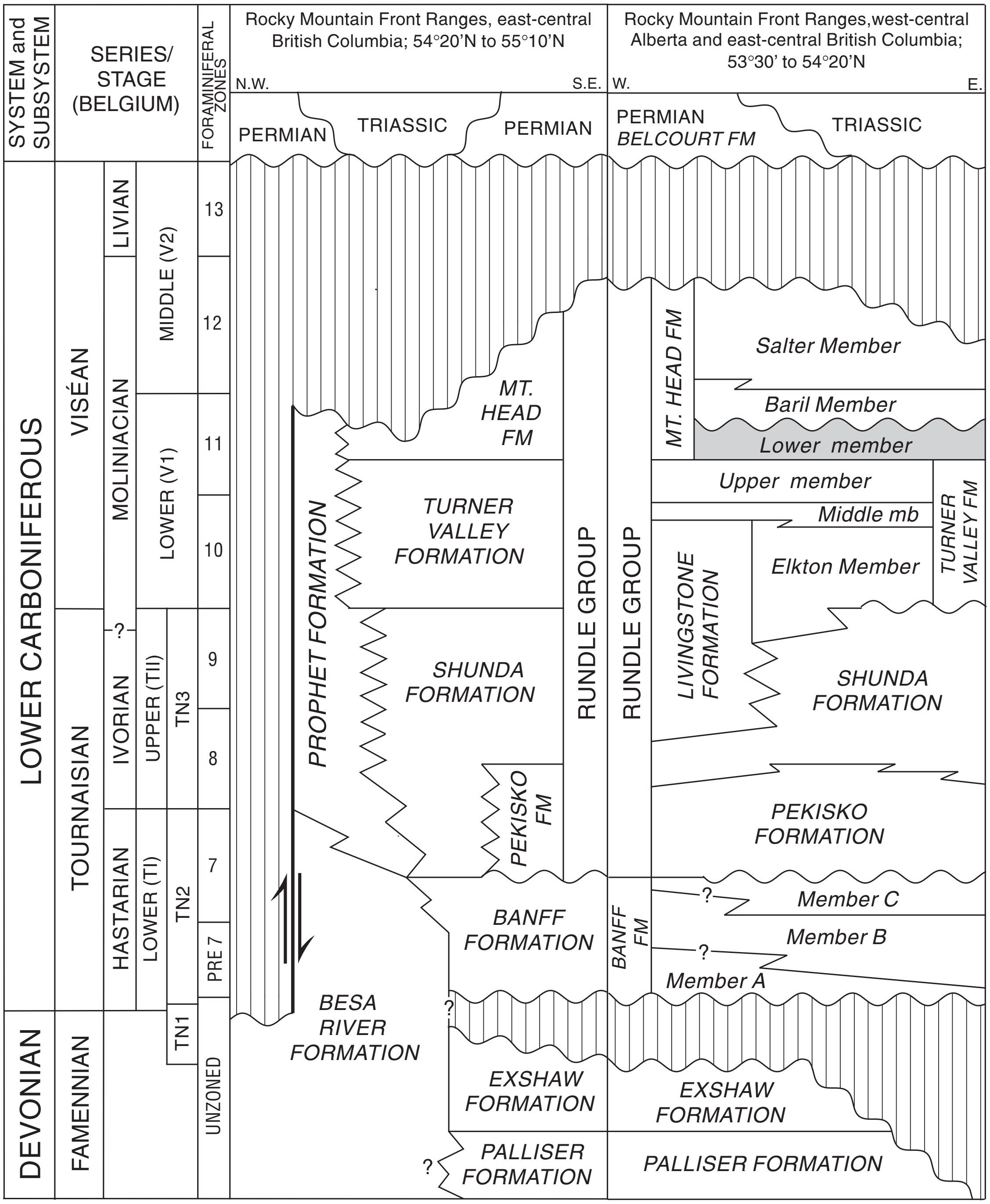
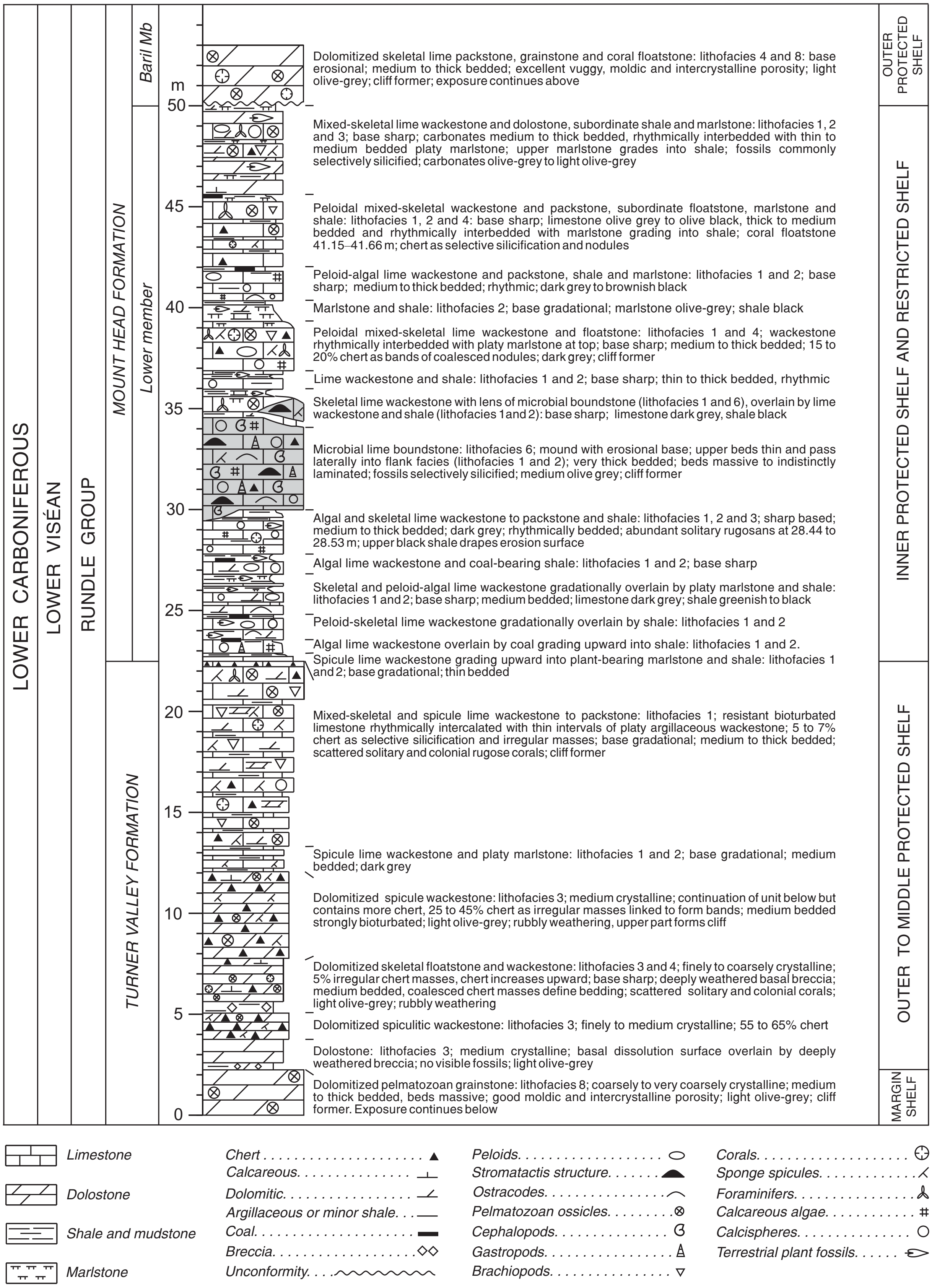


Figure 2. *Correlation of Lower Carboniferous lithostratigraphic units in east-central British Columbia and west-central Alberta with chronostratigraphic units and the foraminiferal zones of Mamet and Skipp (1970) (from Richards et al., 1994).*

eastern side of Ochak Mountain (Fig. 1, loc. 1) by Bamber and his GSC colleague, R.I. Thompson, in 1978. The following year, Bamber and Thompson returned to Ochak Mountain with one of the authors (WWN) to assemble additional collections. Nearly 100 kg of limestone (boundstone) was etched in acetic acid (Fig. 4) and most of the ammonoids described herein were recovered. Additionally, the limestones yielded several hundred specimens of coiled, cyrtoconic and orthoconic nautiloids and a like number of gastropods. Other, less common faunal elements recovered in the process included brachiopods, bivalves, trilobites, blastoids, and conodonts.

Ammonoids from those initial collections that were identified to generic level in a preliminary report by Nassichuk in 1981 and cited by Mamet et al. (1986) included



Dolomitized skeletal lime packstone, grainstone and coral floatstone: lithofacies 4 and 8: base erosional; medium to thick bedded; excellent vuggy, moldic and intercrystalline porosity; light olive-grey; cliff former; exposure continues above

Mixed-skeletal lime wackestone and dolostone, subordinate shale and marlstone: lithofacies 1, 2 and 3; base sharp; carbonates medium to thick bedded, rhythmically interbedded with thin to medium bedded platy marlstone; upper marlstone grades into shale; fossils commonly selectively silicified; carbonates olive-grey to light olive-grey

Peloidal mixed-skeletal wackestone and packstone, subordinate floatstone, marlstone and shale: lithofacies 1, 2 and 4: base sharp; limestone olive grey to olive black, thick to medium bedded and rhythmically interbedded with marlstone grading into shale; coral floatstone 41.15–41.66 m; chert as selective silicification and nodules

Peloid-algal lime wackestone and packstone, shale and marlstone: lithofacies 1 and 2; base sharp; medium to thick bedded; rhythmic; dark grey to brownish black

Marlstone and shale: lithofacies 2; base gradational; marlstone olive-grey; shale black

Peloidal mixed-skeletal lime wackestone and floatstone: lithofacies 1 and 4; wackestone rhythmically interbedded with platy marlstone at top; base sharp; medium to thick bedded; 15 to 20% chert as bands of coalesced nodules; dark grey; cliff former

Lime wackestone and shale: lithofacies 1 and 2; base sharp; thin to thick bedded, rhythmic

Skeletal lime wackestone with lens of microbial boundstone (lithofacies 1 and 6), overlain by lime wackestone and shale (lithofacies 1and 2): base sharp; limestone dark grey, shale black

Microbial lime boundstone: lithofacies 6; mound with erosional base; upper beds thin and pass laterally into flank facies (lithofacies 1 and 2); very thick bedded; beds massive to indistinctly laminated; fossils selectively silicified; medium olive grey; cliff former

Algal and skeletal lime wackestone to packstone and shale: lithofacies 1, 2 and 3; sharp based; medium to thick bedded; dark grey; rhythmically bedded; abundant solitary rugosans at 28.44 to 28.53 m; upper black shale drapes erosion surface

Algal lime wackestone and coal-bearing shale: lithofacies 1 and 2; base sharp

Skeletal and peloid-algal lime wackestone gradationally overlain by platy marlstone and shale: lithofacies 1 and 2; base sharp; medium bedded; limestone dark grey; shale greenish to black

Peloid-skeletal lime wackestone gradationally overlain by shale: lithofacies 1 and 2

Algal lime wackestone overlain by coal grading upward into shale: lithofacies 1 and 2.

Spicule lime wackestone grading upward into plant-bearing marlstone and shale: lithofacies 1 and 2; base gradational; thin bedded

Mixed-skeletal and spicule lime wackestone to packstone: lithofacies 1; resistant bioturbated limestone rhythmically intercalated with thin intervals of platy argillaceous wackestone; 5 to 7% chert as selective silicification and irregular masses; base gradational; medium to thick bedded; scattered solitary and colonial rugose corals; cliff former

Spicule lime wackestone and platy marlstone: lithofacies 1 and 2; base gradational; medium bedded; dark grey

Dolomitized spicule wackestone: lithofacies 3; medium crystalline; continuation of unit below but contains more chert, 25 to 45% chert as irregular masses linked to form bands; medium bedded strongly bioturbated; light olive-grey; rubbly weathering, upper part forms cliff

Dolomitized skeletal floatstone and wackestone: lithofacies 3 and 4; finely to coarsely crystalline; 5% irregular chert masses, chert increases upward; base sharp; deeply weathered basal breccia; medium bedded, coalesced chert masses define bedding; scattered solitary and colonial corals; light olive-grey; rubbly weathering

Dolomitized spiculitic wackestone: lithofacies 3; finely to medium crystalline; 55 to 65% chert

Dolostone: lithofacies 3; medium crystalline; basal dissolution surface overlain by deeply weathered breccia; no visible fossils; light olive-grey

Dolomitized pelmatozoan grainstone: lithofacies 8; coarsely to very coarsely crystalline; medium to thick bedded, beds massive; good moldic and intercrystalline porosity; light olive-grey; cliff former. Exposure continues below

Figure 3. *Columnar section showing characteristics and stratigraphic relations of the lower member of the Mount Head Formation at locality 1 (section 92RAH3), east side of Ochak Mountain, east-central British Columbia.*

Figure 4. *Selectively silicified nautiloids and gastropods in acid-etched limestone from a thrombolitic microbial mound in the lower member of the Mount Head Formation, Ochak Mountain, east-central British Columbia (Fig. 1, loc. 1).*

Merocanites, *Pericyclus*, *Muensteroceras* and *Beyrichoceratoides*. Specimens assigned to the latter three genera are here included in *Polaricyclus* Riley, *Goniocycloides* n. gen., and *Eurites* Kusina and *Dzhaprakoceras* Popov. Conodonts associated with the Ochak Mountain ammonoids, including *Polygnathus mehli* Thompson, *Eotaphrus burlingtonensis* Pierce and Langenheim and several other species, were identified by H.R. Lane (pers. comm., 1979) who assigned an early Viséan (middle Osagean) age (Appendix 3). Conodont biostratigraphy for the lower Mount Head Formation and underlying Turner Valley Formation in east-central British Columbia was summarized by Higgins et al. (1991) and other data on conodonts provided by Higgins are in Appendix 4 of this report. Lower Viséan foraminifers identified from the lower member and the Turner Valley Formation by B.L. Mamet are listed in Appendix 1 and those identified by P.L. Brenckle in Appendix 2.

The formational nomenclature currently applied to the Lower Carboniferous succession in the study area (Fig.1) was introduced by Beauchamp et al. (1986) and Mamet et al. (1986, fig. 3) who divided the succession of the Monkman Pass map area according to the nomenclature used in southwestern Alberta. Earlier, Bamber et al. (1984, fig. 4) included in the Turner Valley and Debolt formations all of the interval called the lower Mount Head Formation in this paper. Mamet et al. (1986, fig. 3) presented a schematic stratigraphic column for the Ochak Mountain–Belcourt Creek area and showed both the lower part of the Mount Head Formation, including the ammonoid horizon in the lower member, and much of the underlying Turner Valley Formation, to be of early Viséan age. The same age was determined for the lower Mount Head and the upper Turner Valley formations in the Sukunka River area, directly north of the Monkman Pass map area, by Beauchamp and Mamet (1985). Foraminifers, including species of *Eoparastaffella* and *Eoendothyranopsis* from strata below and above the ammonoid horizon at Ochak Mountain were assigned an early Viséan (Zone 11) age by Mamet *(in* Mamet et al., 1986).

Subsequently, the lower Mount Head Formation in east-central British Columbia was subdivided from the base upward into the Wileman?, Baril, and Salter members (Richards, 1989a), names extended into the study area from the lower Mount Head Formation of southwestern Alberta. The unit referred to as the lower member in this report was called the Wileman? by Richards (1989a) because it lay at the same stratigraphic level as the Wileman Member in Alberta but differed somewhat from it lithologically.

During July 1991 the authors of this report returned to Ochak Mountain to study the ammonoid beds in detail and to collect additional fossils. Some ammonoids were assembled but fieldwork was terminated when one of us (DMW) was injured on the mountain. A few months later, Nassichuk returned to Ochak Mountain with T. Jerzykiewicz of the GSC and S. Dzulynski, a visiting scientist from Jagiellonian University, Krakow, Poland to complete the collections. The biostratigraphy and ammonoid paleontology of the lower member (Wileman?) was the subject of Work's (1993) Ph.D. thesis at the University of Iowa under the supervision of B.F. Glenister and W.W. Nassichuk. Finally, Richards revisited Ochak Mountain and the headwaters of Belcourt Creek (Fig. 1, loc. 1, 10) in 1992, 1994 and 1997 to complete regional stratigraphic studies, and discovered that the ammonoids described herein occur within Waulsortian-like microbial mounds.

The ammonoid fauna of the lower member is particularly significant because of its association with other taxonomic groups (conodonts and foraminifers) that provide a basis for analysis of the Tournaisian–Viséan boundary elsewhere in North America, particularly the standard Mississippi River Valley succession. Conodonts associated with the ammonoids of the lower member can be related to the Mississippi Valley succession and are, in turn, bracketed by the definitive Viséan foraminifer *Eoparastaffella* with subangular outer periphery.

ACKNOWLEDGMENTS

We thank E.W. Bamber (Geological Survey of Canada) for his generous support in assembling collections and for biostratigraphic information about specific sites. We are also indebted to R.I. Thompson and T. Jerzykiewicz (Geological Survey of Canada) and S. Dzulynski (Jagiellonian University, Poland) for assistance in collecting ammonoids from the Mount Head Formation.

H.R. Lane and P.L. Brenckle (both formerly Amoco Production Company, Houston), B.L. Mamet (University of Montreal), and A.C. Higgins (Stratadata, Ltd. London, U.K.) provided identifications and interpretations of conodonts and foraminifers recovered from the study area. We have also benefited from discussions with W.M. Furnish and G. Klapper (University of Iowa) regarding aspects of Lower Carboniferous ammonoid taxonomy and conodont biostratigraphy.

Type and other specimens were examined through the courtesy of J. Golden (University of Iowa), J.W.M. Thompson (U.S. National Museum of Natural History), R.D. White (Peabody Museum of Natural History, Yale University), G.F. Gunnell (University of Michigan), R.D. Norby (Illinois State Geological Survey), C.E. Mason (Morehead State University), M. Petersen (Brigham Young University), C. Spinosa (Boise State University), A. Sleeman (Geological Survey of Ireland, Dublin), N. Monaghan (National Museum of Ireland, Dublin), P.N. Wyse Jackson (Geological Museum, Trinity College, Dublin), M.K. Howarth and D. Phillips (The Natural History Museum, London), M. Dorling (Sedgwick Museum of Geology, Cambridge), H.C. Ivimey-Cook (British Geological Survey, Keyworth), P. Sartenaer, A. Dhondt, and J. Godefroid (Institut royal des Sciences Naturelles de Belgique, Brussels), H. Jahnke and O.H. Walliser (Institute und Museum für Geologie und Paläontologie Der Georg-August Universität, Göttingen), L.F. Kusina and M.F. Bogoslovskaya (Paleontological Institute, Russian Academy of Sciences, Moscow), and A.V. Popov (All-Russian Geological Institute, St. Petersburg).

The final manuscript benefited from thoughtful reviews by E.W. Bamber (Geological Survey of Canada) and B.F. Glenister (University of Iowa).

REGIONAL STRATIGRAPHIC SETTING

The ammonoids described herein occur in the lower Viséan, lower member of the Mount Head Formation in the Monkman Pass map area (Fig. 1–5). The carbonates and subordinate fine grained siliciclastics of the lithologically variable Mount Head Formation are widely distributed, extending from the Rocky Mountains and foothills of southeastern British Columbia and southwestern Alberta into the eastern Rocky Mountains of west-central Alberta and east-central British Columbia (Macqueen and Bamber, 1968; Richards 1989a; Sando et al., 1990; Richards et al., 1993). In southeastern British Columbia and southwestern Alberta, the Wileman Member constitutes the basal unit of the Mount Head Formation. In east-central British Columbia and east-central Alberta (the study area, Fig. 1), the lower member of the Mount Head has been called the Wileman? Member (Richards, 1989a; Richards et al., 1993), because it characteristically contains limestone and shale not found in the type Wileman of southwestern Alberta, which consists mainly of recessive silty dolostone grading into siltstone. The differences are great enough to warrant a new name for the ammonoid-bearing unit of the Monkman Pass region, but this regional stratigraphic work is beyond the scope of the present project.

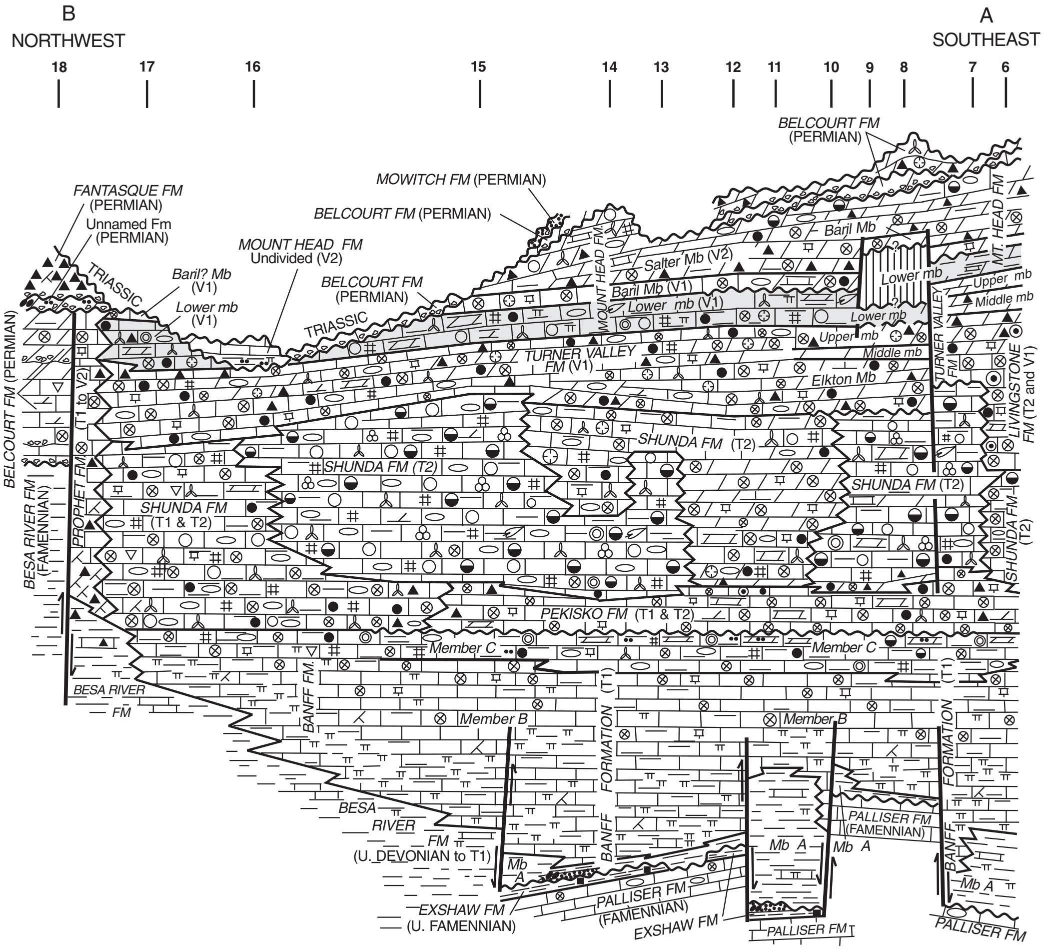
In the subsurface east of the study area, correlatives of the lower Mount Head lie within the lower to upper Viséan Debolt Formation. There, they are widely distributed in the middle Debolt (Richards et al., 1994).

Northwest of the Albright Ridge section (Fig. 1, 5, loc. 15), the lower member of the Mount Head Formation may have been completely eroded prior to deposition of the Permian succession. In that region, the unit designated the Wileman? by Richards (1989a, fig. 9.44) and Richards et al. (1994, fig. 14.14) lacks the shale and argillaceous to silty carbonates that typify the lower member and may, therefore, be part of the middle to upper Turner Valley Formation.

The ammonoid-rich carbonate lithofacies of the lower member of the Mount Head have been recognized at several

LEGEND

- ▨ *Dolostone*
- ▨ *Limestone*
- ▨ *Marlstone*
- ▨ *Spiculite*
- ▨ *Sandstone*
- ▨ *Conglomerate*
- ▨ *Shale and mudstone*
- ▨ *Hiatus*



V3 = Upper Viséan
V2 = Middle Viséan
V1 = Lower Viséan
T2 = Upper Tournaisian
T1 = Lower Tournaisian

Horizontal scale
km
0 20

Vertical scale
m
0 100

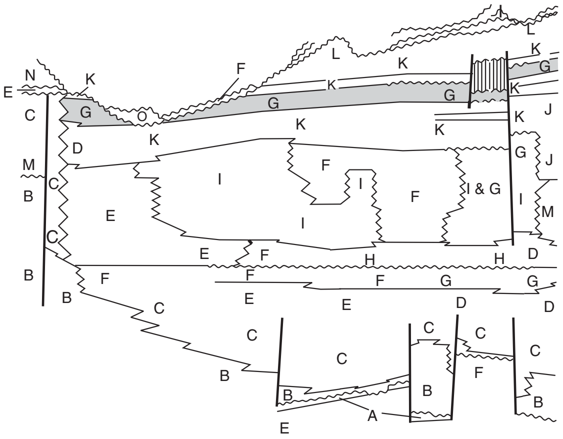
Locations of sections

6. Jarvis Lakes; 54°06'21"N, 120°12'27"W
7. Hanington Cr.; 54°10'46"N, 120°14'45"W
8. Mt. Meosin; 54°17'08"N, 120°18'55"W
9. Muinok Mtn.; 54°20'03"N, 120°23'19"W
10. Belcourt Cr.; 54°21'54"N, 120°29'58"W
11. Red Deer Cr.; 54°27'00"N, 120°35'14"W
12. Mt. Becker; 54°31'02"N, 120°38'46"W
13. Onion Lake; 54°37'57"N, 120°45'34"W
14. Fellers Cr.; 54°42'19"N, 120°53'06"W
15. Albright Ridge; 54°48'15"N, 121°17'37"W
16. Mt. Paulson; 55°06'32"N, 121°48'23"W
17. Watson Peak; 55°13'58"N, 122°05'07"W

Chert . . . . ▲▲
Calcareous . . . . ⊥
Dolomitic . . . . ⟋
Silty . . . . ••
Phosphatic . . . . ●●
Bituminous . . . . ■
Fenestral fabric . . . . ◒
Ooids . . . . ⊙
Peloids . . . . ⬭
Pelletoids . . . . ●
Aggregate grains . . . . ஃ
Pelmatozoan ossicles. . . . . . ⊗
Corals . . . . ⊕
Brachiopods . . . . ▽
Bryozoans . . . . ⌑
Foraminifers . . . . ⅄
Sponge spicules . . . . ⋌
Calcispheres . . . . ○
Calcareous algae . . . . #
Oncolites . . . . ◎
Terrestrial plants . . . . ⌀
Unconformity . . . . ∿∿
Normal fault . . . . ⇌

Environments of deposition

A. Euxinic basin
B. Basin (partly euxinic)
C. Slope
D. Upper slope and shelf margin (platform)
E. Upper slope and shallow shelf (ramp)
F. Shallow shelf (ramp)
G. Protected shelf and restricted shelf (platform)
H. Shelf margin and protected shelf (platform)
I. Shallow shelf and restricted shelf (ramp)
J. Inner shelf margin (platform)
K. Protected shelf (platform)
L. Restricted shelf
M. Slope to shallow shelf (ramp in part)
N. Basin? to shallow shelf
O. Shallow-marine valley fill



localities in the western Rocky Mountain Front Ranges of the Monkman Pass map area in east-central British Columbia. The ammonoids are associated with abundant nautiloids and gastropods and occur in small microbial mounds (Fig. 6). Similar mounds that contain abundant nautiloids and gastropods, but have not yielded ammonoids, occur in the lower member as far south as the Kvass Creek region (Fig. 1, loc. 4) in Willmore Wilderness Provincial Park, west-central Alberta (NTS 83 E/11). Abundant gastropods, locally associated with nautiloids, are also present in basal beds of the overlying Baril Member of the Mount Head Formation at several localities in the region, but do not occur in mounds. The best location for ammonoids, the one from which most of the goniatites described here were collected, is a cirque situated on the eastern side of Ochak Mountain (NTS 93-I/7), east-central British Columbia (Fig. 1, loc. 1). There, they are preserved in several microbial mounds that occur in the middle to upper parts of the lower member (Fig. 3, 6, 7).

In the study area, the lower member of the Mount Head Formation thins toward the southeast and east, but displays substantial local variation. At Ochak Mountain, the reference section for the lower member (Fig. 3) is 27.5 m thick, but on the northeast side of Mount Meosin 12.7 km to the southeast, it is only 14.4 m thick. The Ochak Mountain section is one of the thicker known occurrences of the lower member in the study area. A slightly thicker section comprising 36.4 m of strata is present at Wapiti Pass (Fig. 1, loc. 19), 21.0 km northwest of Ochak Mountain. In Willmore Wilderness Provincial Park, the lower member is 22.4 m thick at Monoghan Creek in the western front ranges but only 9.8 m thick at Mount Hunter in the eastern front ranges. At Mount Childear in the western front ranges of northern Willmore Park, the lower member is anomalously thin (5.4 m) because of deep erosion prior to deposition of the overlying Baril Member. For the same reason, the Mount Meosin section is also thinner than normal.

In the study area, the recessive carbonates, shale, and marlstone of the lower member overlie the resistant, carbonate-dominated lower Viséan Turner Valley Formation and are overlain by lower to middle Viséan carbonates of the Baril Member (Fig. 3, 5, 7). Since these three units were recently described by Richards (1989a), Sando et al. (1990), and Richards et al. (1993), only the lower member is described here.

At Ochak Mountain and most other localities in the Monkman Pass map area, the contact with the underlying Turner Valley Formation is conformable and gradational through 10 cm or more. The Mount Head–Turner Valley contact is placed at a point where resistant, chert-rich, mixed-skeletal packstone and grainstone characteristic of the Turner Valley pass upward into a recessive succession dominated by shale and marlstone intercalated with argillaceous carbonates (Fig. 3, 7). A marked to subtle break in slope coincides with the contact. In Willmore Wilderness Park, the top of the Turner Valley Formation is commonly a minor erosion surface resulting from pedogenic processes.

On the Sukunka Uplift (Fig. 8), the contact between the lower member of the Mount Head and the overlying Baril Member is generally an undulatory erosion surface resulting from transgressive ravinement. It is, however, apparently conformable at some southwestern occurrences in the Monkman Pass map area. At Ochak Mountain, the contact is sharp and probably erosional (Fig. 3). The contact between the lower member and the Baril Member is marked by an abrupt change from shale and marlstone to cliff-forming skeletal packstone and grainstone; large- to very large-scale crossbedding is commonly present in the lower Baril. At most localities, the base of the Baril shows deep scours.

The Mount Head's lower member in the study area resembles the Wileman Member in southwestern Alberta but some important differences are apparent. In both regions, the member is lithologically heterogeneous, and characterized by the predominance of carbonates containing either abundant terrigenous silt or clay. At its type section in the eastern Rocky Mountains southwest of Calgary, greyish orange weathering dolostone containing abundant silt and grading into dolomitic siltstone is predominant. Elsewhere in southwestern Alberta, the member contains substantial intervals of argillaceous limestone of restricted-shelf aspect and a diversity of other carbonate lithofacies and anhydrite of peritidal origin (Macqueen and Bamber, 1968; Richards, 1989a; Richards et al., 1993). In Willmore Wilderness Park, dolostone containing minor silt is common in the lower member, but in the Monkman Pass map area it is not a common rock type. In the latter area, the member is dominated by argillaceous limestone and dolostone rhythmically interbedded with shale and marlstone (Fig. 3, 6).

PALEOTECTONIC SETTING

In the study area, ammonoid-bearing strata of the basal Mount Head Formation were deposited on the broad,

__Figure 5.__ Partly schematic, non-palinspastic cross-section showing relation of lower member of Mount Head Formation to other Lower Carboniferous stratigraphic units, eastern Rocky Mountains, east-central British Columbia (modified from Richards et al., 1994). Note: Richards et al., referred to the lower member of the Mount Head as Wileman? Member. See Figure 2 for line of section A–B.

***Figure 6.** Core and northeastern side of ammonoid-bearing microbial mound (5.5 m thick) in middle part of lower member, Mount Head Formation, east side of Ochak Mountain, east-central British Columbia (Fig. 1, loc. 1). Mound (arrowheads indicate base and top) consists of thrombolitic lime boundstone and overlies erosion surface that truncates beds of lime wackestone (lithofacies 1) intercalated with shale and marlstone. Overlying deposits are dominated by lithofacies 1 (ISPG photo 4102-22).*

northwest-trending Sukunka Uplift (Fig. 8). The latter was bounded on the northeast by the Peace River Embayment and on the southwest by the pericratonic Prophet Trough (Richards et al., 1993, 1994). Richards (1989a) and Richards et al. (1993) considered the uplift to be part of the Peace River Embayment, but subsequent work (Richards et al., 1994) indicated that the uplift formed the southwestern rim of the Peace River Embayment and should be considered as a separate paleotectonic element. The Sukunka Uplift extends from west-central Alberta to the easterly trending Fort Saint John Graben in northeastern British Columbia. The graben connects the Peace River Embayment to the Prophet Trough (Barclay et al., 1990; Richards et al., 1994).

The Sukunka Uplift was a successor of the northwestern part of the West Alberta Ridge, which was the result of widespread Late Silurian epeirogenic uplift (Moore, 1989). Transgression of the West Alberta Ridge began during the Middle Devonian, and by the middle Frasnian it had been onlapped by marine carbonates and terrigenous clastics (Grayston et al., 1964; Douglas et al., 1970; Moore, 1989; Morrow and Geldsetzer, 1988). Sukunka Uplift, a site of recurrent tectonism, first developed during late Famennian to earliest Tournaisian time. In most of the region, the uplift persisted into Early Permian time, but in the northwest it was episodically positive into the Early Triassic. This is indicated by the local presence of the Lower Triassic Sulphur Mountain Formation on lower Viséan strata of the Rundle Group in the northwestern part of the Monkman Pass map area and in the southern part of the adjacent Dawson Creek and Pine Pass map areas (Richards, 1989a; Richards et al., 1994; Henderson et al., 1994).

The Sukunka Uplift resulted largely from broad upwarping related to contractional events along the western margin of the ancestral North American plate (Richards 1989a; Richards et al., 1993, 1994). Broad upwarping is indicated by gradual southwestward (toward Sukunka Uplift and eastern hinge of Prophet Trough) thinning and shallowing trends at several stratigraphic levels in the upper Paleozoic succesion of west-central Alberta and east-central British Columbia. The thinning trends are illustrated on isopach maps and regional cross-sections of Richards et al. (1994) and Henderson et al. (1994). Southwestward regional thinning is particularly prominent at the level of the upper Viséan to Moscovian Stoddart Group, which attains more than 300 m in the Peace River Embayment but thins southwestward to zero along the Sukunka Uplift. A similar

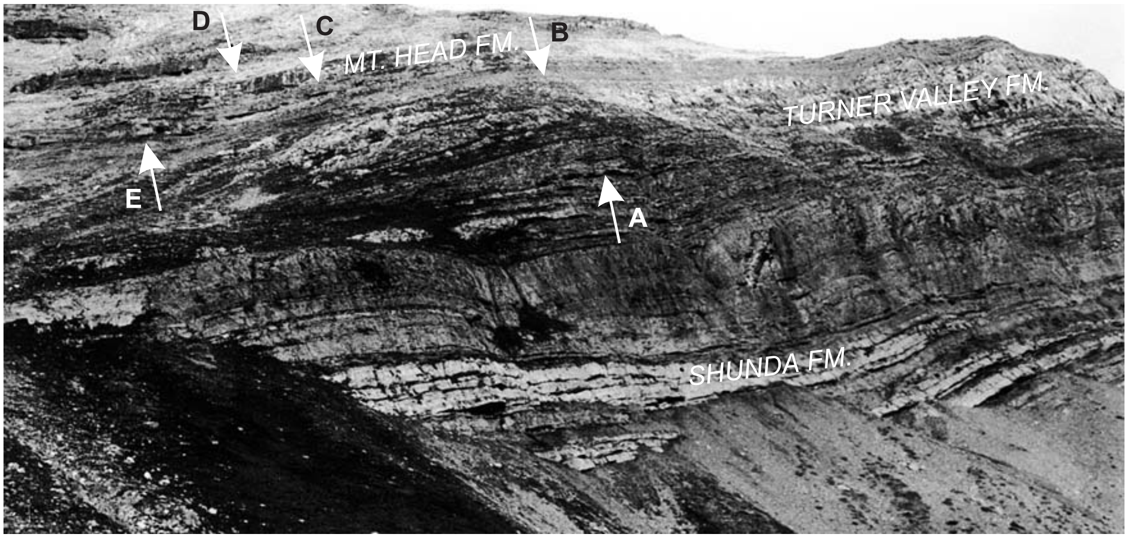


Figure 7. *Lower Carboniferous succession in cirque on eastern side of Ochak Mountain (Fig. 1, loc. 1); view is toward northwest. Arrowheads indicate:* ***A*** *- contact between Shunda Formation and overlying Turner Valley Formation (83.0 m thick),* ***B*** *- top of Turner Valley Formation and base of lower member (27.5 m thick) of Mount Head Formation,* ***C*** *- top of lower member and base of Baril Member of Mount Head Formation,* ***D*** *- top of Baril Member and base of Salter Member of Mount Head, and* ***E*** *- microbial mound shown in Figure 6 (ISPG photo 4526-23).*

trend is evident in the Permian succession, which locally thins westward to zero along the eastern side of the uplift and then thickens abruptly farther westward.

Sukunka Uplift is also partly of block-fault origin. Along the northeastern side of the uplift, adjacent to the Peace River Embayment, marked southwest thinning at several stratigraphic levels in the upper Paleozoic succession is considered to be the result of differential erosion across at least one major northwest-striking normal fault (Richards et al., 1994). Additional evidence for major northwest-striking normal faults is provided in the southern part of the Pine Pass map area (Fig. 5, loc. 17, 18) by abrupt westward thinning of the Tournaisian Banff Formation and the upper Tournaisian to middle Viséan Rundle Group. On the east side of the fault zone, several hundred metres of Lower Carboniferous strata are preserved, but on the west side the Carboniferous has been completly eroded and Lower Permian (Asselian and Sakmarian) carbonates of the Belcourt Formation unconformably overlie upper Famennian black shale of the Besa River Formation (Richards et al., 1994, fig. 14.32–35). In the study area, further evidence for normal faults is indicated by thickness and stratigraphic changes between closely spaced stratigraphic sections in the eastern Rocky Mountains of the Monkman Pass map area (Richards et al., 1994, fig. 14.14).

The Peace River Embayment of northwestern Alberta and northeastern British Columbia opened westward into Prophet Trough and was a broad, fault-controlled re-entrant into the western cratonic platform (Fig. 8). The principal depositional and structural axis of the embayment had an easterly trend and coincided approximately with that of the Late Devonian Peace River Arch (Richards 1989a; Richards et al., 1994; O'Connell et al., 1990). Regional subsidence accompanied by extensive block faulting along northeasterly and northwesterly striking normal faults facilitated deposition of a thick Carboniferous succession in the embayment, which included an extensive graben system (Barclay et al., 1990).

The Prophet Trough, which includes the thickest Carboniferous sections in southwestern Canada, developed during the latest Devonian to Early Carboniferous (Richards, 1989a; Richards et al., 1994). The trough was connected to the Antler Foreland Basin of the western United States and extended from southeastern British Columbia to the Late Devonian and Early Carboniferous Yukon Fold Belt. A broad hinge zone, marking a point at which water depths and sedimentation rates increased rapidly basinward, formed the boundary between the trough and the cratonic platform. In the study area, the Sukunka Uplift represents the eastern hinge zone of the trough. The western boundary of the trough is poorly defined but was an elevated rim, extensively exposed from the Famennian into the early Viséan but subsequently largely transgressed. Along the southwestern side of Sukunka Uplift, lithofacies deposited in the Prophet Trough were mostly removed by several episodes of regional Mesozoic erosion that accompanied development of the Rocky Mountains.

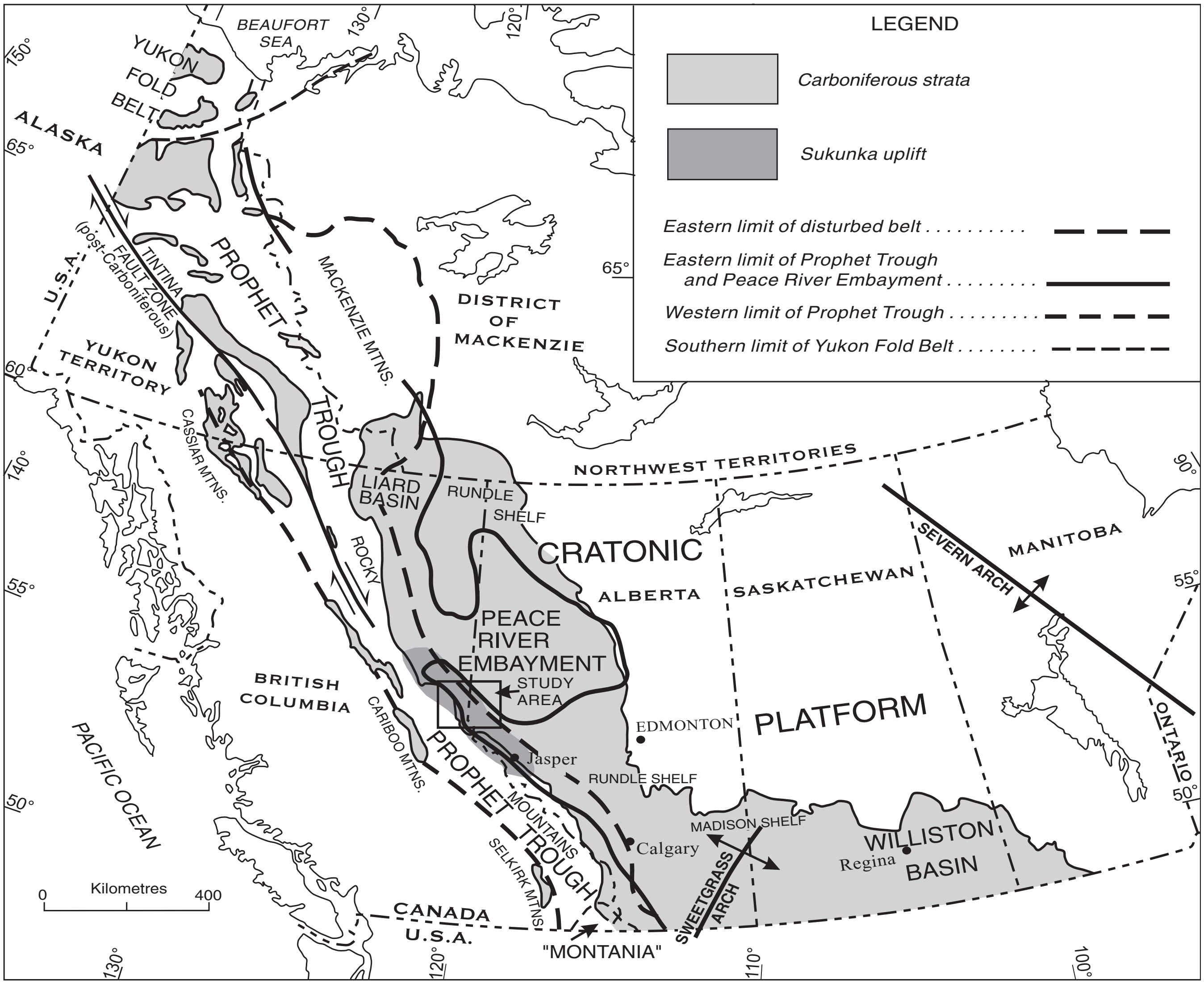


Figure 8. *Paleotectonic elements and Carboniferous strata, Western Canada Sedimentary Basin (modified from Richards et al., 1994).*

LITHOFACIES IN THE LOWER MEMBER OF THE MOUNT HEAD FORMATION

The following eight lithofacies, in order of decreasing abundance, constitute the Mount Head's lower member in the study area: 1) fine grained lime wackestone, 2) shale and marlstone, 3) massive dolostone, 4) skeletal lime floatstone, 5) fenestral cryptalgal boundstone, 6) microbial boundstone, 7) laminated dolostone, and 8) grainstone (Table 1). Of these, lithofacies 6 is particularly important because it contains the ammonoids described here, and because it is also the principal mound facies, whereas the others collectively represent the intermound deposits. For these reasons, lithofacies 6 is discussed in considerable detail.

Lithofacies 1: fine grained lime wackestone

Lithofacies 1 consists of medium dark grey to dark grey and olive-black (GSA colour chart), fine grained lime wackestone and subordinate lime packstone. Deposits of the lithofacies are relatively recessive but commonly form low cliffs. This is the predominate lithofacies in the lower member at Ochak Mountain (Fig. 3, 6) and elsewhere in the Monkman Pass map area. The lithofacies is also preserved at the Kvass Creek locality in the western front ranges of Willmore Wilderness Park.

The deposits are mainly medium bedded (10–30 cm) but range from thin bedded (1–10 cm) to thick bedded (30–

Table 1. Main lithofacies features of the lower member of the Mount Head Formation in the study area

Lithofacies	Rock types	Bedding/structure	Grain type	Distribution/location	Depositional environment	Diagenesis
(1) Fine grained lime wackestone	Lime wackestone and packstone; three microfacies based on main allochems: 1) spicule, 2) peloid algal, and 3) mixed skeletal. Deposits argillaceous and variably dolomitic, medium dark grey to olive black.	Medium bedded, bases of beds commonly sharp and tops gradational. Most beds have good lateral continuity, but some are truncated by paleochannels. Most beds internally churned, but some show small-scale crossbedding, laminae and domal stromatolites.	Sponge spicules dominate in spicule microfacies. Peloid-algal microfacies dominated by peloids and algae. Mixed-skeletal microfacies contains: pelmatozoan ossicles, sponge spicules, peloids, corals, foraminifers, algae and brachiopods.	Main lithofacies in Wileman of study area. Intercalated with lithofacies 2; passes eastward into lithofacies 3 and 7. Commonly overlies and grades into lithofacies 4. Locally abruptly overlain by lithofacies 6 and passes rapidly into microbial boundstone of latter facies at flanks of mounds.	Deposited in shallow-subtidal to intertidal mud-flat settings on the protected shelf of a carbonate platform. Deposited in intermound settings. Occurs in regressive systems tract of Turner Valley/Wileman T–R sequence.	Early diagenetic chert nodules, selective silicification. Variably dolomitized after chertification. Blocky to bladed meteoric-phreatic cements in former chambers of allochems.
(2) Shale and marlstone	Siliciclastic mudstone and calcareous to dolomitic marlstone with subordinate shale and minor coal. Deposits mainly grayish black to brownish black in east-central B.C. and greenish grey to light olive grey in Willmore Wilderness Park.	Occurs as laminae and beds up to several metres thick but mainly medium bedded. Generally rhythmically interbedded with lithofacies 1 and 3; beds locally truncated by paleochannels. Beds internally churned to thinly laminated.	Terrigenous silt and carbonized terrestrial plant fossils common in brownish black shale and mudstone. Scattered corals, pelmatozoan ossicles, bryozoans and brachiopods present in platy marlstone that is intercalated with lithofacies 1.	Widely distributed, volumetrically second most abundant Wileman lithofacies. In east-central B.C., facies becomes less abundant northwestward. Interbedded with all of other lithofacies. Tongues of lithofacies 2 extend into marginal deposits of some microbial mounds.	Deposits with coal and abundant terrestrial plant fossils record deposition in coastal marshes to lacustrine settings; those with marine bioclasts formed in shallow-neritic to intertidal environments on the protected shelf of a carbonate platform. Represents part of regressive systems tract of Turner Valley/Wileman T–R sequence.	Commonly partly dolomitized; some selective silicification of macrofossils
(3) Massive dolostone	Sparsely fossiliferous, finely to medium crystalline dolostone; variably calcareous to cherty; medium grey to light olive grey.	Well bedded, commonly rhythmically interbedded with lithofacies 1 and 2. Bases of beds sharp, tops commonly gradational. Beds internally massive (churned).	Scattered pelmatozoan ossicles, brachiopods and corals; poorly preserved peloids, pisoliths and aggregate grains; minor quartz silt. Terrestrial plant fossils locally common.	Main facies in Willmore Wilderness Park; a minor facies in east-central B.C., occurring mainly in upper Wileman except where lithofacies 1 extensively dolomitized. Abundance increases upward and northeastward overall. Interbedded with lithofacies 2 and grades laterally into lithofacies 1.	Deposited in shallow-neritic to intertidal environments (intermound setting) on the protected shelf of a carbonate platform. Part of regressive systems tract of Turner Valley/Wileman T–R sequence.	Early chertification (before dolomitization). Lithofacies resulted from extensive late dolomitization (after deposition of Mount Head Fm.) of limestone in lithofacies 1.
(4) Skeletal lime floatstone	Mixed-skeletal lime floatstone; containing abundant coarse-grained fossil debris set in matrix of lime wackestone and packstone. Medium to dark grey, cherty.	Mainly medium bedded but ranges from medium to thick bedded. Beds generally sharp based and with good lateral continuity; some beds occur in channel fills. Most beds internally massive. On southeast side of microbial mound at Ochak Mtn., facies forms debris apron containing clinoforms.	Coarse allochemical fraction comprises solitary and colonial corals; intermediate fraction consists of oncolites, molluscs, brachiopods and coarse pelmatozoan debris. Fine grained component (granule or smaller) is dominated by pelmatozoan debris, foraminifers and algae.	A minor component of most sections but is well developed at localities 21 and 12. At the latter, it occurs in a large-scale channel fill. At Ochak Mtn., facies is well developed in the middle Wileman on the S.E. side of a microbial mound. There, it occurs as a debris apron against the mound and as adjacent intermound deposits.	Intermound settings and as debris aprons on microbial mounds. Deposited in shallow-neritic, relatively open-marine, protected-shelf settings on a carbonate platform. Records minor transgressions in regressive systems tract of Wileman/Turner Valley T–R sequence.	Early selective silicification and formation of chert nodules. Bladed and blocky, meteoric-phreatic calcite cement in former chambers of fossils.
(5) Fenestral cryptalgae boundstone	Dolomitized fenestral cryptalgal lime boundstone and minor fenestral lime boundstone. Light to medium grey.	Thin to medium bedded; beds have subplanar boundaries and show well developed to diffuse internal laminae and fenestrae.	Abundant peloids, aggregate grains, calcispheres, and calcareous algae are preserved in the limestone. Dolomitized deposits contain poorly preserved peloids and aggregate grains; scattered gastropods in some beds.	Common and widely developed in Willmore Wilderness Park but not common to the northwest. In Willmore region, proportion of this facies increases northeastward. Interbedded with carbonates of lithofacies 2 and 3 and greenish grey shale of lithofacies 2.	Deposited in supratidal to high-intertidal, restricted-shelf environments on a carbonate platform. A regressive facies in regressive systems tract of Wileman/Turner Valley T–R sequence.	Early (syndepositional hypersaline dolomitization), blocky calcite and dolomite cement in fenestrae.
(6) Microbial boundstone	Fossiliferous microbial lime boundstone and subordinate dolomitized microbial boundstone. Variably cherty, medium dark grey to light olive grey.	Forms cores of small (<10 m thick) carbonate mounds. Thick to very thick bedded; beds show reticulate thrombolitic framework. Sparry calcite cement and internal sediment partly to totally fill large elongate cavities, stromatactis structures and smaller cavities. Spongioform microstructure common. Local carbonate dykes.	Abundant ammonoids, nautiloids and gastropods at southwestern localities; abundance of cephalopods decreases northeastward. Abundant calcareous algae and peloids; sponges, sponge spicules, ostracodes and foraminifers are locally common.	Forms cores of mounds in middle to upper Wileman Member of east-central B.C.; locally present in northwestern Willmore Park. Overlies lithofacies 1 and 2, basal contacts of mounds commonly erosional. Mounds are conformably overlain by lithofacies 1 and less commonly lithofacies 2. Flank facies mainly lithofacies 1 and 2 but locally 4.	Deposited in shallow-neritic (< 15 m) to intertidal relatively high-energy (moderate wave or current action) to low-energy, protected-shelf environments on a carbonate platform. Episodes of subaerial exposure. Mound growth initiated by transgression and terminated by regression accompanied by terrigenous influx. Mounds show growth stages slowed or terminated by terrigenous influx. Occurs in high-order T–R sequences.	Cavities lined with isopachous, inclusion-rich, marine-phreatic calcite cement overlain by internal sediment and/or clear equant to bladed mosaics of meteoric-phreatic to deeper subsurface origin. Recrystallized microspar also present as isopachous marine cement. Selectively silicified molluscs.
(7) Laminated dolostone	Slightly silty and argillaceous finely crystalline dolostone; lenses of intraclast breccia (dolopackstone to grainstone). Medium to light olive grey.	Medium to thick bedded. Shows abundant planar to wavy laminae and less commonly dome-shaped stromatolites. Small-scale crossbedding and mud cracks are evident locally.	Sparsely fossiliferous (no megascopic fossils observed); intraclasts of finely crystalline dolostone common. Associated relict lenses of dolomitic limestone contain peloids, sponge spicules and indeterminate bioclasts.	Widely preserved in Willmore Park (proportion increases eastward) but is not extensively developed in east-central B.C.. Interbedded with shale and marlstone of lithofacies 1 and carbonates of lithofacies 1, 3 and 5.	Deposited in shallow-subtidal to intertidal and supratidal environments on the restricted shelf of a carbonate platform. Represents part of regressive systems tract of Turner Valley/Wileman T–R sequence.	Dolomite may be partly of syndepositional hypersaline origin. Presence of relict limestone lenses indicates extensive post-depositional dolomitization of limestone of lithofacies 1.
(8) Grainstone	Skeletal dolograinstone and subordinate lime grainstone. Light olive grey.	Medium to thick bedded. Bases of units commonly erosional. Beds commonly show medium to moderately large-scale crossbedding.	Main allochems in dolostone are pelmatozoan ossicles; those in limestone are pelmatozoan ossicles, foraminifers, peloids and brachiopods.	A minor facies preserved mainly in the lower Wileman of northwestern Willmore Park. Generally overlies and underlies lithofacies 1 and 2.	Deposited in shallow-neritic peritidal environments on a carbonate platform during minor high-order transgressions. Represents part of regressive systems tract of Turner Valley/Wileman T–R sequence.	Early selective silicification of bioclasts. Dolostone records late (post-Wileman) dolomitization of lime grainstone. Meteoric-phreatic calcite cement in lime grainstone.

100 cm). Individual beds generally have subplanar to broadly undulatory boundaries and commonly extend across outcrop faces. Beds of the lithofacies are, however, locally truncated by erosion surfaces of large-scale paleochannels and occur within the channel fills. Lithofacies 1 is generally rhythmically interbedded with shale and marlstone (lithofacies 2). Beds of lithofacies 1 abruptly overlie beds and laminae of lithofacies 2 and grade upward into the latter. Lithofacies 1 also commonly overlies and grades into beds of the skeletal floatstone lithofacies. Less commonly, lithofaces 1 is abruptly overlain by microbial boundstone (lithofacies 6). It also grades laterally into lithofacies 6 at the margins of the mounds. Lithofacies 1 passes eastward to southeastward into the massive dolostone lithofacies, which is the predominant lithofacies in the lower member of Willmore Wilderness Park.

Beds of lithofacies 1 are slightly argillaceous and become more argillaceous and less resistant upward. Most beds are also variably dolomitic and locally grade into calcareous dolostone. The beds commonly show a crude upward fining and tend to be platy weathering in their upper parts. Most beds are strongly bioturbated; primary sedimentary structures and identifiable trace fossils are generally absent. A few beds contain small-scale crossbedding, wavy to subplanar laminae, and domal stromatolites. Diagenetic chert, occurring as a selective replacement of fossils and as irregular to smooth nodules, is present in some beds but is generally not a major constituent. The most common identifiable trace fossil is *Zoophycos* sp. Terrestrial plant fossils (mainly leaves and stems of lycopods) are common and tend to become more common upward within beds. Scattered and generally fragmented pelmatozoans, gastropods, and brachiopods are present.

Three microfacies, named after their main constituent allochems, constitute most of the lithofacies: I) the spicule microfacies, II) the peloid–algal microfacies, and III) the mixed-skeletal microfacies. In the mixed-skeletal microfacies, the allochems include: corals, pelmatozoan ossicles, sponge spicules, foraminifers, calcareous algae, brachiopods, ostracodes, and peloids. The peloid–algal microfacies predominates in most occurrences of lithofacies 1 at Ochak Mountain and elsewhere in the Monkman Pass map area, but its importance decreases basinward as that of the mixed-skeletal microfacies increases. The mixed-skeletal microfacies is commonly preserved in the upper 13 m of the lower member at the Ochak Mountain section. Within individual beds, the mixed-skeletal microfacies tends to grade upward into either the spicule microfacies or the peloid–algal microfacies.

Lithofacies 2: shale and marlstone

Lithofacies 2 comprises mudstone and marlstone with subordinate shale and minor coal. This lithofacies is volumetrically the second most important lithofacies at Ochak Mountain (Fig. 3) and in most of the Monkman Pass map area. The deposits are grayish black to brownish black in the Ochak Mountain section and throughout the Monkman Pass map area. In Willmore Wilderness Park, greenish grey to light olive-grey deposits predominate. In the Monkman Pass map area, the beds are commonly darkest and most carbonaceous near their bases and tops and grade into medial light olive-grey deposits. The marlstones are typically platy weathering and grade into shale and mudstone of lithofacies 2 and into limestone and dolostone of lithofacies 1 and 3. Thin coal seams are preserved locally; abundant coal lenses are also present in the Monkman Pass region and are locally present to the south. Lithofaces 2 is recessive and commonly covered, and many beds were dug out at the Ochak Mountain and other sections.

Lithofacies 2 occurs as laminae and beds up to several metres thick, but most beds are between 5 and 50 cm thick. The beds and laminae generally have good lateral continuity and extend across outcrop faces. This lithofacies is locally truncated by the erosion surfaces of large-scale paleochannels and occurs within the fill sequences of the channels.

Beds of lithofacies 2 are generally rhythmically interbedded with carbonates of lithofacies 1 and 3. Beds of the shale and marlstone lithofacies have subplanar sharp to gradational bases, whereas their tops are generally slightly undulatory and erosional. Beds of lithofacies 2 are commonly truncated below the bases of the microbial mounds (lithofacies 6) and abruptly to gradationally overlie some mounds. Tongues of lithofacies 2 locally extend into the marginal deposits of the mounds. There, they are truncated toward the mound cores below beds of the microbial boundstone lithofacies.

In the Ochak Mountain region, the dark-coloured deposits of lithofacies 2 contain abundant lycopod remains, including some small stumps that are in growth position and up to 12 cm in diameter. Plants are not common in the light-coloured shale and mudstone that predominate in Willmore Wilderness Park and in the middle of some thicker beds of this lithofacies in the Monkman Pass map area. Scattered brachiopods, bryozoans, solitary rugose corals and other macrofossils are commonly preserved in occurrences of platy marlstone that are interbedded with lithofacies 1 and the skeletal-floatstone lithofacies.

Lithofacies 3: massive dolostone

Lithofacies 3 comprises well bedded, sparsely fossiliferous, finely to medium crystalline dolostone. The dolostone is medium grey to light olive-grey and weathers yellowish grey. Deposits of the lithofacies are relatively recessive but commonly form low cliffs. Lithofacies 3 is the predominant lithofacies in the lower member of Willmore Wilderness Park; there, it becomes more abundant eastward. In the Ochak Mountain section and elsewhere in the Monkman Pass map area, it is a minor lithofacies occurring mainly in the upper part of the lower member.

Most of lithofacies 3 is medium bedded. The beds have good lateral continuity and are commonly rhythmically interbedded with shale and marlstone of lithofacies 2. Bases of the dolostone beds are generally sharp and subplanar; their tops are gradational with overlying deposits of lithofacies 2 and range from planar to undulatory. Individal beds are mainly massive and strongly bioturbated but locally show diffuse internal laminae. Lithofacies 3 is also commonly closely associated with lime wackestone of lithofacies 1 and grades into the latter. In Willmore Wilderness Park, lithofacies 3 is interbedded with the fenestral cryptalgal boundstone lithofacies and the laminated dolostone lithofacies.

Lithofacies 3 lacks abundant macrofossils; scattered pelmatozoan ossicles, brachiopods, and corals occur locally and were selectively silicified in some beds. Poorly preserved peloids, pisoliths, and aggregate grains comprising peloids are evident in thin sections. Terrestrial plant fossils (stems and leaves) are common at Ochak Mountain; small rhizoliths are also present. Minor quartz silt (< 2 per cent by volume) is generally present. Most of lithofacies 3 resulted from dolomitization of lithofacies 1, as indicated by the allochems and spatial relations.

Lithofacies 4: skeletal lime floatstone

Lithofacies 4 is characterized by abundant solitary and colonial corals, brachiopods and pelmatozoan ossicles set in a matrix of lime wackestone and packstone. This medium to dark grey, strongly bioturbated lithofacies resembles the fine grained lime wackestone lithofacies except for the presence of the solitary and colonial rugose and tabulate corals. Lithofacies 4 is a volumetrically minor lithofacies in most of the lower member at Ochak Mountain but is locally well developed. This lithofacies is also a minor component of the Willmore Wilderness sections. Lithofacies 4 is best developed in the Mount Becker and Becker Creek sections (Fig. 1, loc. 12, 21); there, it is one of the main lithofacies.

Lithofacies 4 is mainly medium bedded but ranges from medium to thick bedded. The beds generally have good lateral continuity but are truncated by large-scale paleochannels at some localities. At Ochak Mountain, lithofacies 4 is commonly present in the upper part of the lower member but is particularly well developed in the middle part of the member on the southeast flank of the ammonoid-bearing microbial mound shown in Figure 3. There, lithofacies 4 occurs as a cliff-forming unit that is 2 to 3 m thick and comprises floatstone dominated by large, selectively silicified, solitary rugose corals. According to E.W. Bamber (pers. comm., 1997) the corals are mainly representatives of *Vesiculcophyllum* Easton. Those coral-rich deposits pass abruptly into a debris apron of cephalopod-bearing lime floatstone (also lithofacies 4) that in turn abuts against lime boundstone (lithofacies 6) of the adjacent mound. In the Mount Becker section, lithofacies 4 is the principal deposit in a large paleochannel fill. Beds of lithofacies 4 are generally rhythmically interbedded with shale and marlstone of lithofacies 2 and commonly grade into wackestone of lithofacies 1. Lithofacies 4 generally overlies beds and laminae of lithofacies 2 abruptly and grades upward into the latter.

Deposits of lithofacies 4 contain minor to abundant chert as nodules, irregular masses, and selectively silicified body fossils. The main microfacies in the lithofacies is mixed-skeletal lime wackestone, which closely resembles the microfacies of the same name in lithofacies 1.

Lithofacies 5: fenestral cryptalgal boundstone

Lithofacies 5 comprises dolomitized fenestral cryptalgal boundstone and minor lime boundstone. The deposits are light to medium grey and weather yellowish grey. Lithofacies 5 is widely developed in Willmore Wilderness Park but constitutes less than 15 per cent of the sections measured. In the Monkman Pass area, it is not developed in most sections.

Most beds of this thin to medium bedded lithofacies have subplanar boundaries and show internal laminae. Outcrops are moderately resistant, forming low cliffs. Lithofacies 5 is interbedded with carbonates of lithofaces 2 and 3 and greenish grey shale of lithofacies 2. The dolomitized deposits are finely crystalline and contain poorly preserved peloids and aggregate grains; scattered gastropods are present in some beds. Abundant calcispheres, other calcareous algae and peloids are preserved in the limestone. The fenestrae are locally open, but most are filled with coarsely crystalline blocky dolomite. Many beds have grainstone fabrics resulting from numerous stages of wetting and drying (grainification).

Lithofacies 6: microbial boundstone

Lithofacies 6 comprises mounds of medium dark grey to light olive-grey lime boundstone containing numerous stromatactis structures and smaller fenestrae filled with internal sediment and sparry calcite cement (Fig. 3, 6). Fragmented to relatively well preserved ammonoids, nautiloids, and gastropods are generally present throughout these thick to very thick bedded (> 100 cm) deposits. The mounds are either isolated or occur as complexes of small, coaesced mounds. The thickness of the isolated mounds varies between 2 and 8 m, and they are substantially wider than thick. The complexes are generally less than 10 m thick and extend several tens of metres along strike. The mounds are most abundant and largest in the westernmost occurrences of the lower member in the central part of Monkman Pass map area. The mounds are developed in the middle to upper parts of the member and occur at two or more stratigraphic levels at some localities. At eastern occurrences of the lower Mount Head Formation, beds of cephalopod-rich carbonates resembling those of the mounds are common but generally do not form mounds.

A single, well exposed mound on the eastern side of Ochack Mountain (Fig. 3, 6, 7) was extensively studied for this project and forms the basis for the description of lithofacies 6. The mound attains a maximum known thickness of 5.5 m and is exposed for 44.2 m along the face of the outcrop. It constitutes the northwestern part of a complex of small, closely spaced to coalesced mounds that extends many metres along the face of the outcrop. Several other mounds are exposed at other localities on the eastern side of the mountain but were not examined in as much detail.

The mounds comprise a resistant core facies encased by flanking and capping deposits of the intermound lithofacies association. The core deposits are very resistant relative to surrounding lithofacies and erode out to form low cliffs and hummocks on ledges. The foundations of the mounds are broadly undulatory, concave erosion surfaces that truncate from less than one to several metres of underlying strata in the lower Mount Head Formation. For several metres below the mound illustrated in Figures 3 and 6, the strata have been warped gently downward by postdepositional compaction. In the Ochak Mountain region, the underlying deposits comprise lime wackestone (lithofacies 1) intercalated with shale and marlstone of lithofacies 2. At the Kvass Creek section, a mound abruptly overlies lithofacies 5. Strata in the lower parts of the core facies onlap the basal erosion surfaces. Beds in the middle to upper parts of the core thin toward the core margin; there, they grade laterally into the flanking deposits, which are dominated by lithofacies 1 but include lithofacies 2 and 4. The flanking deposits generally contrast with the core lithofacies by being more argillaceous and lacking the abundant molluscs and stromatactis structures.

The upper surfaces of the cores are slightly to distinctly convex and are conformably overlain by capping lithofacies. At Ochak Mountain, the latter comprise lime wackestone of lithofacies 1 and marlstone to plant-rich shale of lithofacies 2. In the Kvass Creek section, the core of a mound is conformably overlain by silty, finely crystalline dolostone of lithofacies 3 interbedded with greenish grey shale and marlstone of lithofacies 2.

The mounds at Ochak Mountain and most other localities have minor topographic relief. Slopes on the upper sides of their cores are mainly less than 5°, and evidence for substantial dips in the flanking beds is also absent. The flanking beds generally thin slightly away from the cores, as do the beds in the deposits capping the mound tops. The core facies on the southeast side of the mound shown in Figures 3 and 6 terminates abruptly against a debris apron of cephalopod-bearing lime floatstone (lithofacies 4) showing diffuse clinoforms dipping at low angles away from the mound. However, the flanking deposits of most mounds lack conspicuous breccias and other deposits shed from the cores. In contrast, some of the large mounds at locality 10 have substantial topographic relief, cores with steep (almost vertical) upper slopes, and steeply inclined flanking beds (lithofacies 4 and 1) that fine away from the core facies.

Most of the core facies is made up of limestone that has the texture of microbial boundstone and contains numerous cavities filled with sparry calcite cement and internal sediment. The sediment encasing the spar cement is matrix-rich but contains enough allochems to produce a wackestone or packstone texture. In outcrop, the core facies appears massive; in thin sections and polished slabs it shows crude undulatory laminae resembling those of thrombolites. The crude laminae locally form indistinct convex-upward structures resembling small, dome-shaped stromatolites. Wave and current-formed sedimentary structures and well-defined concentric laminae, like those of stromatolites, are absent. Trace fossils are rare and evidence for extensive bioturbation is absent.

The former cavities in the core facies include relatively large (mainly between 10 and 60 mm long) structures that closely resemble features called stromatactis structure by Bathurst (1980), Pratt (1982), Bourque and Gignac (1983), and Flajas and Hussner (1993). The stromatactis structures of lithofacies 6 have digitate, convex upper margins and subplanar to gently undulatory lower surfaces. These former voids are commonly lined with one or more generations of cloudy (inclusion rich) isopachous radial-fibrous calcite cement overlain by a later, bladed to blocky calcite mosaic and subordinate megaquartz. The stromatactis structures grade into numerous smaller elongate to irregular fenestrae that are interconnected to form a crude reticulate network. They also pass locally into elongate vugs up to 25 cm long and lined with white botryoidal calcite. The isopachous cements are commonly thicker and better developed on the roofs of both the stromatactis structures and the smaller fenestrae. On the floors, the cements are commonly intercalated with thin, dark, micritic laminae and layers of internal sediment. Many of the stromatactis structures are partly to completely filled with lime mud containing abundant articulated to disarticulated ostracodes. Others contain internal sediment dominated by peloids. The cement- and sediment-filled cavities lack any obvious skeletal supporting structures.

Many of the smaller fenestrae in lithofacies 6 resemble the large stromatactis structures described above by having smooth floors, digitate tops, internal sediment and one or more generations of isopachous cements. Others differ by having digitate floors and tops. The networks of smaller fenestrae in the mound at Ochak Mountain commonly resemble reticulate patterns resulting from dissolution or replacement of spicules and infilling of canals in some Paleozoic demosponges (see Bourque and Gignac, 1983; Beresi and Rigby, 1993). Therefore, some of the networks probably represent poorly preserved sponges. Support for the latter interpretation is provided by the association of well preserved sponge spicules with some networks. The reticulate structure of lithofacies 6 also closely resembles spar-filled fenestrae developed in fenestral cryptalgal laminites and thrombolitic lime boundstones described by Aitken (1967), Pratt and James (1982), Aitken and Narbonne (1989), Clough and Blodget (1989), and many others. Reticulate thrombolite frameworks develop when patchy algal mats expand or are constrained during upward accretion causing branching and anastomosis (Pratt, 1982). The reticulate structure of the Mount Head Formation mounds is also similar to that occurring in large, crudely laminated, columnar, modern Bahamian stromatolites described by Riding et al. (1991).

Spongioform microstructure of Pratt (1982) is commonly well developed in the core facies. The microstructure is characterized by clotted masses of peloids and calcispheres separated by interparticle and tiny fenestral pores. This microstructure is considered by Pratt (1982) to be characteristic of microbial-bound sediment in laminated stromatolites or in thrombolites.

The matrix-rich carbonate sediment that encases the cement- and sediment-filled fenestrae and stromatactis structures in lithofacies 6 contains a diverse array of allochems, but the dominant allochems in most samples are algae, particularly *Calcisphaera* spp. Calcispheres closely resemble the reproductive cysts of the modern dasycladacian *Acetabularia* and have, therefore, been considered to be calcified reproductive bodies of dasycladacian algae (Marszalek, 1975; Wray, 1977). In addition to calcispheres, thalli of several other algae are common. The associated fauna is dominated by ammonoids, nautiloids, and gastropods but also includes pelecypods, trilobites, and small foraminifers. The molluscs vary from fragmentary to almost complete and are commonly silicified, thereby permitting extraction by acid etching. Sponge spicules are scattered in most samples and generally constitute a minor proportion of the allochems. However, in parts of lithofacies 6 spicules predominate. Arrays of in situ occular megasclers are locally present. In contrast to flanking and overlying lithofacies, terrestrial plant remains are rare to absent.

All of the ammonoids extracted from the microbial mounds in the vicinity of Ochak Mountain lack a living chamber, and living chambers are preserved on only a small proportion of the nautiloids. The incomplete to fragmentary nature of the majority of the cephalopods (see Fig. 1) indicates postmortem reworking by waves and currents. Reworking is also indicated by the presence of fragmentary cephalopods in a debris apron (lithofacies 4) on the southeast end of the mound shown in Figures 3 and 6.

Lithofacies 6 is interpreted as a microbial boundstone resulting largely from passive binding of invertebrates (particularly sponges and molluscs) and locally derived sediment by microbial mats (algae and cyanobacteria) and from the calcium-carbonate-precipitating activities of the latter. This interpretation is based on the striking similarity of the deposits to crudely laminated Bahamian stromatolites described by Riding et al. (1991), and to thrombolites. In addition, the lithofacies strongly resembles microbial buildups described from the Lower Carboniferous by Adams (1984), Webb (1987), Brunton and Mundy (1988), Pickard (1992) and others. Deposits of the lithofacies locally show laminae and are, therefore, in part stromatolitic. Most of the lithofacies lacks well defined laminae, has a reticulate internal framework and is considered thrombolitic. Thrombolites, however, typically have a branching structure and occur as discrete heads (Pratt and James, 1982, 1989). Neither of the latter features were observed in the Mount Head mounds. Sponges clearly contributed to the development of the mound at Ochak Mountain, but additional work is required to determine their role.

The origins of the stromatactis structure and related fenestrae in the microbial boundstone lithofacies appear to be related in part to processes responsible for formation of voids in peritidal cryptalgal laminites and stromatolites. According to Pratt (1982), fenestrae in unlithified sediment can form by several mechanisms: gas escape, burrowing, decay of organic material, and desiccation shrinkage. Laminoid fenestral fabric is characteristic of supratidal, intertidal, and shallow-subtidal cryptalgal deposits and, in most cases, is interpreted as having formed by the bridging of voids by algal mats or by decay of microbial material (Tebbut et al., 1965; Shinn, 1968; Logan, 1974; Pratt, 1982; Monty, 1976). In modern subtidal Bahamian stromatolites, voids that closely resemble the stromatactis structure in lithofacies 6 are developed a short distance below the living microbial surficial layers. Presumably, the recent voids resulted from decay of algae and cyanobacteria combined with the burrowing and boring activities of worms and other invertebrates (see Riding et al., 1991). The resemblance of the stromatactis structure and smaller fenestrae in the Mount

Head Formation mounds to fenestrae of cryptalgal origin is strongly suggestive of an origin related to sediment binding by microbial mats. The voids probably developed near the sediment–water interface, because many contain internal sediment in which articulated ostracodes are preserved.

Stromatactis can also result from early marine cementation of growth cavities in sponges and by the decay of uncemented sponge tissue (Bourque and Gignac, 1983; Beauchamp, 1989). In mounds of the basal Mount Head Formation, the local presence of abundant spicules and common occurrence of reticular networks of small fenestrae representing poorly preserved sponges indicate that some of the stromatactis structures resulted from the cementation and decay of sponges.

The isopachous nature of the first-generation calcite cement and its relation to fossiliferous internal sediment indicates syndepositional precipitation in the marine phreatic zone. An early marine origin for similar cements has been proven by numerous authors including Davies (1977) and Davies et al. (1989). Overlying coarse to very coarsely crystalline bladed to equant blocky mosaics are characteristic of later cements precipitated from meteoric–phreatic or subsurface connate solutions.

The microbial mounds in the lower member resemble Lower Carboniferous Waulsortian mounds in that they contain stromatactis structure and abundant syndepositional marine cement, have a high proportion of lime mud, and are characterized by the paucity of skeletal frame-building fossils. Like Waulsortian mounds, the larger microbial mounds commonly comprise a massive core facies flanked by thinner bedded, coarse grained debris aprons. The Mount Head mounds differ in lacking the abundant bryozoans and pelmatozoans of Waulsortian mounds. Furthermore, mounds in the lower Mount Head Formation are small structures that comprise deposits resulting from trapping and binding of sediment by shallow-subtidal microbial mats. Numerous Waulsortian mounds achieved topographic relief of many metres, grew to large dimensions, developed mainly in relatively deep water (aphotic, partly at depths below 300 m), and display four stages of depth-related growth (Lees, 1982; Smith, 1982; Lees and Miller, 1985).

Lithofacies 7: laminated dolostone

Lithofacies 7 comprises beds of finely crystalline dolostone containing planar to wavy laminae and, less commonly, dome-shaped stromatolites. Small-scale crossbedding and mud cracks are evident locally. This medium grey to light olive-grey lithofacies is widely preserved in Willmore Wilderness Park but is not extensively developed in the Monkman Pass map area. Lithofacies 7 is interbedded with shale and marlstone of lithofacies 2 and carbonates of lithofacies 1, 3 and 5. Lithofacies 7 is medium to thick bedded, moderately recessive, and platy weathering. Lenses of intraclast breccia resulting from syndepositional disruption of laminae are commonly intercalated with the laminated deposits. Megascopic fossils are lacking, and most beds are slightly silty and argillaceous. In the Kvass Creek section (Fig. 1, loc. 4), some occurrences of the lithofacies show relict lenses of dolomitic, algal–peloid lime wackestone containing indeterminate bioclasts and sponge spicules.

Lithofacies 8: grainstone

Lithofacies 8 comprises medium to thick bedded, light olive-grey dolograinstone and subordinate lime grainstone. This minor lithofacies, which is mainly preserved in the basal part of the lower member, was not observed at Ochak Mountain. It is best developed in the lower member at the Kvass Creek and Mount Meosin localities (Fig. 1, loc. 4, 8), where it forms fining-upward units that commonly show medium- to moderately large-scale crossbedding. The deposits commonly overlie deep scours and appear to represent channel fills and transgressive lags. Occurrences of lithofacies 8 generally overlie shale and marlstone of lithofacies 2 and laminated to massive dolostones of lithofacies 3 and 7. They are, in turn, overlain by fine-grained deposits of lithofacies 1 and 3. The limestones are peloidal mixed-skeletal grainstone in which the main allochems are pelmatozoan ossicles, endothyrid foraminifers, peloids, and brachiopods.

ENVIRONMENTAL INTERPRETATIONS

Carbonate ramp and platform models

The Lower Carboniferous carbonate-dominated strata of the Western Canada Sedimentary Basin (WCSB) were deposited on carbonate ramps and poorly differentiated carbonate platforms (Fig. 9). Following Richards et al. (1993, 1994), the concept of a carbonate ramp used here is basically that of Wilson (1975), who derived his model largely from that of Ahr (1973). Ahr considered a ramp to be a two-dimensional surface, whereas Wilson interpreted it as a body of carbonate strata. Carbonate ramps are large buildups that prograde away from positive areas and down gentle regional slopes. Ramps lack an obvious break in slope, and lithofacies on them occur as wide, irregular belts with the highest energy deposits close to the main shoreline. The Carboniferous ramp model used by Richards et al. (1993, 1994) resembles the homoclinal ramp of Read (1982); however, Read considered a ramp to be a type of platform and a two-dimensional surface.

Carbonate platforms are large buildups that have a more or less horizontal top (shelf) and relatively abrupt shelf margins, where sediment deposited in high-energy environments occurs (Wilson, 1975). On platforms, the shelf margin is separated from the main shoreline by a broad, relatively low-energy, protected-shelf environment, where carbonates are deposited in the neritic and intertidal zones. This model is similar to the rimmed carbonate shelf model of Read (1982). In the WCSB, the carbonate platforms of Early Carboniferous time had depositional shelf margins dominated by broad, shallow-water sand belts; shelf-margin reefs are lacking (Richards, 1989a; Richards et al., 1993).

Lithofacies of the lower Mount Head Formation have been interpreted as platform deposits formed in restricted-shelf and protected-shelf settings (Richards, 1989a; Sando et al., 1990; Richards et al., 1993). In southeastern British Columbia and southwestern Alberta, peritidal shelf lithofacies of the Wileman Member grade basinward into shelf-margin grainstone of the Livingstone Formation, thereby indicating deposition on a rimmed platform. In the study area, however, deposition on a rimmed platform cannot be proven for the basal Mount Head Formation because the evidence was removed by regional, post-Early Carboniferous erosion. At the localities preserving the most basinward (southwestward) Carboniferous successions in the area, the Mount Head's lower member comprises peritidal lithofacies, rather than those characteristic of the shelf-margin grainstone belt. At Ochak Mountain, the lower member contains a substantially higher proportion of fine-grained terrigenous clastics than do occurrences to the south. At times of high terrigenous influx, ramps tend to develop rather than platforms; therefore, the potential for ramp development was greater at Ochak Mountain than to the southeast.

Environments of deposition of lithofacies in the lower member

In the lower member of the Mount Head Formation from southwestern Alberta into east-central British Columbia, deposition in restricted-shelf settings (lagoons to supratidal flats) and low-energy, protected-shelf environments (Fig. 9) is recorded by the presence of evaporites and related solution-collapse breccias, nodules pseudomorphic after

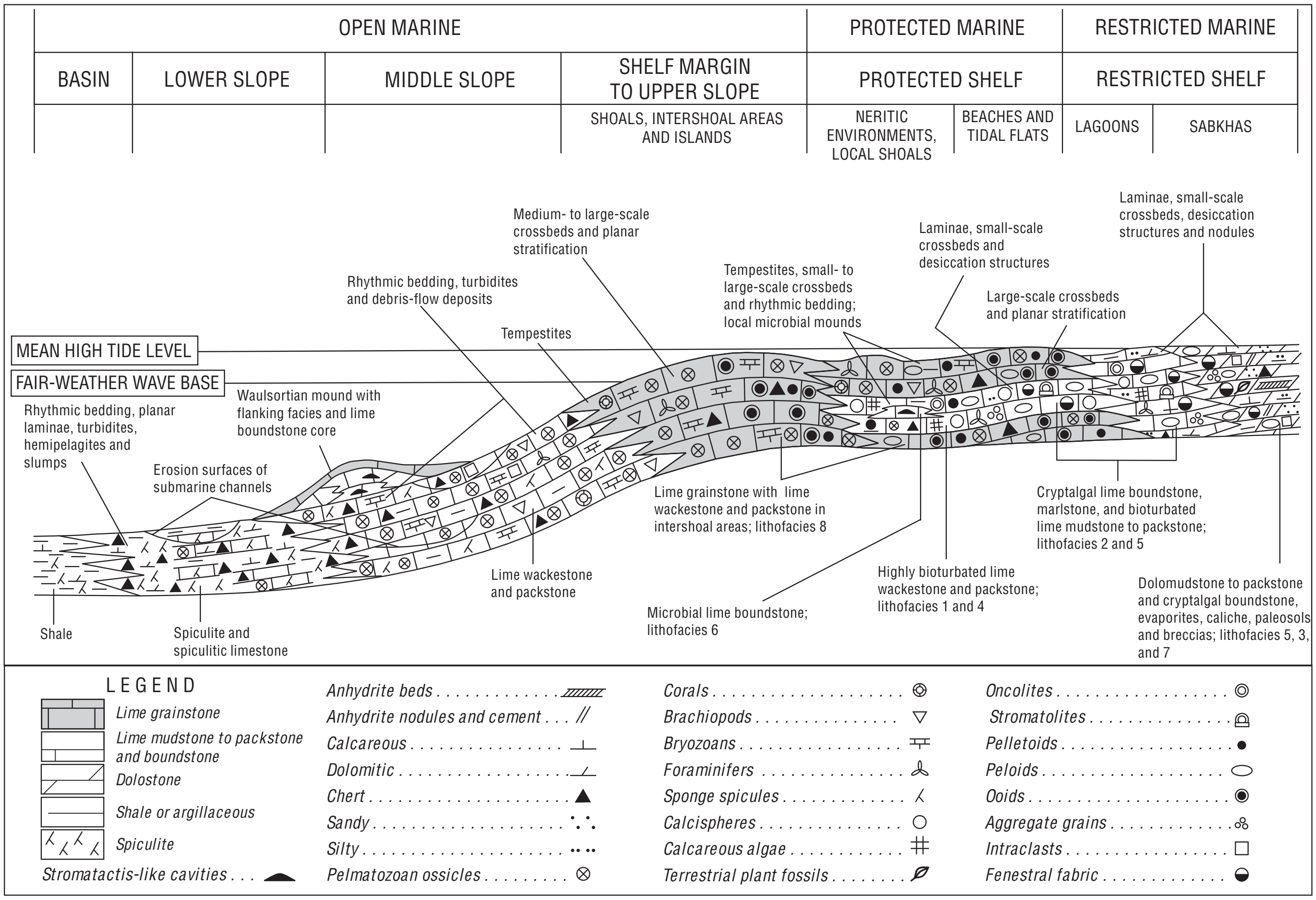


Figure 9. *Depositional model of a Carboniferous carbonate platform with a shelf rimmed by carbonate sands (modified from Richards et al., 1994). Model shows relations of lithofacies discussed in text to principal environments.*

anhydrite, and an impoverished biota dominated by algae. Such deposition is also indicated by the abundant structures and fabrics (stromatolites and fenestral fabrics) indicative of subaerial exposure and very shallow water, and by the predominance of matrix-rich carbonates lacking large-scale crossbedding and other high-energy indicators (Macqueen and Bamber, 1968; Richards, 1989a; Richards et al., 1993). In the study area, evaporites and related breccias are absent; nevertheless, the lower member is dominated by deposits and fossils indicative of deposition in low-energy-peritidal to shallow-subtidal settings (Fig. 3).

Intermound lithofacies association, lithofacies 1 to 5, 7 and 8

Lithofacies 1 of the lower member in the study area records deposition in environments intermediate between those of the skeletal lime floatstone lithofacies (lithofacies 4) and the other facies. It represents shallow-subtidal to intertidal mudflat environments (Fig. 9). Such an origin is indicated by the presence of abundant terrestrial plant fossils, a shallow-marine biota dominated by algae and foraminifers, the strongly bioturbated, matrix-rich nature of the deposits, and the close spatial relationship of this facies to peritidal deposits of lithofacies 2 and 5. The deposits of lithofacies 1 are locally stromatolitic and grade into laminated dolostone of lithofacies 7. Structures and fabrics indicative of subaerial exposure are absent, but the close association between deposits of lithofacies 1 and those of the shale and marlstone and the fenestral cryptalgal boundstone lithofacies indicates peritidal sedimentation. The predominance of calcispheres (probable dasycladaceans) in much of lithofacies 1 supports the interpretation of deposition in a shallow-water, low-energy setting. In modern carbonate environments, dasaycladaceans are characteristic of water depths of 10 m or less in restricted-marine bays and lagoons (Flugel, 1982, p. 333). In the Lower Carboniferous of the WCSB, calcispheres are most abundant in restricted-marine carbonates and low-energy, peritidal deposits of the protected shelf (Richards et al., 1993, fig. 4E4, 4E5).

The environment in which the lime wackestone of lithofacies 1 was deposited probably resembled that in the most sheltered subtidal positions on the lee side of Andros Island in the Bahamas. There, the main deposits formed at water depths of less than 6 m and consist of aragonite muds containing abundant dasycladacians and a sparse fauna including locally conspicuous gastropods. Current- and wave-formed crossbedding is rare in this setting on Andros, but evidence for bioturbation is common (Bathurst, 1971, p. 136).

In the study area, lithofacies 2, 5, 7 and unfossiliferous deposits of the massive dolostone lithofacies (lithofacies 3) represent the most landward paleoenvironments (Fig. 9). In the shale and marlstone of lithofacies 2, the presence of coal and abundant lycopod fossils, including some stumps in growth position, indicate the development of coastal marshes or lacustrine environments above the shallow-subtidal to intertidal deposits of other lithofacies (particularly lithofacies 1) in the lower member. Lithofacies 5 was deposited in supratidal to high-intertidal restricted-shelf settings. Fenestral fabric like that of lithofacies 5 results mainly from syndepositional diagenetic alteration of typically micritic sediments on periodically exposed peritidal flats in supratidal and, less commonly, intertidal settings (Fischer, 1964; Tebbut et al., 1965; Shinn, 1968; Mazzullo and Birdwell, 1989). The presence of stromatolites, lack of marine body fossils, and the close association with beds of lithofacies 1 comprising peloid–foraminifer–algal wackestone indicate that the laminated dolostone of lithofacies 7 represents deposition in shallow-subtidal to intertidal and supratidal settings. The massive dolostone of lithofacies 3 is the predominant deposit at the most landward occurrences of the lower member and represents several paleoenvironments. The silty deposits of this facies that lack body fossils and are interbedded with lithofacies 5 are probably largely of supratidal origin. Fossiliferous occurrences of lithofacies 3 are dolomitized equivalents of lithofacies 1 and represent a slightly deeper setting.

In the lower member, lithofacies 4 and 8 have the most open-marine aspect. Most occurrences of lithofacies 4 (lime floatstone) were deposited in relatively open-marine but low-energy protected shelf settings as indicated by the predominance of open-marine bioclasts (abundant corals, pelmatozoan ossicles, brachiopods and bryozoans) in strongly bioturbated, matrix-rich sediment lacking evidence for subaerial exposure. The debris aprons flanking some of the larger microbial mounds probably represent slightly higher energy subtidal conditions because they grade into grainstone and contain debris eroded from adjacent core facies. Grainstone of lithofacies 8 is also dominated by open-marine bioclasts, but its occurrence in channel fills and its spatial relation to other Mount Head Formation lithofacies suggests deposition in peritidal settings during minor transgressions.

Mound facies, lithofacies 6

The microbial boundstone of lithofacies 6 was deposited as mounds in a shallow-subtidal, low-energy, protected-shelf setting (Fig. 9). At Ochak Mountain, deposition in shallow water (depths of less than 15 m) is indicated by several criteria. Calcispheres are ubiquitous in the lithofacies. Modern dasycladacians tend to be most abundant in the shallow water of restricted-marine bays and lagoons. A shallow-water origin is also indicated by the lithofacies relationships of the deposits (enclosed mainly by lithofacies

1 and 2). Deposition mainly in shallow-subtidal instead of intertidal to supratidal settings is indicated by the predominance of isopachous marine calcite as the earliest cement in the stromatactis structures. The presence of cement on all surfaces of the cavities indicates that they were filled with water; early cementation took place principally in the marine phreatic zone instead of in the marine vadose zone. In marginal deposits of the core facies at Ochak Mountain, some beds of lithofacies 6 are abruptly overlain by shale containing abundant terrestrial plant fossils. The presence of the latter suggests episodes of subaerial exposure. In other parts of the world, Carboniferous microbial mounds resembling those of the Mount Head Formation lower member formed mainly in shallow-subtidal settings, but some show evidence for periods of subaerial exposure (Webb, 1987; Adams, 1984; Pickard, 1992).

Deposition in low-energy environments is recorded by the matrix-rich nature of the mound deposits in the basal Mount Head and by the lack of wave- and current-formed structures. However, the presence of the debris apron (lithofacies 4) on the southeast side of the mound studied in detail at Ochak Mountain (Fig. 3, 6) indicates moderate wave and current activity on parts of some mounds. The setting was somewhat restricted, as is indicated by the relatively impoverished fauna of the core facies, and is interpreted as having been similar to that occurring on the leeward side of Andros Island. It was not hypersaline, however, because cephalopods are common in the mounds and some of the flank facies contain abundant corals.

Mound growth was initiated by minor transgressions. In the Ochak Mountain section, this is recorded by the presence of the microbial boundstone lithofacies above plant-bearing black shale that drapes an erosion surface developed on lithofacies 1 and 2. The flanking facies on the northwest side of the Ochak mound consists of lime wackestone of lithofacies 1 intercalated with shale and marlstone (lithofacies 2), thereby indicating that substantial depths were not attained during the transgression. The presence of coral floatstone (lithofacies 4) on the southeast side of the mound indicates that greatest water depths were established on that side.

The mound at Ochak Mountain records two or more growth stages, each slowed or terminated by terrigenous influx. Each subsequent growth stage was stimulated by minor transgressions. In the marginal deposits of the core, transgression is indicated by the presence of microbial boundstone over black shale. In the correlative flanking beds, the transgressions are recorded by the presence of lithofacies 1 and 4 above plant-bearing beds of lithofacies 2. The final stage of mound development at Ochak Mountain was terminated by a terrigenous influx accompanied by regression, as is indicated by the presence of 1.07 m of lithofacies 1 grading upward into black, coal-bearing shale.

SEQUENCE STRATIGRAPHY

Sequence stratigraphic analysis has become an important standard procedure since the development of the depositional sequence concept by Vail et al. (1977) and its refinement by Van Wagoner et al. (1988), Posamentier et al. (1988), Posamentier and Vail (1988) and Sarg (1988). Several types of sequences have been defined, including: tectono-stratigraphic sequences (Sloss, 1963; 1964), depositional sequences (Vail et al., 1977), genetic stratigraphic sequences (Galloway, 1989), and transgressive–regressive sequences (T–R sequences) which are commonly called T–R cycles (e.g., Johnson et al., 1985). Of these four types, the depositional sequence is probably most widely utilized, although the T–R sequence model has recently been strongly promoted by Embry and Johannessen (1992), Embry (1993) and others.

The Lower Carboniferous succession in the study area is discussed in terms of T–R sequences because the stratigraphy and depositional history of the Lower Carboniferous in the WCSB has been discussed recently in terms of T–R events and sequences in several regional studies (Chatellier, 1988; Richards, 1989a; Richards et al., 1993, 1994). Also, T–R sequences can be readily recognized in surface and subsurface Carboniferous sections using objective criteria. Regional subaerial unconformities form components of the boundaries of T–R sequences and do not occur within them as in genetic stratigraphic sequences. In addition, the correlative conformity – the transgressive surface – can be recognized in most cases. A major problem with the use of depositional sequences for basin analysis is that the correlative conformity has little or no lithological expression and cannot be objectively located in most stratigraphic sections (Embry, 1990, 1993).

The lower Viséan Turner Valley Formation and the overlying lower member of the Mount Head Formation jointly constitute a regionally developed T–R sequence termed the Turner Valley/Wileman sequence by Richards (1989a). Using the hierarchial scheme for T–R sequences established by Embry (1993), this sequence is classified as third-order. The Turner Valley/Wileman sequence overlies the Tournaisian Pekisko/Shunda sequence of Richards and is overlain by the lower and middle Viséan Baril/Salter sequence. In most areas, including the southeastern part of the study region, the Turner Valley Formation records two main transgressions, an intervening regression and numerous minor T–R events. At Ochak Mountain and elsewhere in east-central British Columbia, however, the

Turner Valley Formation appears to record only one major transgression and the early phase of a subsequent regional regression.

Open-marine, skeletal to oolitic grainstone and packstone of the lower Turner Valley Formation above restricted-marine carbonates and evaporites of the Shunda Formation record the first regional transgression in the Turner Valley/Wileman sequence. From southwestern to west-central Alberta, the base of the sequence is a minor unconformity that coincides with the base of the Turner Valley Formation and generally resulted from transgressive ravinement of supratidal to intratidal carbonate facies of the upper Shunda Formation. Evidence for a subaerial unconformity at the boundary has not been observed. At Ochak Mountain and elsewhere in the region northwest of Willmore Wilderness Park, the base of the sequence is a conformable transgressive surface that commonly lies in the upper Shunda Formation, and the Shunda–Turner Valley contact is conformable. Subsequent regional regression is widely recorded by the middle Turner Valley Formation, but northwest of Willmore Wilderness Park it is not so readily apparent.

Skeletal to oolitic grainstone and associated protected-shelf deposits in the lower part of the upper Turner Valley Formation record a second widespread transgression in the Turner Valley/Wileman sequence. This event is clearly recorded in Willmore Wilderness Park and elsewhere in western Alberta, but in east-central British Columbia it is difficult to identify.

The regressive phase of sedimentation in the sequence is best recorded by restricted-shelf lithofacies of the Wileman Member and its correlatives, but the early phase of the regression is widely recorded by the middle to upper Turner Valley Formation. During deposition of the Wileman, the regression culminated with widespread subaerial exposure accompanied by local regressive erosion.

The transgressive systems tract of the Turner Valley/Wileman sequence is preserved in the uppermost Shunda Formation and into the basal Turner Valley Formation. Maximum water depths were established during deposition of the lower Turner Valley, but a maximum flooding surface has not been identified. The regressive systems tract comprises the middle to upper part of the lower Turner Valley Formation, the middle to upper Turner Valley Formation, and the Wileman Member and its correlative – the lower member of the Mount Head Formation in the study area. Maximum regression took place during deposition of the Wileman Member. In the study area, a minor unconformity (surface of transgressive ravinement) at the base of the overlying Baril Member generally marks the base of the overlying Baril/Salter sequence.

BIOSTRATIGRAPHY OF THE LOWER MEMBER OF THE MOUNT HEAD FORMATION

Tournaisian–Viséan boundary

The position of the Tournaisian–Viséan boundary in North America is a complex and controversial problem that specialists in biostratigraphically significant fossil groups have been struggling to resolve for many years. For comprehensive reviews of historical and faunal aspects of this correlation problem attention is drawn to Austin et al. (1973) and to Brenckle et al. (1974, 1982). Although no consensus has been established on the position of the boundary in the Mississippi Valley there is general agreement that the foraminifer *Eoparastaffella* Vdovenko, which first appears in the basal Viséan in bed 141 of the Tournaisian–Viséan Boundary Stratotype (Conil et al., 1969; Paproth et al., 1983), is positive evidence of Viséan age (e.g., Mamet and Skipp, 1970, 1971; Lipina and Reitlinger, 1971; Lipina, 1973; Conil et al., 1976, 1991; Vdovenko, 1980; Brenckle et al., 1982; Beauchamp and Mamet, 1985; Vdovenko et al., 1985; Mamet et al., 1986; Brenckle and Groves, 1986; Brenckle, 1991; Riley, 1990, 1993, 1994). Unfortunately, *Eoparastaffella* has never been recovered in the standard Mississippi Valley succession (Brenckle, 1991). Nevertheless, it does occur both below and above the ammonoids from the lower member of the Mount Head Formation, which are directly associated with biostratigraphically important conodonts that also occur in the Mississippi Valley. Accordingly, we are able to correlate the ammonoid strata of the basal Mount Head Formation directly to the Mississippi Valley succession and by inference can point in a general way to the probable position of the Tournaisian–Viséan boundary in the Mississippi Valley.

In the study area the stratigraphically lowest occurrence of *Eoparastaffella* is within the middle part of the Turner Valley Formation, which underlies the lower member of the Mount Head Formation. According to Mamet (pers. comm., 1992; Appendix 1) this occurrence is 45 m above the base of the Turner Valley Formation, which places it some 55 m below our ammonoid horizon within the lower Mount Head Formation. According to Mamet (pers. comm., 1997), most, if not all representatives of *Eoparastaffella* within the Turner Valley Formation, and all other species of the genus that occur in the Baril and Salter members of the Mount Head Formation above the lower member are characterized by a "keeled" outer periphery; that is, subangular to angular in the sense of Hance and Muchez (1995). Hance (1997) designated such species "morphotype 2" and suggested that the transition from rounded species of *Eoparastaffella* (morphotype 1) to subangular or angular species (morphotype 2) marks the Tournaisian–Viséan boundary. In any case, foraminiferal data suggest that the middle Turner Valley–lower Mount Head interval, including the ammonoid horizon, is of Viséan age throughout the Ochak Mountain–Belcourt Creek area (Mamet, pers. comm., 1997; Appendix 1; Mamet et al., 1986).

Conodonts obtained from the ammonoid beds at Ochak Mountain (GSC loc. 80116) were identified by H.R. Lane (pers. comm., 1979; Appendix 3) and include *Eotaphrus burlingtonensis* Pierce and Langenheim and *Polygnathus mehli* Thompson. In the Mississippi Valley, the upper concurrent ranges of these two species closely precede the appearance of *Gnathodus texanus* Roundy in rocks assigned to the upper part of the *anchoralis–latus* Zone (faunal unit 5B of Lane, 1978, p. 169). This level occurs near the top of the middle Osagean Burlington Formation in its type area (Brenckle et al., 1974; Lane, 1978; Brenckle and Lane, 1981) (Fig. 10). Since the representatives of Viséan *Eoparastaffella* that occur in the middle of the Turner Valley Formation are also in the upper *anchoralis–latus* Zone (Higgins, pers. comm., 1994; Appendix 4), it follows that the Tournaisian–Viséan boundary falls within the *anchoralis–latus* zone of Lane et al. (1980) and thus corresponds to a

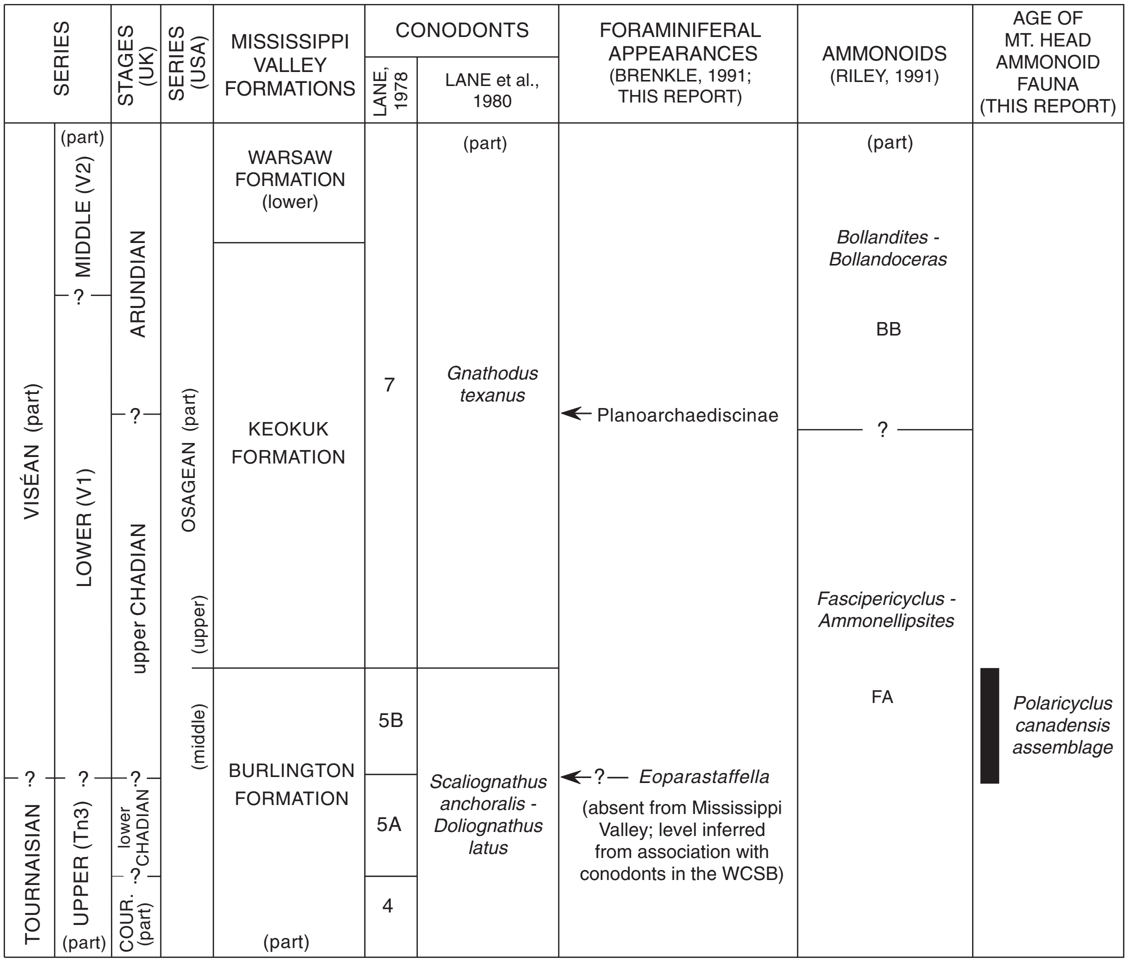


Figure 10. *Correlation of the* ***Polaricyclus canadensis*** *ammonoid assemblage in the lower member of the Mount Head Formation to standard successions in the Mississippi River Valley and northwest Europe. The Mount Head ammonoids are directly associated with conodonts (faunal unit 5B of Lane, 1978) that indicate correlation with the upper part of the middle Osagean Burlington Formation in the Mississippi Valley. The ammonoid beds are, in turn, underlain and overlain by strata containing representatives of the definitive Viséan foraminifer* ***Eoparastaffella*** *with subangular outer periphery. Question mark indicates that position of series or stage boundary relative to Mississippi Valley succession is uncertain. See text for explanation. Based on Lane (1974, fig. 2; 1978, fig. 3); H.R. Lane (pers. comm., 1979; Appendix 3); Lane et al. (1980, table 1); Paproth et al. (1983, enclosure); A.C. Higgins (pers. comm., 1985; Appendix 4); Kammer et al. (1990, fig. 1); Brenckle (1991, fig. 1); Conil et al. (1991, fig. 5); B.L. Mamet (pers. comm. 1992; Appendix 1); Riley (1993, fig. 1; 1994, fig. 6); and our own observations.*

position within the middle Osagean Burlington Formation of the Mississippi Valley (Fig. 10) as was previously suggested by Austin et al. (1973), Brenckle et al., (1982), Lane and Ziegler (1983), Brenckle and Groves (1986), and Brenckle (1991) largely on the basis of conodont evidence alone.

Ammonoids

Polaricyclus canadensis assemblage

Description. The lower Mount Head Formation ammonoid assemblage is dominated by the pericyclids *Polaricyclus canadensis* n. sp. and *Goniocycloides ochakensis* n. gen. et sp., but includes *Merocanites rileyi* n. sp., *Imitoceras tardum* n. sp., *Irinoceras bamberi* n. sp., *Eurites kusinae* n. sp., *Dzhaprakoceras belcourtense* n. sp., *D. crassum* n. sp. and *Furnishoceras heterolobatum* n. gen. et sp. These ammonoids form the basis for the *Polaricyclus canadensis* assemblage, which identifies the *Polaricyclus canadensis* assemblage zone within the lower member of the Mount Head Formation. This interval has been identified at a number of localities in east-central British Columbia, but stratigraphic and biostratigraphic relationships are best developed at Ochak Mountain (Fig. 1, loc. 1), the type area for both *Polaricyclus canadensis* and *Goniocycloides ochakensis*. The *Polaricyclus canadensis* assemblage corresponds to a portion of Zone 11 of the Mamet foraminifer scheme. The accompanying conodont fauna belongs to the upper *Scaliognathus anchoralis–Doliognathus latus* Zone of Lane et al. (1980) (Fig. 10).

Age and correlation. The *Polaricyclus canadensis* assemblage correlates with a portion of the latest Tournaisian–early Viséan Chadian Stage, Dinantian Subsystem, in the British succession. Although the Tournaisian and Viséan series are based on sections in Belgium where distinctive ammonoid faunas are absent, mid-Dinantian successions in the Craven Basin in the United Kingdom (George et al., 1976) are replete with ammonoids and other faunal groups and may be preferable to the Belgian standards for global correlation. The mid-Dinantian ammonoid succession described by Riley (1996) can be correlated by associated faunas to conodont and foraminifer zones in the Belgian sections. The British successions are particularly well displayed and the diverse and cosmopolitan ammonoid faunas therein provide a reliable basis for correlation between Britain, western Europe, the Urals, Central Asia and North America (Riley, 1991, 1996).

The biostratigraphy of the British Chadian was explained in considerable detail by Riley (1990, 1993, 1994). Lower and upper Chadian substages are recognized in an interval that encompasses the *Fascipericyclus–Ammonellipsites* ammonoid Zone. Although the base of the Chadian was initially thought to coincide with the base of the Viséan Series at its stratotype in Belgium, Riley (1990, 1994) indicated that Cf4a2 Subzone assemblages with *Eoparastaffella* entered higher in the sequence than previously reported. Accordingly, Riley (1990, 1993, 1994) suggested that the Tournaisian–Viséan boundary coincided with the base of the "upper Chadian", recognized by the presence of *Eoparastaffella* and other taxa, including *Gnathodus homopunctatus* that are strictly Viséan. This level lies within the upper portion of the *Fascipericyclus–Ammonellipsites* ammonoid Zone. Although substantially more detailed stratigraphic discrimination has become possible in recent years (Riley, 1991, fig. 1; 1996, textfig. 3), ammonoids do not readily define the Tournaisian–Viséan (early–late Chadian) boundary (Ramsbottom and Saunders, 1985), and correct age assignment of isolated boundary faunas is commonly dependent on complementary evidence from other fossil groups that can be related to the Belgian standard.

Correlation of the lower Mount Head *Polaricyclus canadensis* interval to the mid-Dinantian zonation is shown in Figure 10. The eight genera recognized in this assemblage are collectively characteristic of the *Fascipericyclus–Ammonellipsites* Zone. Documented concurrent ranges of these genera in Eurasia and North America span the interval from highest Tournaisian (lower Chadian) at least through lowest Viséan (upper Chadian). *Merocanites*, a prolecanitid that ranges from the lower Chadian or possibly even the highest Courceyan (upper Tournaisian), where its appearance defines the base of the *Fascipericyclus–Ammonellipsites* Zone, extends into the lower Asbian (B1) (lower upper Viséan) in Europe (Riley, 1990, 1991). The distinctive pericyclid *Polaricyclus* appears first in the lower Chadian, and recovery of this genus from the lower member of the Mount Head Formation establishes a maximum age. *Polaricyclus* extends no higher than the middle *Fascipericyclus–Ammonellipsites* Zone in the British succession (middle Chadian; highest Tournaisian) (Riley, 1991; N.J. Riley, pers. comm., 1996), but ranges higher in the North American Midcontinent, being represented in the upper Osagean Boone Formation, which is correlative with the upper Chadian (basal Viséan) portion of the *Fascipericyclus–Ammonellipsites* Zone in British terms. *Goniocycloides* does not appear to have a direct counterpart in the European succession, but similar advanced pericyclids characterized by strongly incised ventral lobes and subacute to angular first lateral saddles appear to be confined to the Chadian and possibly highest Courceyan (highest Tournaisian–basal Viséan). *Eurites* characterizes the upper Tournaisian (Courceyan–lower Chadian) (Riley, 1991) but ranges into the basal Viséan (upper Chadian) in Ireland (Smyth, 1951). *Dzhaprakoceras* ranges from the lower Chadian or possibly even the upper Courceyan (upper Tournaisian) into the Arundian (middle Viséan) (Riley, 1991, 1996). *Imitoceras* s.s. appeared in the middle Tournaisian (Kinderhookian, Hastarian) (House, 1993), extending through the upper Tournaisian as a rare element into the lowest Viséan (*fide* Becker, 1993a; Liang and Zhu, 1988), whereas the earliest *Irinoceras* appeared in the upper Tournaisian (lower Ivorian) and persisted into the lower Namurian (Nm_1c_1; Arnsbergian, E2) (Ruzhencev and Bogoslovskaya, 1971). These occurrences establish a probable minimum age of earliest Viséan (late Chadian), but they may also indicate a latest Tournaisian (early Chadian) age. Although late Tournaisian (early Chadian) cannot be precluded, an earliest Viséan (late Chadian) age is favoured, in light of the presence of the definitive Viséan foraminifer *Eoparastaffella* with subangular outer periphery at several levels in the underlying Turner Valley Formation (B.L. Mamet, pers. comm., 1997; Appendix 1). Based on the conventional concept of *Eoparastaffella* as a reliable indicator of Viséan age, the entire upper Turner Valley–lower Mount Head interval, including the *Polaricyclus canadensis* assemblage, would be unquestionably Viséan.

On balance, ammonoid and foraminiferal evidence relates the *Polaricyclus canadensis* interval to a relatively narrow range of earliest Viséan age, which in terms of the standard Lower Carboniferous ammonoid succession can be equated to the middle Chadian portion of the *Fascipericyclus–Ammonellipsites* Zone (Fig. 10). *Fascipericyclus–Ammonellipsites* zonal faunas, which include elements similar to the lower Mount Head assemblage, are known from throughout northwest Europe, including Britain (George and Howell, 1939; Riley, 1991, 1996), Ireland (Foord, 1903; Smyth, 1951), France (Böhm, 1935; Delépine, 1935), Belgium (Delépine, 1940a), and Germany (Holzapfel, 1889; Schmidt, 1925; Schindewolf, 1951); Spain (Kullmann, 1961, 1963; Wagner-Gentis, 1960, 1964; Higgins and Wagner-Gentis, 1982); the north Urals region of the Russian Federation (Kusina, 1971, 1973, 1974, 1980, 1983); Kazakhstan (Librovitch, 1940; Monakhova, 1955); Kyrgyzstan (Librovitch, 1927; Popov, 1965, 1968); Iran (Walliser, 1966); China, including Xijiang (Liang and Liu, 1987) and Xinjiang (Sheng, 1984; Liang and Wang, 1992); Australia (Campbell et al., 1983); and North Africa, including Algeria (Pareyn, 1961; Lemosquet et al., 1985) and Morocco (Delépine, 1941). Most of these have been compared in the definitive studies of Popov (1968), Kusina (1980) and Riley (1991). Equivalent North American faunas are reviewed below.

Comparison with middle and late Osagean ammonoids in the North American Midcontinent and Cordillera

Fascipericyclus–Ammonellipsites zonal faunas equivalent, at least in part, to the *Polaricyclus canadensis* assemblage occur in the Grand Falls Member of the Boone Formation in Kansas (Gordon, 1965); the Reeds Spring Formation in Missouri (Miller and Garner, 1955; Gordon, 1965); the New Providence and Nada members of the Borden Formation in Kentucky (Gordon and Mason, 1985; Work and Mason, work in progress, 1999); the Marshall Sandstone in Michigan (Miller and Garner, 1955; Weyer, 1972b; Gordon and Mason, 1985); the Delle Phosphatic Member of the Woodman Formation in Utah (Peterson, 1969; Sandberg and Gutschick, 1984); the Kuna Formation in Alaska (Gordon, 1957); and the Clausen Formation in the Northwest Territories. All of these occurrences are reviewed below.

Kansas

An upper Osagean faunule described by Gordon (1965) from the Grand Falls Member of the Boone Formation near Baxter Springs, Cherokee County, southeast Kansas is broadly comparable in age to the lower member of the Mount Head Formation. It includes *Polaricyclus ballardensis* (Gordon, 1965) (=*Ammonellipsites* (*Stenocyclus*) *ballardensis* of Gordon, 1965; taxonomic revision herein) and *Winchelloceras*? sp. (=*Muensteroceras*? sp. of Gordon, 1965) which occur with brachiopods of lower Keokuk (early late Osagean) aspect, according to Gordon (1965, p. 13). This interval, known as the *Ammonellipsites ballardensis* Zone (Ramsbottom and Saunders, 1985, fig. 4), represents a potentially important biostratigraphic datum. Conodonts reported by Thompson from the Grand Falls, including *Gnathodus texanus* and *Taphrognathus varians* Branson and Mehl, indicate a late Osagean (Keokuk) age (Thompson *in* Goebel et al., 1968; Thompson and Fellows, 1970, appendix, section F, p. 164-166; T.L. Thompson, pers. comm., 1996), and thus support reference of the *Polaricyclus ballardensis* assemblage to a relatively high (upper Chadian, lower Viséan) level in the *Fascipericyclus–Ammonellipsites* Zone.

Missouri

Miller and Garner (1955, p. 150, footnote, textfig. 12A, pl. 6, fig. 11) recorded a single fragmentary *Merocanites* from the base of the Reeds Spring Formation at Roaring River State Park, Barry County, southwest Missouri that indicates possible correlation with the *Polaricyclus canadensis* assemblage. Gordon (1965, p. 13, 284-285, fig. 94, pl. 16, fig. 24) later assigned this specimen to *Merocanites* cf. *M. drostei* Collinson, 1955 (herein considered a probable synonym of *M. houghtoni* (Winchell, 1862)). Conodont studies in the Roaring River section by Thompson and Fellows (1970, appendix, section C, p. 156-160, units 23-26) have shown that the ammonoid-bearing basal beds of the Reeds Spring Formation are in the *Gnathodus bulbosus* Zone of Thompson, 1967 (=faunal unit 6 of Lane, 1974, fig. 2, p. 278, which equates roughly with the uppermost *anchoralis–latus* Zone of Lane et al., 1980) and are latest middle or possibly early late Osagean in age (see also Collinson et al., 1971, p. 380, 381).

Kentucky

Undescribed, but verified, equivalents of the *Polaricyclus ballardensis* assemblage have been identified in the Nada and New Providence members of the Borden Formation in east- and north-central Kentucky (Gordon and Mason, 1985; Work and Mason, work in progress, 1999). *Polaricyclus ballardensis* (=*Ammonellipsites* sp. of Mason *in* Chaplin et al., 1985) and *Winchelloceras allei* (Winchell, 1862a) (includes *Eogonioloboceras*? sp. of Gordon and Mason, 1985, p. 194) occur in the upper part of the Nada Member in the Hilltop Church section near Frenchburg, Menifee County, Kentucky (Gordon and Mason, 1985, p. 194, D in fig. 2; Mason *in* Chaplin et al., 1985, p. 121, fig. 24) associated with conodonts of early late Osagean (early Keokuk) age, as determined by T.L. Thompson (pers. comm., 1997). A related ammonoid fauna believed to represent approximately the same zone was reported by Gordon and Mason (1985, p. 195, section 4 in fig. 3) from the lower part of the New Providence Member (= Coral Ridge Member, New Providence Formation of Gordon and Mason) at Coral Ridge, Jefferson County, Kentucky. It includes *Polaricyclus ballardensis* and *Michiganites*? *greenei* (S.A. Miller, 1892) together with *Winchelloceras* n. sp. [=Grand Falls *Muensteroceras*? sp. of Gordon, 1965] (Work and Mason, work in progress, 1999; these taxa were referred to *Ammonellipsites* n. sp., *Merocanites* (*Michiganites*) n. sp., and *Beyrichoceras* n. sp, respectively, by Gordon and Mason, 1985, p. 195). Conodonts associated with *Polaricyclus ballardensis* at the Coral Ridge locality, including *Gnathodus texanus*, indicate an early late Osagean (early Keokuk) age, as determined by T.L. Thompson (pers. comm., 1997). The holotype of *Michiganites*? *greenei* was recovered from the same unit at New Albany in adjacent Clark County, Indiana (Work and Mason, work in progress, 1999).

Lower faunas reported by Gordon and Mason from the Borden Formation include *Eurites* n. sp. and *Merocanites drostei* Collinson, 1955 from the lower part of the Nancy Member (=Conway Siltstone Member, Broadhead Formation of Collinson, 1955), near Berea, Madison County, Kentucky (Gordon and Mason, 1985, p. 193, F in fig. 2); and *Dzhaprakoceras* n. sp. and *Merocanites* sp. from the middle of the Cowbell Member at Stanton, Powell County, Kentucky (Gordon and Mason, 1985, p. 194, E in fig. 2). Precise correlation of this interval is unclear at present, but it appears to be equivalent to portions of the middle Osagean (lower *Fascipericyclus*–*Ammonellipsites* Zone).

Michigan

Osagean ammonoids from Michigan include the classic Marshall Sandstone faunas (Winchell, 1862a,b, 1865, 1870; Miller and Garner, 1955), which have been reinterpreted by Weyer (1972b) and Gordon and Mason (1985). Weyer (1972b) discriminated an upper faunal complex of early Viséan age within the Marshall, which was later designated the *Winchelloceras allei* assemblage by Gordon and Mason (1985, p. 196-197, fig. 4). It includes *Winchelloceras allei* (Winchell, 1862a), *Merocanites houghtoni* (Winchell, 1862a), *Michiganites marshallensis* (Winchell, 1862a), and *Irinoceras romingeri* (Winchell, 1862b) which, according to Gordon and Mason (1985, p. 197), occur in the lower middle part of the Marshall Sandstone in Calhoun, Hillsdale, Jackson, Ottawa, and Van Buren counties in southwestern Michigan. This interval correlates with the beds in the Nada Member of the Borden Formation near Frenchburg, Kentucky, mentioned earlier, that yielded *Winchelloceras allei* and *Polaricyclus ballardensis* (Gordon and Mason, 1985, p. 196, 197; Work and Mason, work in progress, 1999). The *Winchelloceras allei* assemblage is clearly no older than late middle Osagean (late Burlington) in age and generally resembles the fauna of the Wileman Member. Representation of the pericyclid genera *Polaricyclus* and *Goniocycloides* is, however, noticeably lacking.

Utah

Comparable Osagean ammonoids have been reported from the Delle Phosphatic Member of the Woodman Formation in western Utah. A compressed juvenile pericyclid figured by Sandberg and Gutschick (1984, pl. 8, fig. J) from the Delle Member (=Deseret Limestone of authors) at Flux, Tooele County, Utah (Sandberg and Gutschick, 1979, p. 119, fig. 8; between FLUX-13R and FLUX-4 beds) is referrable to *Polaricyclus*; although lack of sutural information precludes definite identification, the form of the constrictions and details of shell sculpture indicate affinity with equivalent stages of *P. ballardensis* and *P. canadensis*; the latter is described herein, from the lower member of the Mount Head Formation in east-central British Columbia. Four to five metres higher in the same section (Sandberg and Gutschick, 1979, p. 119, fig. 8, station FD-23MPc [4]), Petersen (1969; M.S. Petersen, pers. comm., 1995) recovered abundant representatives of at least two undescribed species of *Dzhaprakoceras* (referred to *Dzhaprakoceras* and *Beyrichoceras* by Petersen, 1969; and Sandberg and Gutschick, 1979, 1980, 1984) from large gray-black limestone concretions in phosphatic shale. Conodont studies in the Flux section by C.A. Sandberg (pers. comm., 1996) have shown that both of the ammonoid-bearing levels in the Delle Phosphatic Member are in the *mehli*–lower *texanus* Zone of Poole and Sandberg (1991) and are thus of late middle or early late Osagean age.

Alaska

A small Osagean faunule described by Gordon (1957) from the Lisburne Group in the Kiligwa River Valley, eastern

De Long Mountains, northern Alaska, indicates possible correlation with the *Polaricyclus canadensis* assemblage. *Polaricyclus polaris* (Gordon, 1957) (=*Ammonellipsites* (*Fascipericyclus*) *polaris* of Gordon, 1957) was recovered from stratigraphically isolated black shales subsequently included in the Kuna Formation of Mull et al. (1982) (A.G. Harris, pers. comm., 1995). Conodonts reported by Harris from comparable strata in the type section of the Kuna Formation and at other localities in the De Long Mountains indicate a middle to late Osagean (late Tournaisian–early Viséan) age, beginning in the lower part of *anchoralis–latus* Zone and extending through at least the lower part of the *texanus* Zone (Harris *in* Dumoulin et al., 1994, p. 79-81, fig. 3, 4; A.H. Harris, unpublished U.S. Geological Survey conodont collections; pers. comm., 1995). The ammonoids themselves suggest a middle or early late Osagean age.

Northwest Territories

Fascipericyclus–Ammonellipsites zonal ammonoids were found at two levels in the Clausen Formation at Jackfish Gap, southwestern District of Mackenzie (lat. 61°05'N, long. 123°58'30"W) by E. O'Bertos of Triad Oil Company Ltd. in 1960. *Polaricyclus* n. sp. was recovered from a succession of concretionary black shales 27.4 m (90 ft.) below the top of the Clausen. *Dzhaprakoceras* n. sp. was recovered from between 79.9–86 m (262–282 ft.) below the top of the Clausen. Palynymorphs identified by J. Utting (*in* Richards, 1989b, p. 33, appendix F, p. 132) from 90 m below the top of Clausen at Jackfish Gap suggest a probable late Tournaisian (Tn3) age. On the basis of late Tournaisian foraminiferal faunas from the overlying Flett Formation, Bamber and Mamet (1978, fig. 4, 9) tentatively placed the upper boundary of the Clausen Formation within Mamet Zone 8, thus assigning the upper Clausen an early late Tournaisian (early Osagean) age. The ammonoids, however, indicate a distinctly younger latest Tournaisian (middle Osagean) age.

AMMONOID LOCALITIES

The ammonoids described in this report were collected from the mound facies (lithofacies 6) of the lower member of the Mount Head Formation at localities 1, 10 and 20 in the vicinity of Ochak Mountain, east-central British Columbia (Fig. 1). At Ochak Mountain (loc. 1), ammonoids were collected from three sublocalities designated as localities 1A, 1B and 1C. All three are from the same stratigraphic level and are presumed to be at the same level as localities 10 and 20.

Locality 1A, (GSC loc. C-225675) Fig. 1. East side Ochak Mountain; latitude 54°20'19"N, longitude 120°30'01"W, UTM zone 10u, 6023900N, 662550E; NTS 93-I/7, Wapiti Pass map area; east-central British Columbia; B.C. Richard's section 92RAH3 (Fig. 3). This locality lies 1.9 km east of the summit of Ochak Mountain at an elevation of about 2012 m. The site, on the western headwall of a cirque that opens eastward, is above a tarn lying at the foot of the headwall and is equivalent to the upper part of E.W. Bamber's section 5BR78. Ammonoids collected from this locality occur in several limestone blocks but preservation precluded either extraction or detailed study.

Locality 1B, (GSC loc. C-80116) Fig. 1. East side of Ochak Mountain; latitude 54°20'16"N, longitude 120°30'00"W; UTM zone 10u, 6023500N, 662600E; boundary between Wapiti Pass (93-I/7) and Belcourt Lake (93-I/8) map areas, east-central British Columbia. This locality lies 200 to 250 m south of locality 1A and is found on the western headwall of the eastward-opening cirque. The locality was discovered by E.W. Bamber in 1978. Subsequent collections were made by Bamber, W.W. Nassichuk, and R.I. Thompson in 1979. The ammonoids occur from 7 to 12 m above the base of the Mount Head Formation. Associated conodonts are discussed in Appendix 3.

Ammonoids at this locality include:
Merocanites rileyi n. sp.
Imitoceras tardum n. sp.
Irinoceras bamberi n. sp.
Goniocycloides ochakensis n. gen. et sp.
Polaricyclus canadensis n. sp.
Eurites kusinae n. sp.
Dzhaprakoceras belcourtense n. sp.
Dzhaprakoceras crassum n. sp.
Furnishoceras heterolobatum n. gen. et sp.

Locality 1C, (GSC loc. C-178983) Fig. 1. East side Ochak Mountain; latitude 54°20'12"N, longitude 120°30'05"W; UTM zone 10u, 6023650N, 662450E; NTS 93-I/7, Wapiti Pass map area; east-central British Columbia. This locality lies 25 m west of the rim of the eastward-facing cirque headwall, where localities 1A and 1B are situated. The site is 1.9 km east of the summit of Ochak Mountain and about 250 to 300 m southwest of locality 1A. The collection was assembled by W.W. Nassichuk and B.C. Richards in 1991. The locality is along strike from and at the same stratigraphic level as localities 1A and 1B.

Ammonoids at this locality include:
Merocanites rileyi n. sp.
Irinoceras bamberi n. sp.
Goniocycloides ochakensis n. gen. et sp.
Polaricyclus canadensis n. sp.
Eurites kusinae n. sp.
Dzhaprakoceras belcourtense n. sp.
Dzhaprakoceras crassum n. sp.

Locality 10A, (GSC loc. C-7400) Fig. 1. Belcourt Creek; latitude 54°21'30"N, longitude 120°29'40"W; UTM zone 10u, 6026050N, 6637500E; NTS 93-I/8, Belcourt Lake map area; east-central British Columbia. This locality is on the rim of a north-facing cirque headwall on the east side of an unnamed mountain. The cirque contains an unnamed tributary of Belcourt Creek. The site is 2.9 km northeast of the summit of Ochak Mountain and occurs in the upper part of E.W. Bamber's section 7BR70 (Mamet et al., 1986, fig. 3). The collection was assembled by E.W. Bamber in 1970 from 22.3 to 23.2 m above the base of the Mount Head Formation.

Ammonoids at this locality include:
Merocanites rileyi n. sp.
Polaricyclus canadensis n. sp.
Goniocycloides ochakensis n. gen. et sp.
Dzhaprakoceras belcourtense n. sp.

Locality 20, (GSC loc. C-11489) Fig. 1. Southwest of Muinok Mountain; latitude 54°18'38"N, longitude 120°26'43"W; UTM zone 10u, 6020800N, 666200E; NTS 93-I/7, Wapiti Pass map area; east-central British Columbia. This locality is E.W. Bamber's station 1BR71 on the north face of a northeasterly trending ridge north of upper Belcourt Creek. The site is 4.35 km southwest of the summit of Muinok Mountain. The collection was assembled by E.W. Bamber in 1971. Its precise stratigraphic position above the base of the lower member of the Mount Head Formation could not be determined.

Ammonoids at this locality include:
Merocanites rileyi n. sp.
Irinoceras bamberi n. sp.
Goniocycloides ochakensis n. gen et sp.
Polaricyclus canadensis n. sp.
Eurites kusinae n. sp.
Dzhaprakoceras belcourtense n. sp.
Furnishoceras heterolobatum n. gen. et sp.

SYSTEMATIC PALEONTOLOGY

All type specimens are deposited in the National Type Collection of Plant and Invertebrate Fossils of the Geological Survey of Canada, 601 Booth Street, Ottawa; additional reference materials are housed in the collections of the Geological Survey of Canada, Calgary.

Abbreviations for repository collections referred to in the text are:

GSC - Geological Survey of Canada, Ottawa.
USNM - United States National Museum of Natural History, Washington, D.C.
SUI - University of Iowa, Iowa City.

Dimensions D, H, W, and U represent conch diameter, corresponding whorl height and width, and umbilical diameter measured from seam to seam. Suture terminology is that of Ruzhencev (1960, 1962); *V*, *L*, *U*, *I*, and *D* represent the ventral lobe, lateral lobe, umbilical lobe, internal lateral lobe, and dorsal lobe, respectively.

Order PROLECANITIDA Miller and Furnish, 1954

Superfamily PROLECANITACEAE Hyatt, 1884

Family PROLECANITIDAE Hyatt, 1884

Subfamily PROTOCANITINAE Weyer, 1972a

Genus *Merocanites* Schindewolf, 1922

Type species. Ellipsolites compressus Sowerby, 1813.

Diagnosis. Conch large (up to 18 cm phragmocone diameter), discoidal (W/D, 0.15–0.3) and widely evolute (U/D, 0.35–0.55) with compressed whorls and broadly rounded or subquadrate venter and umbilical shoulders. Mature external sutures are characterized by a broad V-shaped ventral lobe and three lobes across the flank. The internal lobe (*I*) of advanced species is also external or on the seam.

Sutural formula: $VLUU^1:ID$.

Discussion. Two North American species of *Merocanites* have been recognized: *M. houghtoni* (Winchell, 1862a) characterized by compressed whorls with a reputed H/W ratio of 2.8–2.9 at a whorl height of 20 mm (Miller and Garner, 1955, fig. 13B), and *M. drostei* Collinson, 1955, which is less compressed, its whorls having a H/W ratio of 1.8 at a comparable whorl size. Only three specimens of *M. drostei*, all from the Osagean Borden Formation in Kentucky, have been described. It is probable that they represent undistorted *M. houghtoni* and both species need re-evaluation.

The genus *Erdbachites* Weyer, 1965 (type species, *Prolecanites applanatus* Frech, 1899) is a synonym of *Merocanites* as indicated by Riley (1996).

Species composition and distribution

Merocanites applanatus (Frech, 1899) [synonym, *Prolecanites holzapfeli* Frech, 1902]; from the mid-Dinantian Erdbach Limestone (Erdbach horizons II and III of Krebs, 1968) in Germany (Schmidt, 1925; Schindewolf, 1951). Riley (1991, 1996) reported the following British occurrences: Viséan (Holkerian or lower Asbian; upper BB) Milldale Limestone, Staffordshire; and middle Viséan (Holkerian; upper BB) Hodderense Limestone Formation, Lancashire, northwest England. *Merocanites applanatus* has been reported from the lower Viséan El Hariga Formation (S^{2b}), Saoura Valley, Béchar Basin (Pareyn, 1961) and equivalent strata in the Timimoun Shale ("dalle à *Merocanites*"), Timimoun Basin (Conrad, 1985; Lemosquet et al., 1985), both in Algeria; the Bordj d'Erfoud (level b) in Morocco (Delépine, 1941); and from strata of possible early Viséan age in the Shishtu Formation, eastern Iran (Walliser, 1966). Unpublished, but verified, specimens are known from the Kosvinsky Horizon (level 5 of Kusina, 1980), Kozhim River, Prepolar Urals, Russia (L.F. Kusina, pers. comm., 1997).

M. compressus (Sowerby, 1813); from the upper Tournaisian (Courceyan or lower Chadian) [*fide* Riley, 1991] "Blackrock Limestone" in Ireland (Foord and Crick, 1894; Foord, 1903).

M. djaprakensis (Librovitch, 1927); from the Dzhaprak and Akchetash suites (F2–A2 assemblages of Popov, 1968), Tien-Shan, Kyrgyzstan.

M. drostei Collinson, 1955; from middle Osagean strata in the Nancy Member, Borden Formation (=Conway Siltstone Member, Broadhead Formation of Collinson, 1955), east-central Kentucky (Gordon and Mason, 1985).

M. henslowi (Sowerby, 1820); from the lower upper Viséan (lower Asbian; B$_1$) Scarlett Beds, Isle of Man (Foord and Crick, 1894; Lewis, 1930); and Asbian equivalents in Yorkshire, England (Bisat, 1934).

M. houghtoni (Winchell, 1862a); from upper Osagean [*fide* Gordon and Mason, 1985] strata in the middle part of the Marshall Sandstone, southwestern Michigan (Miller and Garner, 1955).

M. ogivalis Pareyn, 1961; from the lower upper Viséan (upper Asbian; S^{2d}) Mazzer Formation, Béchar Basin, Algeria (Pareyn, 1961; Lemosquet and Pareyn, 1985).

M. planorbis Delépine, 1941; from the Bordj d'Erfoud (level b), Morocco.

M. quadrilobus Riley, 1996; from the lower Viséan (upper Chadian; upper FA) Leagram Mudstone Member, Hodder Mudstone Formation, Lancashire, northwest England.

M. rileyi n. sp.; from upper middle Osagean (lower Viséan) strata in the lower member of the Mount Head Formation, east-central British Columbia.

M. similis (Crick, 1895); from the upper Tournaisian (Courceyan or lower Chadian; lower FA) [*fide* Riley, 1991] Haw Bank Limestone, Chatburn Limestone Group, Yorkshire, northwest England (Prentice and Thomas, 1965).

M. subapplanatus Smyth, 1951; from lower Viséan (upper Chadian; upper FA) strata [*fide* Riley, 1996, p. 16] in the Tober Colleen Formation (=Rush Slates of Smyth, 1951), Co. Dublin, Ireland.

M. subhenslowi Wagner-Gentis, 1964; from upper Tournaisian or lower Viséan (Chadian) strata in the Genicera Formation, Cantabrian Mountains, León, northern Spain.

M. tenuis Sheng, 1984; from lower Viséan strata in the middle member, Donggulubasitao Formation, Xinjiang, northwest China.

Merocanites rileyi Work and Nasichuk, n. sp.

Plate 1, figures 14–16; Figure 11

Etymology. Named for N.J. Riley (British Geological Survey, Keyworth).

Diagnosis. A widely umbilicate species of *Merocanites* (U/D, 0.5 at 50–60 mm diameter) with subquadrate whorl sections (H/W, 1.3–1.6). The suture is characterized by a shallow third lateral lobe that is less than 50 per cent the depth of the corresponding second lateral lobe, and an internal lateral lobe (*I*) that extends onto the dorsolateral flank at intermediate diameters.

Description. Merocanites rileyi sp. is represented by four substantially complete silicified phragmocones ranging from 20 to 57 mm in diameter, as well as 25 additional, small septate whorl fragments. The conch is thinly discoidal (W/D approximately 0.2–0.25) and extremely evolute (U/D approximately 0.45–0.5). Whorl sections at large diameters exhibit uniformly rounded umbilical shoulders and parallel flanks that converge slightly to the broadly rounded venter. Growth lines retained on the penultimate volution of GSC 103171 (Pl. 1, fig. 14) trace faint dorsolateral sinus and lateral salient.

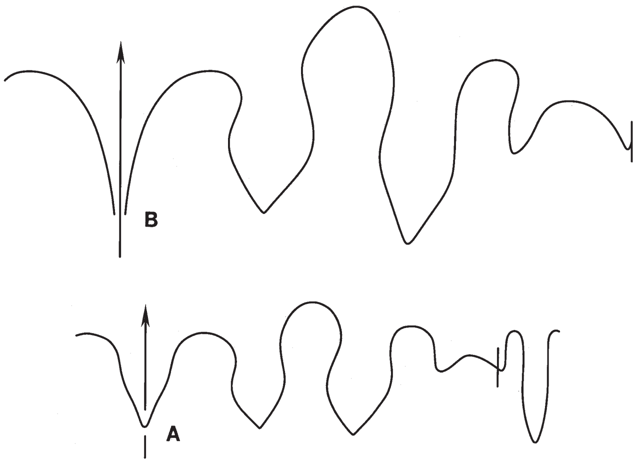


Figure 11. *Sutures of **Merocanites rileyi** Work and Nassichuk, n. sp. **A**, paratype GSC 103172, GSC loc. C-178983, whorl height 5.5 mm. **B**, paratype GSC 103173, GSC loc. C-80116, whorl height 13 mm.*

Sutural ontogeny is represented in Figure 11. Sutures at all observable stages possess a third lateral lobe that is less than 50 percent the depth of the second lateral lobe. The primary internal element (*I*) migrated onto the dorsolateral flank at whorl heights exceeding 12 mm.

Dimensions (mm).

Specimen	D	U/D	H/D	W/D	H/W
Holotype GSC 103171	57.2	0.47	0.33	0.21	1.58
Paratype GSC 103170	43.0	0.47	0.33	0.23	1.30
Paratype GSC 103169	20.6	0.48	0.31	0.23	1.36

Comparisons. Conch proportions and general sutural design of *M. rileyi* are closest to equivalent growth stages of *M. subapplanatus* Smyth, 1951 from lower Viséan strata in the Tober Colleen Formation of Ireland. At maximum size, that is, at a diameter of 57 mm, the conch proportions of *M. rileyi* fall within the range of variability of typical *M. subapplanatus,* but during earlier ontogenetic stages the width of the Canadian specimens is significantly greater than typical representatives of *M. subapplanatus*. Moreover, the suture of the Canadian species is slightly advanced over *M. subapplanatus* as indicated by the position of the primary internal element (*I*). At a whorl height of 13 mm the internal lateral lobe (*I*) of *M. rileyi* is external, situated ventrad of the seam (Fig. 11B), whereas in *M. subapplanatus* this element is internal. All other species of *Merocanites* have comparatively deeper third lateral lobes at comparable whorl heights.

Occurrence. Lower member, Mount Head Formation, east-central British Columbia at GSC localities C-80116 (type locality: holotype GSC 103171; paratypes GSC 103170, 103173), C-178983 (paratypes GSC 103168, 103169, 103172), C-11489, and C-7400.

Types. Holotype GSC 103171; paratypes GSC 103168–103170, 103172, 103173.

Order GONIATITIDA Hyatt, 1884

Suborder TORNOCERATINA Wedekind, 1918

Superfamily PRIONOCERATACEAE Hyatt, 1884

Family PRIONOCERATIDAE Hyatt, 1884

Genus *Imitoceras* Schindewolf, 1923

Type species. Ammonites rotatorius de Koninck, 1844; SD Schindewolf, 1926, Senckenbergiana 8(2), 70.

Diagnosis. Conch discoidal to subdiscoidal (W/D generally 0.3–0.5) and of moderate to large size (mature phragmocone diameter commonly 5–6 cm, but upper Tournaisian forms may exceed 10 cm), with closed umbilicate inner whorls. Growth lines and constrictions form shallow re-entrant on flanks and rounded sinus on venter. Constrictions particularly prominent on juvenile whorls, inconspicuous or absent in later growth stages. External suture characterized by swollen to sagittate ventral lobe and deep angular lateral lobe.

Discussion. The generic diagnosis incorporates distinctions made by Price and House (1984), Becker (1988, 1993a, 1996), and House (1993), who restricted *Imitoceras* to large laterally compressed forms with swollen to sagittate ventral lobes conforming to the upper Tournaisian type species *Goniatites ixion* Hall, 1860 [=*I. rotatorium* (de Koninck, 1844)]. This rather small, dominantly middle–upper Tournaisian group differs from the generally older (Famennian–?upper Tournaisian) prionoceratid species assigned by recent authors to *Rectimitoceras* Becker, 1996 (type species, *Goniatites linearis* Münster, 1832) [= Gen. nov. B, *lineare* Group of House, 1993; and "*Imitoceras*" *lineare* Group of Becker, 1993a] in which the ventral lobe is narrow and lanceolate and approximates the lateral lobe in depth.

The reader is referred to Becker (1993a, 1996) and House (1993) for discussions of this genus and related prionoceratids, particularly its taxonomic relationship with *Rectimitoceras*.

Species composition and distribution

Imitoceras abundans Miller and Collinson, 1951; from the upper Kinderhookian (upper middle Tournaisian; upper Hastarian) Chouteau Limestone, central and northeastern Missouri; and equivalent strata in the Wassonville Formation, southeastern Iowa (Furnish and Manger, 1973).

I. brevilobatum Miller and Collinson, 1951; from the upper Kinderhookian (upper middle Tournaisian; upper Hastarian) Northview Formation, southwestern Missouri.

I. indianense (Miller, 1891); from the Osagean (upper Tournaisian; Ivorian) New Providence Formation, Borden Group, southern Indiana (Gordon, 1965).

I. jessieae (Miller and Gurley, 1896) [synonym, *Aganides discoidalis* Smith, 1903]; from the upper Kinderhookian (upper middle Tournaisian; upper Hastarian) Chouteau Limestone, central and northeastern Missouri; and equivalent strata in the Wassonville Formation, southeastern Iowa (Miller and Collinson, 1951; Furnish and Manger, 1973).

I. lentiforme Miller and Collinson, 1951; from the upper Kinderhookian (upper middle Tournaisian; upper Hastarian) Chouteau Limestone, central Missouri.

I. rotatorium (de Koninck, 1844) [synonyms, *Goniatites ixion* Hall, 1860 and *Goniatites propinquus* Winchell, 1862a]; from the upper Tournaisian (upper Ivorian; Tn3c) Calcaire de Colonne [*fide* Delépine, 1940a] or (Ivorian; Tn3b) Calcaire de Vaulx [*fide* Conil et al., 1971], near Tournai, Belgium. *Imitoceras rotatorium* has been reported from the upper Tournaisian (S^{1b}) Hassi Sguilma Formation, Saoura Valley, Béchar Basin, Algeria (Pareyn, 1961) and the equivalent Teguentour Shales, Oued Temertasset, Mouydir, Algeria (Follot, 1952; Lemosquet et al., 1985). Other conspecific specimens are known from the Kuilyuk Formation, Kuilyuk River, Chatkal Range, northern Uzbekistan (L.F. Kusina, pers. comm., 1997). Occurrences of the probable synonym *Imitoceras ixion* (Hall, 1860) are known from basal Osagean (upper Tournaisian; lower Ivorian) strata near the base of the New Providence Formation (Rockford Limestone of authors), Borden Group in southern Indiana (Lineback, 1963; Furnish and Manger, 1973; Manger, 1979; Gordon, 1986) and equivalents in northwestern Tennessee (Conkin and Conkin, 1975; Manger, 1979, Mason and Chaplin, 1979); the Nancy Member of the Borden Formation in east-central Kentucky (Mason and Chaplin, 1979; Mason, 1981; Gordon and Mason, 1985); and from lower Osagean strata near the base of the Marshall Sandstone [*fide* Gordon and Mason, 1985] in eastern Michigan (Miller and Garner, 1955).

I. sciotoense (Miller and Faber, 1892) from basal Osagean [*fide* Gordon and Mason, 1985; Gordon, 1986] (upper Tournaisian; lower Ivorian) strata in the Portsmouth Shale Member, Cuyahoga Formation, southern Ohio (Hyde, 1953; Manger, 1971; 1979).

I. sinuatum Gordon, 1965; from the basal Osagean (upper Tournaisian; lower Ivorian) Walls Ferry Limestone bed, St. Joe Limestone Member, Boone Formation, northern Arkansas (Manger, 1979; Gordon, 1986).

I. tardum n. sp.; from upper middle Osagean (lower Viséan) strata in the lower member of the Mount Head Formation, east-central British Columbia.

I. wurmi Schindewolf, 1926; from middle or upper Tournaisian strata in the Rußschiefer Formation, Zadelsdorf, Thuringia, Germany (Schindewolf, 1939; Weyer, 1972b, Becker, 1993a).

I. cf. *xizangense* Liang and Zhu, 1988 (*non* Liang, 1976); from lower Viséan strata in Baoshan County, Yunnan, China (Becker, 1993a).

Imitoceras tardum Work and Nassichuk, n. sp.

Plate 1, figures 1, 2, 5–7, 13; Figure 12

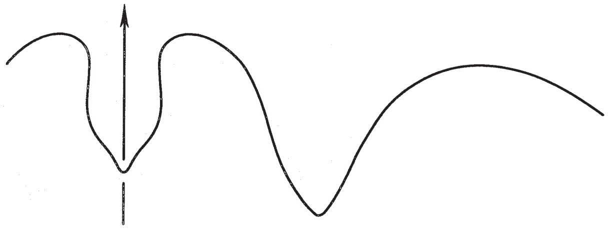


Figure 12. *External suture of* ***Imitoceras tardum*** *Work and Nassichuk, n. sp., holotype GSC 103183, GSC loc. C-80116, diameter 13 mm.*

Diagnosis. A thickly discoidal, highly compressed (W/D, 0.35; H/W, 1.7) *Imitoceras* with three deeply incised constrictions per volution (diameter 10 mm) that trace an indistinct ventral sinus. Suture with broad lanceolate ventral lobe and deep, broadly acuminate first lateral lobe.

Description. Imitoceras tardum is based on two, small, rather coarsely silicified internal moulds of 18 mm and 9.7 mm diameter (holotype GSC 103183 and paratype GSC 103184) that retain fair sutural and sculptural details. The holotype is fragmentary, and consists of nearly two thirds of an outer volution that allows exposure of earlier whorls. The conch is highly involute and thickly discoidal with strongly compressed flanks and narrowly rounded venter (H/W approximates 1.7 and W/D 0.35 at 18 mm diameter). Three strong, forward-arching constrictions are deeply impressed on the flanks of the paratype at 9 mm diameter, becoming progressively weaker ventrally (Pl. 1, fig. 5–7, 13). Each traces a lateral sinus, narrowly rounded ventrolateral salient and an indistinct ventral sinus. Similar constrictions are present on the penultimate volution of the holotype but are lost by 10–12 mm conch diameter. Shell ornament is not preserved.

The external suture (Fig. 12) includes a short lanceolate ventral lobe with moderately inflated flanks and a deep, broadly acuminate lateral lobe. Details of the umbilical lobe are obscure.

Dimensions (mm).

Specimen	**D**	**H/D**	**W/D**	**H/W**
Holotype GSC 103183	18.0	0.57	0.34	1.69
Paratype GSC 103184	9.7	0.57	0.41	1.38

Discussion. In the two available specimens, constrictions are present only on the juvenile whorls (diameter 10 mm), and are absent on the final whorl of the holotype. This change may indicate maturity; if so, the holotype is nearly complete at a small phragmocone diameter (18 mm).

Comparisons. Reference to *Imitoceras* is based on the distinctive form of the suture, especially the shortened, slightly inflated ventral lobe and relatively deep lateral lobe. However, the small size, narrow conch profile and highly distinctive prosiradiate constrictions of *Imitoceras tardum* are quite unlike typical *Imitoceras* and may ultimately warrant distinction at the generic level.

Occurrence. Lower member of the Mount Head Formation, east-central British Columbia at GSC locality C-80116.

Types. Holotype GSC 103183; paratype GSC 103184.

Genus *Irinoceras* Ruzhencev, 1947

Type species. Irinoceras arcuatum Ruzhencev, 1947b.

Diagnosis. Conch large (up to 10 cm phragmocone diameter), subdiscoidal to subglobose (W/D 0.45–0.7) and involute beyond fourth or fifth volution. Coarse transverse costae form deep rounded ventral sinus flanked by broad ventrolateral salients. External suture characterized by inflated, adorally constricted ventral lobe and deep asymmetrical lateral lobe.

Discussion. The concept of *Irinoceras* has been reviewed by Korn (1988), Kusina (1980), and Ruzhencev and Bogoslovskaya (1971) who provided a redescription of the type species. Most species of *Irinoceras* are based on limited numbers of specimens that are insufficient to characterize ontogenetic changes and intraspecific variation. The Canadian *I. bamberi* (described herein) is represented by sufficient material to permit a substantially complete documentation of its morphology (Fig. 13, 14). Early growth stages are particularly well represented and these provide clarification of the generic concept with respect to early whorl ontogeny. Contrary to previous diagnoses that characterized *Irinoceras* as involute throughout ontogeny, the genus shows marked ontogenetic change, juveniles tending to be openly umbilicate with depressed whorls. The initial three or four volutions of *Irinoceras bamberi* are widely evolute and discoidal (Fig. 14). With development of the fifth volution (5–7 mm diameter; Fig. 14) whorls expand abruptly, progressively overlapping and constricting the umbilicus, which is effectively closed by the sixth volution (8–10 mm diameter), initiating an involute condition into maturity. Homeotypes of the Namurian type species *I. arcuatum* provided by M.F. Bogoslovskaya (SUI 62474) reveal a comparable though slightly less protracted evolute juvenile stage in which umbilical constriction and closure occurs between the fourth and fifth volution (6–8 mm diameter).

Aspects of juvenile whorl ontogeny, sutural morphology, and ornament link *Irinoceras* to the problematic middle–upper Tournaisian "*Acutimitoceras*" *werriense* Group of Becker, 1993a. The systematic position of *Imitoceras werriense* (Campbell and Engel, 1963, fig. 8A–C, pl. 5, fig. 6–9) has been a matter of dispute. Kullmann (pers. comm. to B.A. Engel, 1992, cited in Roberts et al., 1993, p.

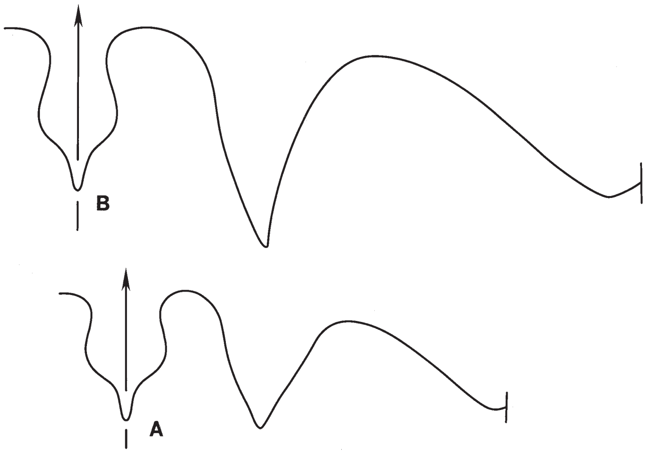


Figure 13. *External sutures of* ***Irinoceras bamberi*** *Work and Nassichuk, n. sp.* ***A****, paratype GSC 103178, GSC loc. C-11489, diameter 10.5 mm.* ***B****, holotype GSC 103174, GSC loc. C-80116, estimated diameter 46–48 mm.*

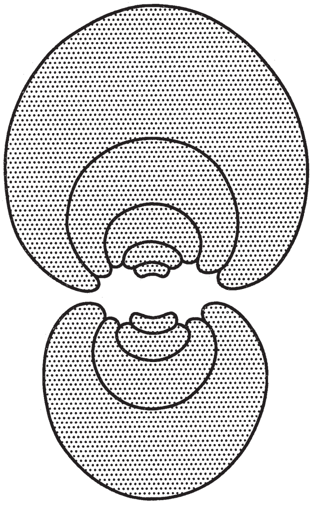


Figure 14. *Cross-section of* ***Irinoceras bamberi*** *Work and Nassichuk, n. sp., paratype GSC 103176, GSC loc. C-11489, diameter 14.3 mm.*

359) assigned the species to *Acutimitoceras* Librovitch, 1957 (type species, *Imitoceras acutum* Schindewolf, 1923) on the basis of its evolute juvenile whorls. Becker (1993a, 1996) rejected this assignment on both morphological (Becker, 1993a, p. 470) and biostratigraphic grounds (developed at length by Roberts et al., 1993, p. 358–359, 362, fig. 5), regarding *Imitoceras werriense* as an unrelated generic-level derivative of *Imitoceras* that independently acquired evolute juvenile coiling: the "*Acutimitoceras*" *werriense* Group. In fact, the presence of evolute juvenile whorls clearly excludes the species from *Imitoceras*, while the constricted *Zadelsdorfia*-like ventral lobe and strong ornament are so unlike *Acutimitoceras* that this assignment is equally unlikely. Instead, the evolute inner whorls, medially inflated ventral lobe, and rather coarse ornament make it a plausible ancestor of *Irinoceras*.

There are other, slightly younger, more advanced species that link "*Acutimitoceras*" *werriense* in the upper–middle Tournaisian to more typical *Irinoceras* species in the highest Tournaisian. The earliest of these, *Gattendorfia*? sp. of Gordon (1965, p. 170–171, fig. 35, pl. 16, fig. 15–17), occurs in the basal Osagean (lower upper Tournaisian; Ivorian) Walls Ferry Limestone of Arkansas and is presumably the basis for Becker's queried Arkansas occurrence of the "*Acutimitoceras*" *werriense* Group (Becker, 1993a, table 4). *Gattendorfia*? sp. was based on a small (16 mm diameter) thickly subdiscoidal phragmocone with fine transverse costae tracing broadly rounded ventrolateral salients and a shallow hyponomic sinus (Gordon, 1965, pl. 16, fig. 15–17). A second, larger fragment bears slightly coarser transverse ornament (3 per 2 mm on ventrolateral flank) and served as the basis for the figured suture (Gordon, 1965, fig. 35) which includes a deep medially expanded ventral lobe and simple V-shaped lateral lobe. Gordon's *Gattendorfia*? sp. was subsequently referred to *Irinoceras* by Weyer (1972b, p. 327). A considerably larger, probably conspecific representative from the same fauna was described by Gordon as *Ammonellipsites* (*Pericyclus*) sp. (Gordon, 1965, p. 174, pl. 17, fig. 1, 2; 1986, p. 12, 20). It comprises the ventral portion of a large phragmocone which bears coarse, rather widely spaced costae that trace a deep hyponomic sinus and broad ventrolateral salients. The medially inflated ventral lobe is clearly undivided and unmistakably relates *Ammonellipsites* (*Pericyclus*) sp. to *Irinoceras*, whereas the overall sutural design and V-shaped lateral lobe suggest identity with the forms attributed by Gordon to *Gattendorfia*? sp. Collectively these specimens represent a discrete species of *Irinoceras* combining the general conch form, ornament, and overall sutural design of "*Acutimitoceras*" *werriense*, with the medially inflated ventral lobe of *Irinoceras*, for which the name *Irinoceras weyeri* Work and Nassichuk, n. sp. is hereby proposed (holotype USNM 119468 [*Gattendorfia*? sp. Gordon, 1965, p. 170–171, pl. 16, fig. 15–17], paratypes USNM 119468 [*Gattendorfia*? sp. Gordon, 1965, p. 170–171, fig. 35] and USNM 119478 [*Ammonellipsites* (*Pericyclus*) sp. Gordon, 1965, p. 174, pl. 17, fig. 1,2]).

Species composition and distribution

Irinoceras altayense Wang, 1983; from upper Viséan (Brigantian; P_1) strata in the Nalinkala Formation, Xinjiang, northwest China (Liang and Wang, 1991).

I. arcuatum Ruzhencev, 1947b; from upper Viséan to lower Namurian (Dombarian; Nm_1a_1-Nm_1c_1) strata in the South Urals (Ruzhencev and Bogoslovskaya, 1971); upper Viséan (Brigantian; P_2) strata in the Aspandou Suite, southwest Darvaz, Tajikistan (Nikolaeva, 1994, 1995); and lower Namurian (Nm_1b; Pendleian; E_1) strata in the Yamansu Formation, Xinjiang, northwest China (Wang, 1981).

I. bamberi n. sp.; from upper middle Osagean (lower Viséan) strata in the lower member of the Mount Head Formation, east-central British Columbia.

I. latecostatum (Nicolaus, 1963); from upper Viséan (upper Asbian; Goa2) strata in the Rheinisches Schiefergebirge, Germany (Korn, 1988; 1989).

I. ornatissimum (de Koninck, 1882); from upper Tournaisian (Courceyan or lower Chadian; FA) strata in Ireland (Foord, 1903). Other conspecific specimens are known from the Erdbach Limestone (Erdbach horizons II and III of Krebs, 1968) in Germany (Holzapfel, 1889; Schmidt, 1925, Schindewolf, 1951); the "horizon á lydiennes" in Montagne Noire, France (Böhm, 1935; Delépine, 1935); and the upper Tournaisian (S^{1b}) Hassi Sguilma Formation, Saoura Valley, Béchar Basin, Algeria (Pareyn, 1961). Questionably conspecific specimen(s) have been reported from upper Viséan (upper Asbian; B_2b) strata at Malham, Yorkshire, England (Bisat, 1934, p. 283, 306; Riley, 1993, fig. 2).

I. romingeri (Winchell, 1862b); from upper Osagean strata [*fide* Gordon and Mason, 1985] in the middle part of the Marshall Sandstone, southwestern Michigan (Miller and Garner, 1955).

I. schulzei (Kullmann, 1963); from upper Viséan ("untere oder mittlere *Goniatites*-Stufe"; Goa or Goß) strata, Cantabrien Mountains, León, northern Spain.

I. stevanovici (Kullmann *in* Stevanovic and Kullmann, 1962); from lower Namurian (Arnsbergian; E_2) strata in Serbia.

I. tuba Campbell, Brown and Coleman, 1983; from upper Viséan (middle or upper Asbian; B_2a-B_2b) strata [*fide* Roberts et al., 1993] in the Mundubbera Sandstone, Queensland; and upper lower or lower middle Viséan (Arundian; BB) strata [*fide* Roberts et al., 1993] in the Flagstaff Formation, New South Wales.

I. weyeri n. sp.; from the basal Osagean (upper Tournaisian; lower Ivorian) Walls Ferry Limestone bed, St. Joe Limestone Member, Boone Formation, northern Arkansas (Gordon, 1965; Weyer, 1972b; Manger, 1979).

Irinoceras bamberi Work and Nassichuk, n. sp.

Plate 1, figures 3, 4, 8–12; Figures 13, 14

Etymology. Irinoceras bamberi is named to recognize the contributions of E.W. Bamber (GSC Calgary) to the Lower Carboniferous biostratigraphy of western North America.

Diagnosis. A thickly subdiscoidal species of *Irinoceras* (W/D, about 0.6 at 50 mm diameter) characterized by uniformly rounded whorl profiles that lack a distinct umbilical shoulder and lateral lobes with relatively straight, unflexed flanks.

Description. Included within *Irinoceras bamberi* are 35 largely fragmented silicified phragmocones ranging from 3 to 48 mm in diameter. The largest specimen, holotype GSC 103174 (Pl. 1, fig. 10, 11), is an incomplete but moderately well-preserved internal mould of 48 mm restored diameter that retains details of conch ornament and external suture. Paratypes GSC 103175–103182 are well preserved, juvenile to submature phragmocones (3–17 mm diameter) which collectively display details of early whorl ontogeny covered previously under the generic heading. Whorl sections at larger diameters are uniformly rounded across the venter and ventrolateral flanks, merging imperceptibly toward the umbilical margin without development of a shoulder. The umbilicus is virtually closed at diameters exceeding 10 mm. Remnants of shell ornament are retained on holotype GSC 103174 and paratype GSC 103175 (Pl. 1, fig. 3, 4, 12). Delicate rounded costae (6 per 5 mm across the venter at 45 mm diameter and 18 per 5 mm at 13 mm diameter) trace a deep, rounded, hyponomic sinus flanked by broad ventrolateral salients. Constrictions (3 per volution) trace a broad but considerably more subdued hyponomic sinus that does not align exactly with external ornament.

At diameters of less than 15 mm the external suture of *Irinoceras bamberi* is distinguished by a broad inflated ventral lobe and a broad expanded lateral lobe with relatively straight, divergent flanks (Fig. 13A). Narrowing of the ventral lobe at diameters greater than 20 mm coincides with a more pronounced deepening of the lateral lobe. The mature suture at 48 mm diameter (Fig. 13B) is characterized by a medially inflated ventral lobe, a narrow, asymmetrically rounded first lateral saddle, a deep, narrowly acuminate lateral lobe, its flanks straightened and relatively unflexed; and a broadly rounded, U-shaped umbilical lobe.

Dimensions (mm).

Specimen	D	U/D	H/D	W/D	H/W
Holotype GSC 103174	*48	–	0.61	0.59	1.04
Paratype GSC 103175	17.0	–	0.61	0.63	0.95
Paratype GSC 103176	14.3	0.02	0.58	0.64	0.92
	10.5	0.06	0.51	0.65	0.88
	8.5	0.09	0.44	0.64	0.80
	5.9	0.24	0.36	0.64	0.68
	4.5	0.38	0.55	0.62	0.57
Paratype GSC 103177	14.3	0.02	0.58	0.64	0.91
Paratype GSC 103178	10.9	0.05	0.55	0.65	0.85
Paratype GSC 103179	8.3	0.08	0.54	0.67	0.80
Paratype GSC 103180	6.6	0.17	0.52	0.63	0.81
Paratype GSC 103181	5.8	0.23	0.46	0.65	0.73
Paratype GSC 103182	3.4	0.41	0.32	0.65	0.50

*Estimate

Comparisons. Irinoceras bamberi appears to be closest to the upper Viséan–lower Namurian (Dombarian) type species, *I. arcuatum* Ruzhencev, 1947b. However, *I. arcuatum* is slightly more compressed than *I. bamberi* (W/D, 0.51 *vs.* 0.59; H/W, 1.17 *vs.* 1.04 at 48 mm diameter) with a slightly wider, more conspicuously inflated ventral lobe and a lateral lobe with a flexed ventrad flank and asymmetrically constricted tip. Both of these species lack the rather pronounced umbilical shoulder present on late volutions of *I. ornatissimum* (de Koninck, 1882) (see Foord, 1903, pl. 37, fig. 1b; Pareyn, 1961, pl. 1, fig. 12, 13). Comparable growth stages of *I. bamberi* (diameter 20 mm) resemble the small holotype of *I. romingeri* (Winchell, 1862b) in conch form, although the whorls of the latter are slightly more compressed (W/D, 0.52 *vs.* 0.60 at 18–20 mm diameter). Also, the lateral lobe in *I. romingeri* (whorl height 10 mm) is narrowly attenuate and conspicuously deeper than the ventral lobe, whereas in *I. bamberi* this element is widely expanded with strongly divergent flanks, and approximates the ventral lobe in depth.

Occurrence. Lower member of the Mount Head Formation, east-central British Columbia at GSC localities C-80116 (type locality: holotype GSC 103174; paratypes GSC 103177, 103179–103182), C-11489 (paratypes GSC 103175, 103176, 103178), and C-178983.

Types. Holotype GSC 103174; paratypes GSC 103175–103182.

Suborder GONIATITINA Hyatt, 1884

Superfamily PERICYCLACEAE Hyatt, 1900

Family PERICYCLIDAE Hyatt, 1900

Discussion. The Pericyclidae are distinctive ancestral (middle Tournaisian–lower Viséan) Goniatitina characterized by prominent transverse sculpture. Ornament is highly variable, ranging from fine to coarse ribs that may cover the entire conch or be confined to the dorsolateral flanks or to juvenile whorls. The ventral lobe was initially narrow and parallel-sided in ancestral forms but during phylogenesis lobe flanks progressively widened, diverging adorally, with a corresponding decrease in width of the adjacent lateral saddle. Concurrently, there was a progressive increase in the height of the median saddle from incipiently bifid in ancestral forms to moderately deep (*hs/hl* about 0.45) in advanced forms.

Ancestry of the group, in the earliest middle Tournaisian (middle Kinderhookian) was in *Goniocyclus* Gordon, 1986 (type species, *Goniatites blairi* Miller and Gurley, 1896). These diminutive (generally less than 30 mm) ancestral pericyclids are distinguished by primitive incipiently bifid ventral lobes and acutely angular ventral sinuses. The earliest record is an undescribed species from about the *Siphonodella sandbergi*–Lower *Siphonodella crenulata* Zone boundary in the Hannibal Shale of Missouri (Work et al., 1988; Becker, 1993a; Work, work in progress, 1999). Typical *Goniocyclus* faunas, as described by Gordon (1986), characterize the *Siphonodella isosticha*–Upper *S. crenulata* Zone where it is represented by at least six distinctive species in Midcontinent and Cordilleran North America. The upper level of the generic range is unknown, but similar forms probably persist into the lower Osagean *Gnathodus typicus* Zone (*sensu* Lane et al., 1980).

A new pericyclid genus *Goniocycloides* is proposed here to accommodate middle Osagean forms with coarse ribs and an angular ventral sinus similar to *Goniocyclus*, but distinguished by deeply subdivided (*hs/hl*, 0.35) ventral lobes with divergent flanks and narrowly rounded first lateral saddles. Lower Osagean (Ivorian) stratigraphic intermediates are currently unknown.

Polaricyclus Riley, 1991 (type species, *Ammonellipsites* (*Fascipericyclus*) *polaris* Gordon, 1957) was proposed for pericyclids with *Ammonellipsites*-like conch form but distinguished by a ventral lobe with divergent flanks, a low median saddle and rounded first lateral saddles. The Alaskan type species *P. polaris* is thickly subdiscoidal with a narrow umbilicus and moderately dense ribbing. A closely related species *P. canadensis* is established below for slightly more compressed and densely ribbed British Columbia material. The new species affords a basis for reassessment of several isolated upper Osagean ammonellipsitins from the Midcontinent and Cordillera which are normally included in *Ammonellipsites* or *Stenocyclus* (e.g., *Ammonellipsites* (*Stenocyclus*) *ballardensis* Gordon, 1965).

Range. Pericyclidae originated near the lower–middle Tournaisian (lower–upper Hastarian) boundary (Gordon, 1986; Kullmann et al., 1991; Becker, 1993a,b; Work, work in progress, 1999) and extend into the lower Viséan (Arundian).

Genus *Goniocycloides* Work and Nassichuk, n. gen.

Type species. Goniocycloides ochakensis n. sp.

Diagnosis. Subdiscoidal pericyclids with moderately large umbilicus (W/D, 0.45–0.6; U/D, 0.2–0.3) and broadly arched venter. Persistant umbilical nodes give rise to strong transverse ribs that increase by bifurcation and intercalation and trace a deep angular hyponomic sinus. Ventral lobe characterized by divergent flanks and high attenuated median saddle (*hs/hl*, 0.35). First lateral saddle wide and narrowly rounded.

Discussion. Derivation of *Goniocycloides* was from the upper Kinderhookian (middle Tournaisian, Hastarian) ancestral pericyclid *Goniocyclus* Gordon, 1986 (type species, *Goniatites blairi* Miller and Gurley, 1896). Both genera are moderately evolute with compressed whorls bearing coarse ribs that trace an angular hyponomic sinus. However, *Goniocycloides* represents a distinct stage of sutural advancement over *Goniocyclus*. Species of *Goniocyclus* are smaller (diameter 30 mm at maturity) than type *Goniocycloides* (diameter at least 60–70 mm) and at maximum size have a primitive incipiently bifid ventral lobe with nearly vertical flanks and a broadly rounded lateral saddle (see Gordon, 1986, fig. 12; Popov and Kusina, 1997, fig. 5; and discussion below). In contrast, mature *Goniocycloides* has a ventral lobe with long, expanded, attenuate prongs and a deep median saddle that divides the lobe to one-third its height, and divergent flanks that pass into a narrowly rounded first lateral saddle. The primitive sutural features of *Goniocyclus* may be partly a function of its comparatively small mature size. However, the strongly divergent ventral lobe flanks and higher median saddle of *Goniocycloides* readily distinguish even juvenile representatives from similar sized adult *Goniocyclus* (contrast Fig. 16 with Gordon, 1986, fig. 12).

Species composition and distribution

Goniocycloides ochakensis n. sp.; from upper middle Osagean (lower Viséan) strata in the lower member of the Mount Head Formation, east-central British Columbia.

Goniocycloides ochakensis Work and Nassichuk, n. sp.

Plate 2, figures 3–5, 9–16; Figures 15–17

Description. Goniocycloides ochakensis is based on hundreds of silicified phragmocones ranging from 4 to

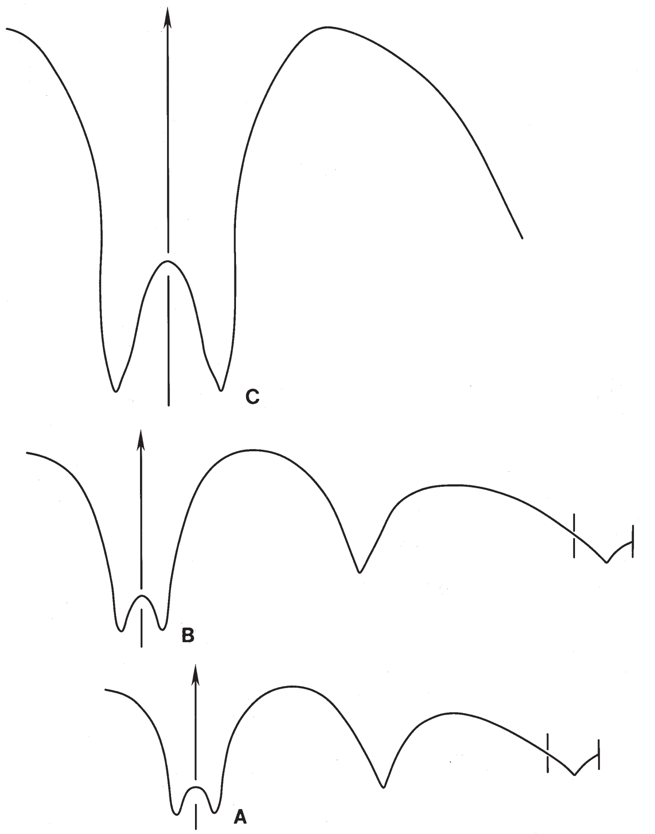


Figure 15. *External sutures of **Goniocycloides ochakensis** Work and Nassichuk, n. sp. **A**, paratype GSC 103194, GSC loc. C-80116, diameter 12.5 mm. **B**, paratype GSC 103187, GSC loc. C-80116, diameter 16 mm. **C**, paratype GSC 103196, GSC loc. C-7400, estimated diameter 33–35 mm.*

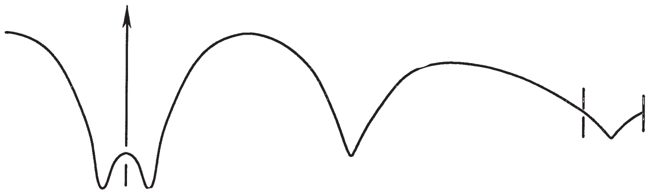


Figure 16. *External suture of **Goniocycloides ochakensis** Work and Nassichuk, n. sp., paratype GSC 103195, GSC loc. C-80116, diameter 14.5 mm.*

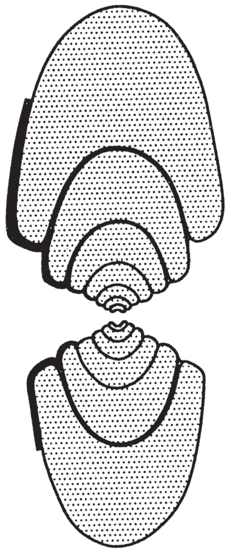


Figure 17. *Cross-section of **Goniocycloides ochakensis** Work and Nassichuk, n. sp., paratype GSC 103187, GSC loc. C-80116, diameter 22.9 mm. True shell thickness is represented.*

30 mm in diameter. Holotype GSC 103185 is a well preserved preadult specimen 21 mm in diameter, which expresses characteristic features of conch form, shell sculpture and suture (Pl. 2, fig. 11, 12). The largest fragment, paratype GSC 103196, achieves a reconstructed whorl height of 18 mm, corresponding to a phragmocone diameter of 40 mm, indicating that ultimate conch diameter exceeded 60 to 70 mm in this species. Conchs are thinly subdiscoidal and moderately evolute (W/D, 0.45–0.6; U/D approximately 0.25). Umbilical shoulders are sharply rounded and flanks somewhat flattened and slightly convergent to the uniformly rounded venter (Fig. 17). Twelve to 14 elongate umbilical nodes per volution occur at diameters exceeding 10 mm. Nodes are distinctly prorsiradiate and give rise to coarse prorsiradiate ribs that strengthen markedly across the flank. In general one rib is directly connected to the node and a second is tenuously linked or intercalates, while two long intercalatories, rarely one, originate low on the flank. Ribs number 38 to 42 per volution at diameters exceeding 10 mm. They project forward from the umbilical shoulder to trace a low dorsolateral salient and a very shallow lateral sinus across midflank then sweep evenly back across the ventrolateral zone to midventer, forming a deep, V-shaped hyponomic sinus that progressively deepens and narrows with increased conch diameter. These features are least prominent near the umbilical shoulder of internal moulds, becoming progressively stronger ventrally (Pl. 2, fig. 9). Three or four constrictions per volution trace a shallow hyponomic sinus and are most prominent on inner volutions less than 15 mm diameter.

Sutural variation in *Goniocycloides ochakensis* is represented in Figures 15 and 16. In early stages, the suture is characterized by ventral lobes with divergent flanks and short, asymmetrical, bluntly pointed ventral prongs (Fig. 15A,B, 16). The first lateral saddle is wide and broadly rounded and the lateral lobe is conspicuously shorter than the median saddle. Beyond 15 to 20 mm diameter, the median saddle becomes progressively higher and noticeably attenuated and the first lateral saddle is narrowly rounded, trending toward angularity (Fig. 15C).

Dimensions (mm).

Specimen	D	U/D	H/D	W/D	H/W
Paratype GSC 103186	25.5	0.25	0.44	0.47	1.00
Paratype GSC 103187	22.9	0.25	0.45	0.44	1.03
	17.0	0.24	0.46	0.46	1.00
	12.7	0.23	0.47	0.51	0.92
	9.4	0.27	0.48	0.56	0.85
Holotype GSC 103185	20.3	0.26	0.46	0.46	1.00
Paratype GSC 103188	18.5	0.27	0.46	0.46	1.00
Paratype GSC 103189	15.0	0.22	0.49	0.50	0.99
Paratype GSC 103190	12.8	0.23	0.47	0.50	0.94
Paratype GSC 103191	8.0	0.25	0.49	0.58	0.85

Comparisons. The only ammonoids with which *Goniocycloides ochakensis* is likely to be confused are species of *Goniocyclus* Gordon, 1986. Several *Goniocyclus* species had already developed umbilical bullae or node-like swellings by the late Kinderhookian (e.g., *Goniocyclus antelopensis* Gordon, 1986 and *G.*? *decipiens* Gordon, 1986) and they are well developed in a contemporary form attributed by Gordon to *Rotopericyclus* Turner, 1948 (type species, *Pericyclus rotuliformis* Crick, 1899), *R. pinyonensis* Gordon, 1986. However, comparison of the types and other figured materials indicates that *Rotopericyclus pinyonensis* is not congeneric with *Rotopericyclus rotuliformis*. Both the relatively coarse, weakly dichotomous primary ribs and subangular ventral sinus of *R. pinyonensis* are more compatible with assignment to *Goniocyclus*, as is the ventral lobe configuration.

Early growth stages of *Goniocycloides ochakensis* show a marked similarity in conch form and ornament to *Goniocyclus pinyonensis* (Gordon, 1986), especially the larger Idaho paratype (Gordon, 1986, fig. 11.25), but the species may be distinguished readily by their sutures. At a diameter of 15 to 16 mm the ventral lobe of the holotype of *G. pinyonensis* (Gordon, 1986, fig. 12) has nearly vertical flanks and only an incipient median saddle, whereas in *G. ochakensis* this element has strongly divergent flanks and a comparatively deep secondary ventral saddle (*hs/hl*, 0.24; Fig. 16). Sutures are unknown in the larger Idaho paratype of *G. pinyonensis*.

Occurrence. Lower member of the Mount Head Formation, east-central British Columbia at GSC localities C-80116 (type locality: holotype GSC 103185; paratypes GSC 103186–103195, 103197, 103198), C-178983, C-11489, and C-7400 (paratype GSC 103196).

Types. Holotype GSC 103185; paratypes GSC 103186–103198.

Genus *Polaricyclus* Riley, 1991

Type species. Ammonellipsites (*Fascipericyclus*) *polaris* Gordon, 1957.

Diagnosis. Small (35 mm at maturity), subdiscoidal (W/D, 0.45–0.6) pericyclids with compressed whorls (H/W greater than 0.9) and narrow umbilicus (U/D less than 0.2). Numerous fine transverse ribs increasing in number on flanks and venter through intercalation, and tracing a broad, shallow hyponomic sinus. Ventral lobes characterized by strongly divergent flanks and weakly incised median saddles (*hs/hl* less than 0.2). First lateral saddle wide and broadly rounded.

Discussion. Polaricyclus was proposed for small pericyclids with *Ammonellipsites*-like conch form and ornament but distinguished by a ventral lobe with strongly divergent flanks and well-rounded first lateral saddle (Riley, 1991). Riley selected as the type species *Ammonellipsites* (*Fascipericyclus*) *polaris* Gordon, 1957, which was described from the Lisburne Group in the west-central Brooks Range, Alaska. The tightly umbilicate juvenile whorls of *P. polaris* lack a serpenticonic stage and are cadiconic and somewhat involute by the third whorl and a diameter of only 3 to 4 mm (Gordon, 1957, fig. 10A). In later stages the conch is thickly subdiscoidal (W/D, 0.55–0.65) and narrowly umbilicate with involute, moderately compressed whorls (U/D, 0.1–0.18; H/W, 0.8–0.9). Divergence of the ultimate one-third volution in the holotype (USNM 118952) and an unfigured paratype (USNM 118953) suggests maturity at 25–30 mm diameter. Riley's generic diagnosis emphasizes features of the external suture which, though well described (Gordon, 1957, p. 34), are inadequately portrayed by Gordon's (1957, fig. 10B) single figured suture, which was based on a juvenile paratype (USNM 118953; same as Gordon, 1957, pl. 4, fig. 7–10) at 9 mm conch diameter. The adult suture of *P. polaris* (Fig. 18) is distinguished by a widely divergent ventral lobe with small, bluntly rounded ventral prongs, a low median saddle (*hs/hl*, 0.2) and a wide, asymmetrically rounded first lateral saddle; the lateral lobe is widely acuminate with expanded flanks.

In addition to the type species, Riley included in *Polaricyclus, Ammonellipsites*? *raricostatus* Kusina, 1980, *Pericyclus minimus* Hind, 1910, and questionably, *Pericyclus kayseri* Schmidt, 1925. With the exception of *P. raricostatus*, original illustrations and descriptions of

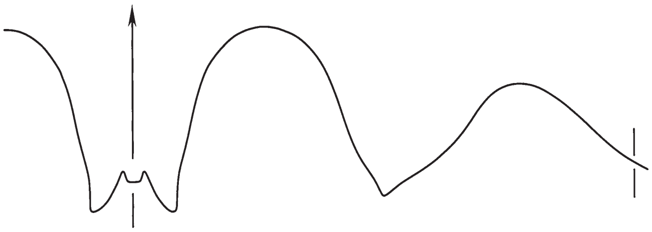


*Figure 18. External suture of **Polaricyclus polaris** (Gordon, 1957) from the Osagean Kuna Formation, Kiligwa River, De Long Mountains, Brooks Range, northern Alaska (USGS loc. 11857); paratype USNM 118953 (same as Gordon, 1957, fig. 10A), estimated diameter 16 mm.*

these species suggest the dimensions and morphology fall within the range of morphology of *Ammonellipsites* Parkinson, 1822 (type species, *Ellipsolithes funatus* Sowerby, 1813). The acute first lateral saddle and high median saddle (*hs/hl,* 0.43) of *P. kayseri* (as illustrated by Holzapfel 1889, pl. 3, fig. 8b) necessitates reference to *Ammonellipsites*. In the absence of illustrated sutures, *P. minimus* cannot be fully assessed, however its protracted serpenticonic stage (illustrated by Smyth, 1951, text-fig. 1g) is quite unlike the tightly umbilicate, cadiconic early whorls of *P. polaris* or *P. canadensis* (described herein) and suggests that it might likewise be referred to *Ammonellipsites*. It is referred here to *Polaricyclus* provisionally, pending documentation of the suture.

Ammonellipsites? *raricostatus* Kusina, 1980 from the Karskaya Suite of Pai-Khoy in Arctic Russia exhibits a sutural outline similar to *P. polaris* but the conch is much more globose and widely umbilicate (U/D, 0.33 *vs.* 0.18 at 24 mm diameter) with higher, steeper umbilical walls and strongly depressed, as opposed to compressed, whorls (H/W, 0.46 *vs.* 0.9–1.0 at 22–24 mm diameter). Additionally, it bears widely spaced, simple transverse ribs (22 per whorl at 24 mm diameter, compared with 60), separated by wide interspaces. It is immediately distinguishable from *P. polaris* and *P. canadensis* and seems to represent a discrete generic-level taxon that includes at least one additional undescribed species from the South Urals in the collections of L.F. Kusina at the Paleontological Institute, Russian Academy of Sciences, Moscow.

Polaricyclus unites a compact group of small, tightly umbilicate ammonellipsitins characterized by their dense intercalate ribbing (50–90 per volution at 20 mm diameter) and relatively simple suture line. Three North American species are recognized: *P. polaris,* characterized by equidimensional whorls (H/W, 0.9 at 20 mm diameter), *P. canadensis*, which is slightly compressed (H/W, 1.0) at a comparable conch diameter, and *P. ballardensis* (Gordon, 1965) which is more compressed (H/W, 1.18). Juveniles of all these species share a distinctive cadiconic whorl stage characterized by tightly umbilicate whorls with fine transverse ribs that can be distinguished at diameters as small as 3–4 mm (Pl. 2, fig. 17, 18; see also Sandberg and Gutschick, 1984, pl. 8, fig. J).

Stenocyclus Schindewolf, 1951 (type species, *Pericyclus carinatus* Schindwolf, 1926) is related to *Polaricyclus*; like the latter, it has a subdiscoidal, narrowly umbilicate conch with prominent wire-like ornament. However, the suture of *Stenocyclus* is considerably advanced over *Polaricyclus*, as indicated by the strongly angular, even attenuate first lateral saddles in even submature forms (see Schindewolf, 1926, fig. 8b; 1939, fig. 6b). In addition, the ventral saddles in *Stenocylus* are more deeply incised than in *Polaricyclus* (*hs/hl*, 0.30 *vs.* 0.15 at 10–12 mm diameter).

Species composition and distribution

Polaricyclus ballardensis (Gordon, 1965); from the upper Osagean (lower Viséan) Grand Falls Member, Boone Formation, southeastern Kansas. Unpublished, but verified, specimens are known from upper Osagean strata in the Nada Member, Borden Formation, east-central Kentucky and the New Providence Member, Borden Formation, north-central Kentucky (Work and Mason, work in progress, 1999).

P. canadensis n. sp.; from upper middle Osagean (lower Viséan) strata in the lower member of the Mount Head Formation, east-central British Columbia.

P. minimus (Hind, 1910); from the latest Tournaisian (middle Chadian; upper FA) [*fide* Riley, 1991] Milldale Limestone, Derbyshire, England (Smyth, 1951).

P. polaris (Gordon, 1957); from middle or upper Osagean (upper Tournaisian or lower Viséan) strata in the Kuna Formation, Lisburne Group, De Long Mountains, Brooks Range, northern Alaska.

P. n. sp.; from middle Osagean (upper Tournaisian) strata in the Clausen Formation, southwestern District of Mackenzie, Northwest Territories.

A compressed juvenile pericyclid figured by Sandberg and Gutschick (1984, pl. 8, fig. J) from the Delle Phosphatic Member of the Woodman Formation in Utah is referrable to *Polaricylus*; although sutures are not visible, the form of the constrictions and details of shell sculpture indicate affinity with *P. ballardensis* and *P. canadensis.*

Polaricyclus canadensis Work and Nassichuk, n. sp.

Plate 2, figures 1, 2, 6–8, 17, 18; Figures 19, 20

Diagnosis. A thickly subdiscoidal, narrowly umbilicate species of *Polaricyclus* (W/D, 0.5 and U/D, 0.08 at 20 mm

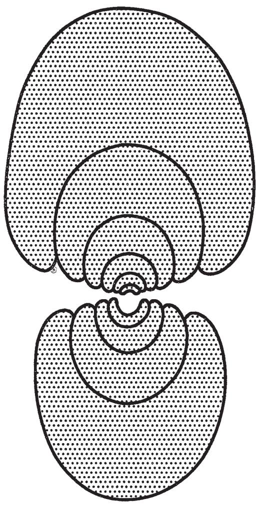


Figure 19. *Cross-section of* ***Polaricyclus canadensis*** *Work and Nassichuk, n. sp., paratype GSC 103201, GSC loc. C-80116, diameter 16 mm.*

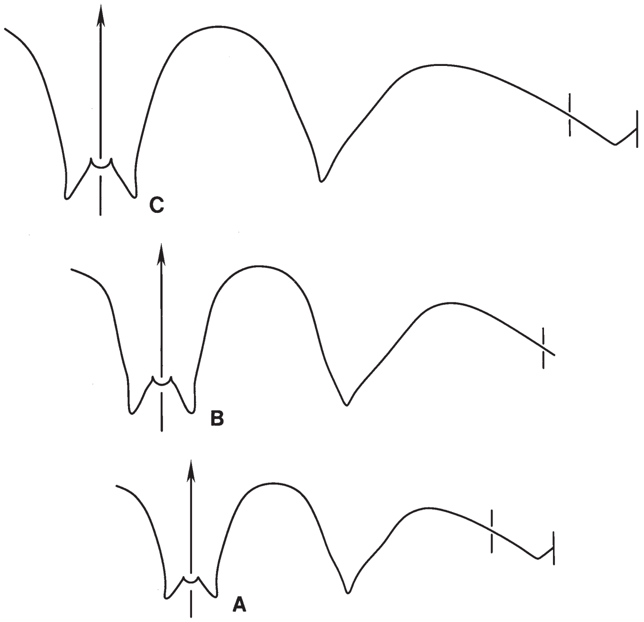


Figure 20. *External sutures of* ***Polaricyclus canadensis*** *Work and Nassichuk, n. sp.* ***A****, paratype GSC 103206, GSC loc. C-80116, diameter 10.5 mm.* ***B****, paratype GSC 103207, GSC loc. C-80116, diameter 13.4 mm.* ***C****, holotype GSC 103199, GSC loc. C-80116, diameter 21 mm.*

diameter) with 62 to 72 thin, sharply defined ribs that form a broad but shallow hyponomic sinus. The mature suture is characterized by a wide and deeply attenuate first lateral lobe that is broadly expanded adorally.

Description. Polaricyclus canadensis is represented by more than 300 silicified phragmocones, ranging from 3 to over 20 mm in diameter. The largest specimen, holotype GSC 103199, is a well preserved phragmocone that retains the dorsolateral trace of the body chamber extending slightly more than three quarters of a volution in length (Pl. 2, fig. 7). Terminal divergence and reinforcement of this ridge indicates that the specimen attained maturity at a phragmocone diameter of 21.4 mm. Conchs are subdiscoidal and involute throughout ontogeny (W/D, 0.5–0.6; U/D less than 0.1), with equidimensional to slightly compressed whorls (H/W, 0.9–1.05) and broadly rounded venter. The umbilical wall is uniformly rounded, merging smoothly into the flank without an abrupt shoulder (Fig. 19). Thin, closely spaced primary ribs extend forward from the umbilical wall where they form a shallow dorsolateral sinus centered on the umbilical shoulder. Ribs follow a straight course across the flanks, passing ventrally into a shallow hyponomic sinus. Generally one, rarely two, intercalatories appear between adjacent primaries on adumbilical flank with additional shorter intercalatories, usually orad, inserted at mid-flank. Ribs number 62 to 72 per volution at diameters exceeding 10 mm. Four or five moderately incised constrictions per volution are most prominent on internal moulds at diameters less than 10 mm.

The external suture at 21 mm diameter (Fig. 20C) is characterized by a deep ventral lobe with divergent, attenuate prongs, low median saddle (*hs/hl*, 0.2), and flanks that diverge abruptly orad into a wide, broadly rounded first lateral saddle; a widely acuminate lateral lobe with constricted tip; and a small, V-shaped umbilical lobe centered on the umbilical wall.

Dimensions (mm).

Specimen	D	U/D	H/D	W/D	H/W
Polaricyclus canadensis					
Holotype GSC 103199	21.4	0.08	0.52	0.50	1.04
Paratype GSC 103200	19.0	0.09	0.52	0.52	1.01
	14.0	0.08	0.52	0.54	0.96
Paratype GSC 103201	16.0	0.08	0.55	0.53	1.05
	11.6	0.08	0.53	0.55	0.95
	8.7	0.08	0.55	0.59	0.94
Paratype GSC 103202	13.2	0.06	0.55	0.55	1.00
Paratype GSC 103203	8.9	0.08	0.55	0.62	0.89
Paratype GSC 103204	5.9	0.08	0.55	0.62	0.89
Paratype GSC 103205	4.2	0.09	0.52	0.74	0.71
Polaricyclus polaris					
Holotype USNM 118952	25.8	0.18	0.51	0.55	0.92

Specimen	D	U/D	H/D	W/D	H/W
Paratype USNM 118953	17.1	0.13	0.51	0.58	0.89
	12.6	0.12	0.49	0.60	0.83
	9.0	0.11	0.53	0.67	0.80
Paratype USNM 118953	10.5	0.10	0.56	0.63	0.89
Polaricyclus ballardensis					
Holotype USNM 119479	*21	0.14	0.55	0.44	1.18

*Estimate

Comparisons. Polaricyclus canadensis can be distinguished from *P. polaris* by its narrower conch with more compressed whorls (W/D, 0.52 *vs.* 0.58; H/W, 1.0 *vs.* 0.9 at 17 mm diameter), slightly smaller umbilicus (U/D, 0.08 *vs.* 0.13 at 17 mm diameter), higher rib density (70 per whorl at 20 mm diameter, compared with 55) and more pronounced ventral sinus. Sutures of *P. canadensis* are similar in general proportions to those of *P. polaris* but differ in moderate attenuation of the ventral prongs and first lateral lobe. Also, the first lateral lobe in *P. polaris* is broadly expanded adorally with divergent flanks, whereas in *P. canadensis* this element is asymmetrical and medially expanded with an asymmetrically constricted tip. *Polaricyclus canadensis* is distinguished from *P. ballardensis* by its lower rib density (70 per whorl at 20 mm diameter, compared with 90) and more pronounced ventral sinus.

The subdiscoidal, narrowly umbilicate conch and fine wire-like ribbing of *P. canadensis* may suggest affinities with species of *Stenocyclus* (e.g., *S.* aff. *virgatus* of Popov, 1968). The broad, rounded lateral saddle and lower median saddle (*hs/hl* less than 0.20 at 20 mm diameter, compared with 0.34 in *Stenocyclus*; see Popov, 1968, fig. 22), however, necessitate assignment to *Polaricyclus*.

Occurrence. Lower member of the Mount Head Formation, east-central British Columbia at GSC localities C-80116 (type locality: holotype GSC 103199; paratypes GSC 103200–103208), C-178983, C-11489, and C-7400.

Types. Holotype GSC 103199; paratypes GSC 103200–103208.

Family MUENSTEROCERATIDAE Librovitch, 1957

Genus *Eurites* Kusina, 1973

Type species. Eurites latus Kusina, 1973.

Diagnosis. Large (5–10 cm), thickly subdiscoidal to globose (W/D, 0.5–0.9) muensteroceratids with moderately to strongly depressed whorls (H/W, 0.4–0.75) and narrow umbilicus (U/D less than 0.3). Transverse striae and constrictions form a broad, rounded, ventral sinus flanked by high dorsolateral salients centered near the umbilical margin. The external suture is muensteroceratid, exhibiting a deep, narrow, ventral lobe (*wl/hl*, 0.3–0.45) with straight parallel flanks.

Discussion. Eurites sphaeroidalis (M'Coy, 1844) and species such as *E. corpulentus* (Crick, 1899), *E. ellipsoidalis* (Crick, 1899), *E. corpulentissimus* (Schindewolf, 1951), and *E. saginatus* (Gordon, 1957) form a compact, predominantly upper Tournaisian (upper Courceyan–lower Chadian) group, the "*sphaeroidale* group" of Delépine (1940b) and Pareyn (1961), distinguished from the ancestral *Muensteroceras* by their subglobose, as opposed to subdiscoidal conch form (W/D, 0.7–0.8 *vs.* 0.4–0.5), and massive, broadly rounded whorls.

Although *Eurites* has been regarded primarily as an upper Tournaisian form (Riley, 1991, fig. 1; 1996, text-fig. 3), its range is now extended upward into the basal Viséan. Occurrences of this age are also present in Ireland, where species have been reported from upper Chadian strata (*fide* Riley, 1996) in the Tober Colleen Formation by Smyth (1951).

Species composition and distribution

Eurites browni (M'Coy, 1844); from upper Tournaisian (Courceyan or lower Chadian) Waulsortian limestones in Ireland (Foord, 1903; Delépine, 1940b).

E. corpulentissimus (Schindewolf, 1951); from the mid-Dinantian Erdbach Limestone, Winterberg, Germany. Other questionably conspecific specimens have been reported from upper Tournaisian or lower Viséan (Chadian) strata in the Genicera Formation ("Marbre Griotte"), Cantabrian Mountains, León, northern Spain (Kullmann, 1961).

E. corpulentus (Crick, 1899); from upper Tournaisian (Courceyan or lower Chadian) Waulsortian limestones in Ireland (Foord, 1903); lower Viséan (upper Chadian; upper FA) [*fide* Riley, 1996] strata in the Tober Colleen Formation (=Rush Slates of Smyth, 1951), Co. Dublin, Ireland (Smyth, 1951); upper Tournaisian or lower Viséan (Chadian) strata in the Genicera Formation ("Marbre Griotte"), Cantabrian Mountains, León, northern Spain (Kullmann, 1961; Wagner-Gentis, 1964); the upper Tournaisian Hassi Sguilma Formation (S^{1b}), Saoura Valley, Béchar Basin, Algeria (Pareyn, 1961); and the Bordj d'Erfoud (level a), Morocco (Delépine, 1941).

E. ellipsoidalis (Crick, 1899); from upper Tournaisian (Courceyan or lower Chadian) Waulsortian limestones in Ireland (Foord, 1903).

E. inflatus (Delépine, 1940a); from upper Tournaisian (lower Moliniacian) Waulsortian limestones at Pauquys and Dréhance, Belgium.

E. kusinae n. sp.; from upper middle Osagean (lower Viséan) strata in the lower member of the Mount Head Formation, east-central British Columbia.

E. latus Kusina, 1973; from the upper Tournaisian Karskaya Suite, Kara River, Pai-Khoy, Arctic Russia.

E. saginatus (Gordon, 1957); from Lower Mississippian [?middle Osagean] strata in the western De Long Mountains, Brooks Range, northern Alaska.

E. sphaeroidalis (M'Coy, 1844); from upper Tournaisian (Courceyan or lower Chadian) Waulsortian limestones in Ireland (Foord, 1903; Delépine, 1940b).

E. n. sp; from middle Osagean strata in the Nancy Member, Borden Formation, east-central Kentucky (Gordon and Mason, 1985; C.E. Mason, pers. comm., 1996).

Eurites kusinae Work and Nassichuk, n. sp.

Plate 3, figures 5, 6, 13, 15; Figure 21

Etymology. Named for L.F. Kusina (Paleontological Institute, Russian Academy of Sciences, Moscow).

Diagnosis. A globose species of *Eurites* (W/D, 0.9 at 25 mm diameter) characterized by strongly depressed whorls (H/W, 0.4–0.45) lacking constrictions, and sutures with a ventral lobe with slightly divergent flanks.

Description. Approximately 25 specimens are assigned to *Eurites kusinae*. The largest, holotype GSC 103209 (Pl. 3, fig. 13, 15), is an incomplete, slightly distorted silicified internal cast of 26 mm restored diameter that preserves sutural details and approximate conch parameters. Paratypes GSC 103211–103213 are well preserved, relatively complete, internal moulds of immature phragmocones, whereas the remainder are fragmentary juvenile phragmocones ranging from 5 to 9 mm in diameter. Conchs are subspherical (W/D, 0.9–1.0) throughout observed ontogeny with strongly depressed whorls (H/W, 0.45–0.5) and a deep, narrow umbilicus (U/D, 0.1–0.25). Whorl sections are broadly rounded across the venter and ventrolateral flanks and achieve maximum width at the umbilical shoulder. The umbilical shoulder is narrowly rounded and the umbilical walls are wide and gently convex. Shell ornament is not preserved, but the internal mould is smooth. Constrictions are absent.

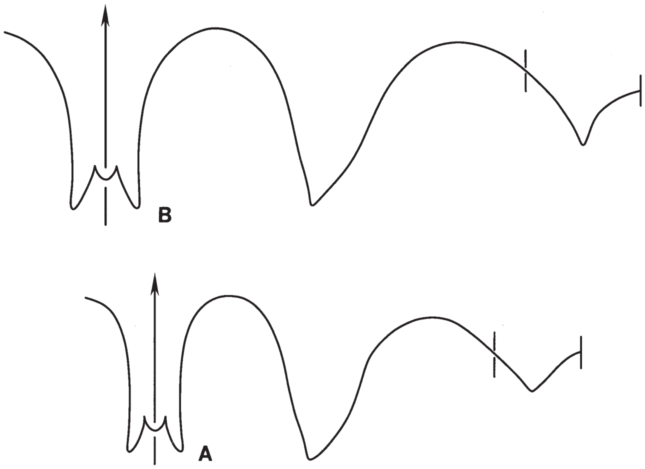


Figure 21. *External sutures of* ***Eurites kusinae*** *Work and Nassichuk, n. sp.* ***A****, paratype GSC 103210, GSC loc. C-80116, diameter 15 mm.* ***B****, holotype GSC 103209, GSC loc. C-80116, diameter 20 mm.*

The external suture (Fig. 21) includes a narrow ventral lobe (*wl/hl*, 0.4) with flanks diverging rather abruptly orad into a broad, asymmetrically rounded first lateral saddle; a deep, asymmetrical, medially constricted first lateral lobe with constricted tip; and a narrow, basally constricted umbilical lobe situated on the umbilical wall.

Dimensions (mm).

Specimen	D	U/D	H/D	W/D	H/W
Holotype GSC 103209	*26	0.26	0.46	0.92	0.46
Paratype GSC 103211	13.0	0.17	0.46	1.00	0.46
Paratype GSC 103212	9.4	0.15	0.48	0.99	0.48
Paratype GSC 103213	5.5	0.09	0.49	1.02	0.49

*Estimate

Comparisons. Eurites kusinae is closest to equivalent growth stages of *E. corpulentissimum* (Schindewolf, 1951) from the Erdbach Limestone of Germany. Both species display low, depressed, narrowly umbilicate juvenile conch form with a broadly rounded whorl profile during intermediate growth stages, and both lack growth constrictions. *Eurites kusinae* may be distinguished from *E. corpulentissimum* by the conspicuously attenuate umbilical lobe and wider, more symmetrically rounded first lateral saddle in the Canadian species. All other species of *Eurites*, including the Alaskan *E. saginatum* (Gordon, 1957), possess whorls with slightly flattened dorsolateral flanks and ornament that includes growth constrictions.

Occurrence. Lower member of the Mount Head Formation, east-central British Columbia at GSC localities C-80116 (type locality: holotype GSC 103209; paratypes GSC 103210, 103212, 103213), C-178983 (paratype GSC 103211), and C-11489.

Types. Holotype GSC 103209; paratypes GSC 103210–103213.

Genus *Dzhaprakoceras* Popov, 1965

Type species. Muensteroceras tianshanicum Librovitch, 1927.

Diagnosis. Highly variable muensteroceratids with thickly discoidal to subglobose, narrowly umbilicate conchs (W/D, 0.3–0.75; U/D, 0.05–0.25) and moderately depressed to strongly compressed whorls (H/W, 0.6–1.5). Juvenile whorls lack a serpenticonic stage. Transverse striae and constrictions form shallow ventral and lateral sinuses. Muensteroceratid suture with a narrow lyrate to adorally constricted ventral lobe, widely rounded lateral saddles, and acute lateral lobes.

Discussion. The concept of *Dzhaprakoceras* and related muensteroceratids has been discussed in considerable detail by Kusina (1980) and Riley (1996) based primarily on large numbers of Chadian–Arundian forms from the Prepolar Urals and Craven Basin, respectively. Recent discussions by Riley (1996) emphasize the absence of a serpenticonic juvenarium in *Dzhaprakoceras* as basis for distinction from the closely related genus *Bollandoceras* Bisat, 1952 (type species, *Beyrichoceras submicronotum* Bisat, 1934). In addition, the suture of *Bollandoceras*, including that of the type species, *B. hodderense* (Bisat, 1924) and *B. minusculum* (Kusina, 1980), has a relatively deep ventral lobe with flexed, slightly divergent flanks, in contrast to the essentially parallel lobe flanks of *Dzhaprakoceras*.

Popov (1965) established *Muensteroceratoides* (type species, *M. aksuensis*) for *Dzhaprakoceras*-like forms with a ventral lobe "with almost straight sides converging conspicuously toward the aperture." He suggested that *Muensteroceratoides* was closely comparable with *Muensteroceras* (type species, *Goniatites oweni* var. *parallela* Hall, 1860) except for the convergent flanks of the ventral lobe and more strongly accentuated growth lines, but failed to state limits that distinguish the new genus from *Dzhaprakoceras*. The type species of *Muensteroceratoides, M. aksuensis* Popov 1965 (Popov, 1968, pl. 2, fig. 1-4) differs from *Dzhaprakoceras tianshanicum* in its slightly larger umbilicus (U/D, 0.18 *vs.* 0.08 at 55 mm diameter); however, as we indicate below, the sutural distinction of *Muensteroceratoides* is not substantiated. Although Popov's (1965, fig. 2; 1968, fig. 16) figured suture of the holotype seemingly conforms (at a whorl height of 14 mm) to the stated generic characters of *Muensteroceratoides*, carefully prepared homeotypes of *M. aksuensis* (SUI 62475) and *D. tianshanicum* (SUI 62476) from the Dzhaprak Suite show identical lyrate ventral lobe configurations at a comparable diameter (whorl height 14 mm) as does Popov's own figured suture of a larger type of *M. aksuensis* (Popov, 1968, fig. 16) at a diameter of 50 mm (whorl height 26 mm). It is clear from this latter illustration that the flanks of the ventral lobe of *Muensteroceratoides aksuensis* are virtually identical to those of type *Dzhaprakoceras, D. tianshanicum*, at a comparable size (Popov, 1965, fig. 1; 1968, fig. 16). In the absence of clear morphological criteria for discriminating these two contemporary genera we follow Kusina (1980) and Korn (1988) in treating *Muensteroceratoides* as a synonym of *Dzhaprakoceras*. This is contrary to the view of Riley (1991, p. 139) who placed in *Muensteroceratoides* stratigraphically older (Ivorian) taxa such as the Australian *Muensteroceras jenkinsi* Campbell, Brown and Coleman, 1983, which in our opinion are more appropriately retained in *Muensteroceras.*

Species composition and distribution

Dzhaprakoceras aksuense (Popov, 1965); from the Akchetash and Dzhaprak suites (F2 and A1–A3 assemblages of Popov, 1968), Tien-Shan, Kyrgyzstan.

D. belcourtense n. sp.; from upper middle Osagean (lower Viséan) strata in the lower member of the Mount Head Formation, east-central British Columbia.

D. bellmanense Riley, 1996; from the lower Viséan (upper Chadian; upper FA) Leagram Mudstone Member, Hodder Mudstone Formation, Lancashire, northwest England.

D. catena Riley, 1996; from the lower Viséan (upper Chadian; upper FA) Leagram Mudstone Member, Hodder Mudstone Formation, Lancashire, northwest England.

D. chermnykhi Kusina, 1980; from lower Viséan (upper Chadian; upper FA) [*fide* Riley, 1991] strata in the Kosvinsky Horizon (level 2 of Kusina, 1980), Kozhim River, Prepolar Urals, Russia.

D. crassum n. sp.; from upper middle Osagean (lower Viséan) strata in the lower member of the Mount Head Formation, east-central British Columbia.

D. deflexum Kusina, 1980; from lower Viséan (?Arundian; lower BB) [*fide* Riley, 1991] strata in the ?Nortnichsky Horizon, Chernaya River, Prepolar Urals, Russia; and the lower Viséan (upper Chadian; upper FA) Leagram Mudstone Member, Hodder Mudstone Formation, Lancashire, northwest England (Riley, 1996).

D. djaprakense (Librovitch, 1927); from the Dzhaprak and Akchetash suites (F2 and A1–A4 assemblages of Popov, 1968), Tien-Shan, Kyrgyzstan; and the Kosvinsky Horizon (level 3 of Kusina, 1980), Kozhim River, Prepolar Urals, Russia. *Dzhaprakoceras djaprakense* has been reported from the upper Tournaisian (Chadian; middle FA) Coplow Limestone Member, Clitheroe Limestone Formation, Lancashire, northwest England (Riley, 1996); the lower part of the Genicera Formation ("Marbre Griotte"), Cantabrian Mountains, León, northern Spain (Kullmann, 1961); and the lower Viséan El Hariga Formation (S^{2b}), Saoura Valley, Béchar Basin, Algeria [described as *Muensteroceras subglobosum* Librovitch, 1927 by Pareyn, 1961].

D. duponti (Delépine, 1940a); from upper Tournaisian (lower Moliniacian) Waulsortian limestones at Dréhance and Pauquys, Belgium; and equivalent (upper Courceyan or lower Chadian) Waulsortian strata in Ireland (Delépine, 1940a; Riley, 1991).

D. flexum Riley, 1996; from the lower Viséan (upper Chadian; upper FA) Leagram Mudstone Member, Hodder Mudstone Formation, Lancashire, northwest England.

D. gracile Kusina *in* Shimansky and Kusina, 1977; from lower Viséan (upper Chadian; upper FA) [*fide* Riley, 1991] strata in the Kosvinsky Horizon (level 3 of Kusina, 1980), Kozhim River, Prepolar Urals, Russia.

D. grande Kusina, 1980; from lower Viséan (upper Chadian; upper FA) strata [*fide* Riley, 1991] in the Kosvinsky Horizon (level 3 of Kusina, 1980), Kozhim River, Prepolar Urals, Russia.

D. hibernicum (Delépine, 1940b); from upper Tournaisian (Courceyan or lower Chadian) Waulsortian strata in Ireland; and the Bordj d'Erfoud (level a), Morocco (Delépine, 1941).

D. hispanicum (Foord and Crick, 1897); from the Genicera Formation ("Marbre Griotte"), Cantabrian Mountains, León, northern Spain (Delépine, 1943; Wagner-Gentis, 1960; Kullmann, 1961); and the lower Viséan El Hariga Formation (S^{2b}), Saoura Valley, Béchar Basin, Algeria [described as *Nautellipsites pseudoparallelus* Delépine, 1941 by Pareyn, 1961]. *Dzhaprakoceras hispanicum* has also been reported from lower Viséan (upper Chadian; upper FA) strata [*fide* Riley, 1996] in the Tober Colleen Formation (= Rush Slates of Smyth, 1951), Co. Dublin, Ireland [described as *Nautellipsites difficilis* Foord by Smyth, 1951; see Riley, 1991]; as well as the upper Tournaisian (lower Chadian; middle FA) Bellman Limestone Member, Clitheroe Limestone Formation, and the lower Viséan (Arundian; lower BB) Chaigley Limestone Member, Hodder Mudstone Formation, both Lancashire, northwest England (Riley, 1996).

D. humile (Schindewolf, 1951); from the mid-Dinantian Erdbach Limestone, Winterberg, Germany.

D. improcerum Kusina, 1980; from the Kosvinsky Horizon (level 1 of Kusina, 1980), Kozhim River, Prepolar Urals, Russia.

D. kokdzharense (Popov, 1965); from the Dzhaprak and Akchetash suites (F2 assemblage of Popov, 1968), Tien-Shan, Kyrgyzstan.

D. koninckianum (Schindewolf, 1951); from upper Tournaisian (lower Moliniacian) Waulsortian limestones at Dréhance and Pauquys, Belgium (Delépine, 1940a); and equivalent Courceyan or lower Chadian strata in Ireland (Riley, 1991); from the Erdbach Limestone (Erdbach II horizon of Krebs, 1968), Germany.

D. latilobatum Kusina, 1983; from lower Viséan (Arundian; BB) [*fide* Riley, 1991] strata in the Kosvinsky Horizon (level 5 of Kusina, 1980), Kozhim River, Prepolar Urals, Russia.

D. latumbilicatum (Kullmann, 1961); from the Genicera Formation ("Marbre Griotte"), Cantabrian Mountains, León, northern Spain.

D.? *levis* Riley, 1996; from the lower Viséan (upper Chadian; upper FA) Leagram Mudstone Member, Hodder Mudstone Formation, Lancashire, northwest England.

D. longilobatum Liang and Wang, 1991; from South Tianshan, Xinjiang, northwest China.

D. narynense (Popov, 1965); from the Dzhaprak Suite, Tien-Shan, Kyrgyzstan.

D. paracatena Riley, 1996; from the lower Viséan (upper Chadian; upper FA) Leagram Mudstone Member, Hodder Mudstone Formation, Lancashire, northwest England.

D. planum Kusina and Yatskov, 1987; from middle Viséan strata in the Milin Suite, Novaya Zemlya.

D. procerum (Schindewolf, 1951); from the mid-Dinantian Erdbach Limestone, Winterberg, Germany.

D. pseudoparallelum (Delépine, 1941); from the Bordj d'Erfoud (level b), Erfoud, Morrocco.

D. quantulum Kusina and Yatskov, 1987; from middle Viséan strata in the Milin Suite, Novaya Zemlya.

D. shabyrense (Popov, 1968); from the Dzhaprak Suite, Tien-Shan, Kyrgyzstan.

D. sinkiangense (Liang, 1963); from the Yeyungou Formation, South Tianshan, Xinjang, northwest China (Liang and Wang, 1991).

D. sonkulicum (Librovitch, 1940); from the Dzhaprak and Akchetash suites (F2 and A1–A2 assemblages of Popov, 1968), Tien-Shan, Kyrgyzstan; and the Kosvinsky Horizon (level 2 of Kusina, 1980), Kozhim River, Prepolar Urals, Russia (Kusina, 1980).

D. subglobosum (Librovitch, 1927); from the Dzhaprak and Akchetash suites (F2 and A1–A4 assemblages of Popov, 1968), Tien-Shan, Kyrgyzstan. *Dzhaprakoceras subglobosum* has been reported from the upper Tournaisian (Chadian; middle FA) Bellman Limestone Member, Clitheroe Limestone Formation, Lancashire, northwest England (Riley, 1996); and the ?Nortnichsky Horizon, Chernaya River, Prepolar Urals, Russia (Kusina, 1980).

D. subtile Kusina, 1980; from lower Viséan (Arundian; BB) [*fide* Riley, 1991] strata in the Kosvinsky Horizon (level 5 of Kusina, 1980), Kozhim River, Prepolar Urals, Russia.

D. tianshanicum (Librovitch, 1927); from the Dzhaprak and Akchetash suites (F2–A4 assemblages of Popov, 1968), Tien-Shan, Kyrgyzstan (Popov, 1974); and from strata of possible early Viséan age in the Shishtu Formation, eastern Iran (Walliser, 1966).

D. undulatum Riley, 1996; from the lower Viséan (upper Chadian; upper FA) Leagram Mudstone Member, Hodder Mudstone Formation, Lancashire, northwest England.

D. westheadi Riley, 1996; from the lower Viséan (upper Chadian; upper FA) Leagram Mudstone Member, Hodder Mudstone Formation, Lancashire, northwest England.

D. n. sp.; from upper Osagean strata in the Delle Phosphatic Member, Woodman Formation, Stansbury Mountains, Utah (Petersen, 1969; M.S. Petersen, pers. comm., 1995).

D. n. sp.; from middle Osagean strata in the Cowbell Member, Borden Formation, east-central Kentucky (Gordon and Mason, 1985; C.E. Mason, pers. comm., 1996).

D. n. sp.; from middle Osagean (upper Tournaisian) strata in the Clausen Formation, southwestern District of Mackenzie, Northwest Territories.

Dzhaprakoceras belcourtense Work and Nassichuk, n. sp.

Plate 3, figures 7–9; Figures 22, 23

Diagnosis. A thickly subdiscoidal, narrowly umbilicate (W/D, 0.55–0.65; U/D less than 0.1) species of *Dzhaprakoceras* with compressed whorls (H/W, 1.0 at 20–25 mm diameter) that lack constrictions. Suture characterized by a deep, narrowly acuminate first lateral lobe with straight flanks.

Description. Included in *Dzhaprakoceras belcourtense* are at least 50, mostly fragmentary, silicified phragmocones. Holotype GSC 103214 and paratypes GSC 103215–103220 are well preserved, essentially complete phragmocones ranging from 6 to 24 mm in diameter. The largest paratype, GSC 103221, represents about one-half whorl of a phragmocone of 35 mm reconstructed diameter. Conchs are thickly subdiscoidal (W/D, 0.55–0.65) and highly involute (U/D, 0.05–0.1) with compressed to depressed whorls (H/W, 0.75–1.05). Conchs larger than 18 mm diameter are characterized by flattened flanks that converge slightly to a broadly rounded venter (Fig. 22). Shell ornament is not preserved. Constrictions are absent.

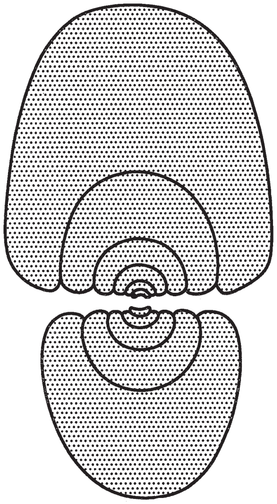


Figure 22. Cross-section of ***Dzhaprakoceras belcourtense*** *Work and Nassichuk, n. sp., paratype GSC 103217, GSC loc. C-7400, diameter 18 mm.*

External suture (Fig. 23) characterized by a narrow, adorally constricted ventral lobe with slightly recurved ventral prongs (in mechanical response to coalescence of adjacent septa) and a deep, narrowly acuminate lateral lobe with straight flanks.

Dimensions (mm).

Specimen	D	U/D	H/D	W/D	H/W
Paratype GSC 103215	24.0	0.06	0.56	0.53	1.06
Paratype GSC 103216	22.2	0.07	0.58	0.55	1.05
	14.9	0.07	0.55	0.64	0.86
	10.0	0.08	0.55	0.71	0.77
Holotype GSC 103214	20.2	0.06	0.60	0.57	1.05
Paratype GSC 103217	18.0	0.05	0.58	0.56	1.04
	12.0	0.07	0.58	0.65	0.89
	8.2	0.09	0.55	0.73	0.75
Paratype GSC 103218	14.9	0.05	0.56	0.63	0.89
Paratype GSC 103219	11.9	0.06	0.59	0.67	0.88
Paratype GSC 103220	6.3	0.11	0.51	0.83	0.62

Comparisons. *Dzhaprakoceras belcourtense* is distinguished from most species assigned to the genus by its deep, narrowly acuminate lateral lobe and constant umbilical diameter. Closest similarities are with *D. hispanicum* (Foord and Crick, 1897) which possesses a similar narrowly umbilicate, subdiscoidal conch form lacking constrictions, and a narrow angular lateral lobe. However, *D. belcourtense*

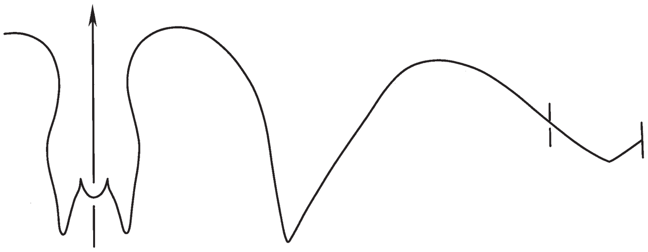


Figure 23. External suture of ***Dzhaprakoceras belcourtense*** *Work and Nassichuk, n. sp., holotype GSC 103214, GSC loc. C-178983, diameter 19 mm.*

is more narrowly umbilicate than *D. hispanicum* (U/D, 0.09 *vs.* 0.25 at 8 mm diameter; 0.07 *vs.* 0.16 at 17–18 mm diameter; 0.06 *vs.* 0.13 at 24–25 mm diameter) at equivalent ontogenetic stages. Also, the lateral lobe in *D. hispanicum*, though narrowly attenuate, has slightly flexed ventral and dorsal flanks, whereas in *D. belcourtense* this element is acutely angular with straightened flanks.

Occurrence. Lower member of the Mount Head Formation, east-central British Columbia at GSC localities C-178983 (type locality: holotype GSC 103214; paratypes GSC 103218–103220, 103222), C-80116 (paratype GSC 103216), C-11489, and C-7400 (paratypes GSC 103215, 103217, 103221).

Types. Holotype GSC 103214; paratypes GSC 103215–103222.

Dzhaprakoceras crassum Work and Nassichuk, n. sp.

Plate 3, figures 10–12, 14; Figures 24, 25

Diagnosis. A subglobose, narrowly umbilicate species of *Dzhaprakoceras* (W/D, 0.6–0.7; U/D, 0.1–0.15 at 15–25 mm diameter) with moderately depressed to equidimensional whorls (H/W, 0.65–0.9) and constrictions that trace a broad, shallow, lateral and hyponomic sinus. Suture characterized by a narrow, angular, nearly symmetrical first lateral lobe.

Description. Dzhaprakoceras crassum is based on eight silicified phragmocones, ranging up to 25 mm in diameter, as well as a number of septate whorl fragments. The most nearly complete specimen, holotype GSC 103223 (Pl. 3, fig. 10, 14), illustrates diagnostic features of shell ornament as well as the suture outline. At diameters of less than 10 mm, conchs are globose (W/D, 0.9–1.0) with moderately umbilicate, strongly depressed whorls (U/D, 0.2–0.25; H/W, 0.5); beyond this stage the whorl section is progressively compressed (H/W, 0.55–0.9 at 12–25 mm diameter), yielding a thickly subglobose, narrowly umbilicate (W/D, 0.6–0.7; U/D, 0.1) conch form at 20–25 mm diameter (Fig. 24). Whorl sections at larger diameters are uniformly rounded across the flanks, converging slightly to a broadly rounded venter. The umbilical shoulder is narrowly rounded and umbilical walls are wide and slightly convex. Remnants of shell ornament are retained on holotype GSC 103223 (Pl. 3, fig. 10, 14). Faint growth striae (6 per 5 mm across the venter at 20 mm diameter) and constrictions (3–4 per volution) trace a broad, shallow, lateral and hyponomic sinus.

The external suture (Fig. 25) is characterized by a narrow, adorally constricted ventral lobe with acute, slightly recurved ventral prongs (in mechanical response to impingement of prongs on preceding lateral saddles) and a deep, acutely angular, nearly symmetrical lateral lobe. The lateral lobe is conspicuously narrow and angular in comparison to most other species of *Dzhaprakoceras.*

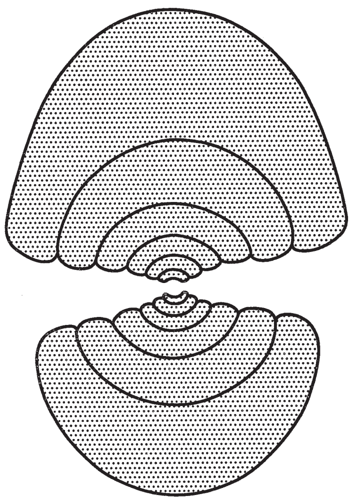


Figure 24. *Cross-section of* ***Dzhaprakoceras crassum*** *Work and Nassichuk, n. sp., paratype GSC 103224, GSC loc. C-178983, diameter 20.2 mm.*

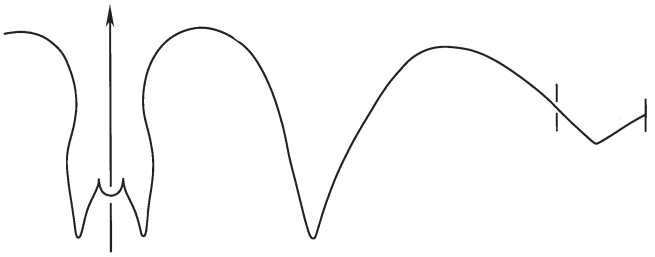


Figure 25. *External suture of* ***Dzhaprakoceras crassum*** *Work and Nassichuk, n. sp., paratype GSC 103225, GSC loc. C-80116, diameter 22 mm.*

Dimensions (mm).

Specimen	D	U/D	H/D	W/D	H/W
Holotype GSC 103223	21.6	0.14	0.53	0.67	0.80
Paratype GSC 103224	20.2	0.13	0.54	0.69	0.78
	15.0	0.15	0.52	0.80	0.65
	11.5	0.18	0.46	0.85	0.54
	8.7	0.22	0.47	0.97	0.49
Paratype GSC 103225	*24.5	0.10	0.54	0.62	0.88

*Estimate

Comparisons. Dzhaprakoceras crassum is distinguished from all other subglobose representatives of the genus (e.g., *D. subglobosum* (Librovitch, 1927)) by peculiarities of the suture line, particularly the lateral lobe. This is considerably more narrrow and angular on *D. crassum* than on most species of *Dzhaprakoceras*. The only exception is *D. belcourtense* n. sp., which at a diameter of 20 mm has a sutural configuration practically identical to *D. crassum*. However, these two species are quite different in conch form: *D. belcourtense* has narrower, more compressed whorls and a smaller umbilicus (H/W, 1.05; U/D, 0.06 at 20 mm diameter; Fig. 22), in contrast to *D. crassum* in which the whorls are wide and depressed with a larger umbilicus (H/W, 0.78; U/D, 0.13 at 20 mm diameter; Fig. 24). Such differences possibly reflect sexual dimorphism, particularly in light of their direct association.

Occurrence. Lower member of the Mount Head Formation, east-central British Columbia at GSC localities C-178983 (type locality: holotype GSC 103223; paratype GSC 103224) and C-80116 (paratypes GSC 103225, 103226).

Types. Holotype GSC 103223; paratypes GSC 103224–103226.

Family FURNISHOCERATIDAE
Work and Nassichuk, n. fam.

Diagnosis. Conch subdiscoidal (W/D, 0.5) with closed umbilicus. Narrow ventral lobe with high secondary saddle and simple, undivided prongs. Lateral lobe very deep, fang-like.

Discussion. The compressed lenticular conch form, closed umbilicus, and general sutural design suggest affinity with the Dimorphoceratidae (e.g., *Dimorphoceras* Hyatt, 1884 – type species, *Goniatites gilbertsoni* Phillips, 1836), but the Furnishoceratidae is distinguished from that family by a narrow ventral lobe with undivided ventral prongs. The elevated ventral lobe and extremely deep, fang-like lateral lobe are similarly reminiscent of *Kazakhoceras* Ruzhencev, 1947a (type species, *Neodimorphoceras hawkinsi* Moore, 1930) and the Berkhoceratidae, but members of that family also have wide ventral lobes, with well defined adventitious elements, absent in the Furnishoceratidae. Other features of *Furnishoceras*, particularly the narrow ventral lobe and simple wedge-shaped ventral prongs, are more nearly compatible with the Muensteroceratidae than with either Dimorphoceratidae or Berkhoceratidae, but the closed-umbilicate conch and overall sutural design clearly excludes it from that family.

Genus *Furnishoceras* Work and Nassichuk, n. gen.

Type species. Furnishoceras heterolobatum n. sp.

Etymology. For W.M. Furnish in honour of a lifetime of extraordinary accomplishment in Paleozoic ammonoid studies.

Diagnosis. Conch subdiscoidal (W/D, 0.5) with closed umbilicus, compressed whorls and narrowly rounded venter. Internal moulds smooth and lacking constrictions. Mature external suture comprises a narrow, elevated ventral lobe with parallel flanks, high median saddle (*hs/hl*, 0.4), and narrow, bluntly pointed ventral prongs; a subquadrate, asymmetrically rounded lateral saddle; an exceptionally deep, narrowly acuminate lateral lobe and a shallow, broadly rounded umbilical lobe.

Discussion. No other Lower Carboniferous ammonoid is closely comparable. The compressed, closed-umbilicate conch form and overall sutural design of *Furnishoceras* anticipates that of the Dimorphoceratidae but differences in the mature ventral lobe are too profound to consider a direct relationship established. Nevertheless, no other known Lower Carboniferous ammonoid shows so close a sutural resemblance to the early dimorphoceratids. The juvenile suture of *Furnishoceras heterolobatum* at a diameter of 3 mm (Fig. 26A) closely resembles that of similar-sized juvenile *Dimorphoceras*, except that the ventral prongs of these latter forms are already incipiently bidentate.

Species composition and distribution

Furnishoceras heterolobatum n. sp.; from upper middle Osagean (lower Viséan) strata in the lower member of the Mount Head Formation, east-central British Columbia.

Furnishoceras heterolobatum Work and Nassichuk, n. sp.

Plate 3, figures 1–4; Figures 26, 27

Description. Furnishoceras heterolobatum is based on 18 largely fragmentary, though otherwise well preserved, silicified phragmocones. The holotype GSC 103227 (Pl. 3, fig. 1–4) is an essentially complete phragmocone 18 mm in diameter that preserves characteristic features of conch form and suture. A larger septate whorl fragment, paratype GSC 103233, comprises parts of five camerae, which at an estimated whorl height of 20 mm, correspond to a reconstructed phragmocone diameter slightly in excess of 35 mm. At 18 mm diameter the conch is subdiscoidal (W/D, 0.47) with a closed umbilicus. Whorl sections are compressed with gently convex flanks converging toward a narrowly rounded venter (Fig. 27). Shell ornament is not preserved, the internal mould is smooth, and constrictions are absent.

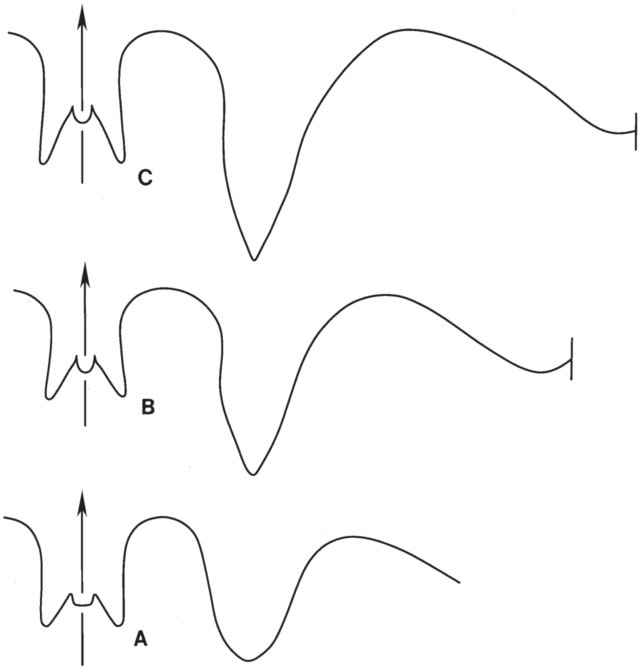


Figure 26. *External sutures of* ***Furnishoceras heterolobatum*** *Work and Nassichuk, n. sp.* ***A****, paratype GSC 103230, GSC loc. C-80116, diameter 3 mm.* ***B****, paratype GSC 103231, GSC loc. C-80116, diameter 12 mm.* ***C****, paratype GSC 103232, GSC loc. C-80116, diameter 17 mm.*

The mature external suture (Fig. 26B,C) is characterized by a short, elevated ventral lobe with parallel flanks, high median saddle (*hs/hl*, 0.4), and slightly divergent, bluntly pointed ventral prongs. A subquadrate, asymmetrically rounded lateral saddle is followed by an exceptionally deep, narrowly acuminate lateral lobe and a shallow, broadly rounded umbilical lobe. Little ontogenetic modification is apparent beyond 15 mm diameter.

Dimensions (mm).

Specimen	D	H/D	W/D	H/W
Holotype GSC 103227	18.0	0.60	0.47	1.29
Paratype GSC 103228	15.0	0.59	0.47	1.28
Paratype GSC 103229	10.4	0.57	0.50	1.18
	6.9	0.59	0.54	1.17
Paratype GSC 103230	4.0	0.60	0.65	0.92

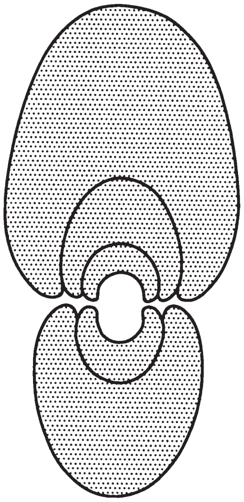


Figure 27. *Cross-section of* ***Furnishoceras heterolobatum*** *Work and Nassichuk, n. sp., paratype GSC 103229, GSC loc. C-80116, diameter 10.5 mm.*

Occurrence. Lower member of the Mount Head Formation, east-central British Columbia at GSC localities C-80116 (type locality: holotype GSC 103227; paratypes GSC 103228–103234) and C-11489 (paratype GSC 103235).

Types. Holotype GSC 103227; paratypes GSC 103228–103235.

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APPENDIX 1
Foraminifers and calcareous algae (B.L. Mamet)

Data in this appendix are paraphrased from reports prepared in 1991 and 1992 by B.L. Mamet (University of Montreal). The samples were collected by B.C. Richards. In this appendix, the locality coordinates given are for the bases of the relevent sections.

Locality 19, Fig. 1. Wapiti Pass; latitude 54^{o}28'52"N, longitude 120^{o}43'20"W; UTM zone 10u, 6039250N, 647600E; NTS 93-I/7, Wapiti Pass map area; east-central British Columbia; section 85RAH11 (GSC localities in metres above base of section).

(GSC loc. C-155440, 237.0 m above base of section) Turner Valley Formation, 58.5 m below top, 48 m above base.
Calcisphaera sp.
Earlandia sp.
Eoendothyranopsis spiroides (Zeller)
Globoendothyra sp.
Spinoendothyra sp.
Age: early Viséan, Zone 11

(GSC loc. C-155442, 245.2 m above base of section) Turner Valley Formation, 50.3 m below top, 56.2 m above base.
Calcisphaera sp.
Dainella sp.
Endothyra sp.
Eoendothyranopsis of the group *E. spiroides* (Zeller)
Eoforschia sp.
Globoendothyra of the group *G. baileyi* (Hall)
Parathurammina sp.
Spinoendothyra sp.
Age: early Viséan, Zone 11

(GSC loc. C-155443, 248.4 m above base of section) Turner Valley Formation, 47.1 m below top, 59.4 m above base.
Calcisphaera sp.
Dainella sp.
Endothyra sp.
Eoendothyranopsis sp.
Eoforschia sp.
Eoparastaffella sp.
Age: early Viséan, Zone 11

(GSC loc. C-155444, 250.2 m above base of section) Turner Valley Formation, 45.3 m below top, 61.2 m above base.
Calcisphaera sp.
Dainella sp.
Earlandia sp.
Endothyra sp.
Eoendothyranopsis hinduensis (Skipp)
Eoendothyranopsis spiroides (Zeller)
Eoforschia sp.
Eoparastaffella ovalis Vdovenko
Paradainella sp.
Plectogyranopsis sp.
Age: early Viséan, Zone 11.

(GSC loc. C-155449, 269.4 m above base of section) Turner Valley Formation, 26.1 m below top, 80.4 m above base.
Calcisphaera sp.
Earlandia sp.
Endothyra sp.
Eoendothyranopsis spiroides spiroides (Zeller)
Eoforschia sp.
Eoparastaffella sp.
Globoendothyra sp.
Latiendothyra sp.
Orthriosiphonoides sp.
Palaeoberesella sp.
Paradainella sp.
Parakamaena sp.
Parathurammina sp.
Plectogyranopsis sp.
Priscella sp.
Pseudochaetetes sp.
Pseudotaxis sp.
Spinoendothyra sp.
Age: early Viséan, Zone 11.

(GSC loc. C-155455, 286.6 m above base of section) Turner Valley Formation, 8.9 m below top.
Eoendothyranopsis hinduensis (Skipp)
Eoendothyranopsis spiroides (Zeller)
Eoforschia sp.
Globoendothyra bridgensis (Skipp)
Age: inadequate assemblage, probably early Viséan.

(GSC loc. C-155456, 288.3 m above base of section) Turner Valley Formation, 7.2 m below top, 99.3 m above base.
Calcisphaera sp.
Dainella sp.
Earlandia sp.
Endothyra sp.
Eoendothyranopsis spiroides (Zeller)
Eoforschia moelleri (Malakhova *in* Dain)
Eoparastaffella sp.
Issinella sp.
Kamaena sp.
Ortonella sp.
Palaeoberesella sp.
Priscella sp.
"*Septatournayella*" sp.
Age: early Viséan, Zone 11.

(GSC loc. C-155460, 292.6 m above base of section) Turner Valley Formation, 2.9 m below top, 103.6 m above base.
Dainella sp.
Eoendothyranopsis spiroides (Zeller)
Eoparastaffella sp.
Ortonella tyrrellensis Mamet and Rudloff
Age: inadequate assemblage; probably early Viséan.

(GSC loc. C-155467, 298.5 m above base of section) Mount Head Formation, lower member, 3.0 m above base.
Calcisphaera sp.
Eoendothyranopsis hinduensis (Skipp)
Eoendothyranopsis spiroides (Zeller)
Eoforschia sp.
Eoparastaffella ovalis Vdovenko
Globoendothyra sp.
Age: inadequate assemblage, probably early Viséan.

(GSC loc. C-155469, 302.0 m above base of section) Mount Head Formation, lower member, 6.5 m above base.
Calcisphaera sp.
Dainella sp.
Endothyra sp.
Eoendothyranopsis hinduensis (Skipp)
Eoendothyranopsis spiroides (Zeller)
Eoparastaffella sp.

Globoendothyra sp.
Issinella sp.
Kamaena sp.
Latiendothyra sp.
Proninella sp.
Spinoendothyra sp.
Age: early Viséan, Zone 11.

(GSC loc. C-155475, 310.0 m above base of section) Mount Head Formation, lower member, 14.5 m above base.
Calcisphaera sp.
Dainella sp.
Earlandia sp.
Endothyra sp.
Eoendothyranopsis hinduensis (Skipp)
Eoforschia sp.
Eoparastaffella sp.
Globoendothyra bridgensis (Skipp)
Parathurammina sp.
Skippella? sp.
Age: early Viséan, Zone 11.

(GSC loc. C-155478, 318.1 m above base of section) Mount Head Formation, lower member, 22.6 m above base.
Dainella sp.
Calcisphaera pachysphaerica (Pronina)
Earlandia sp.
Endothyra sp.
Eoendothyranopsis hinduensis (Skipp)
Eoendothyranopsis spiroides (Zeller)
Eoparastaffella sp.
Globoendothyra sp.
Latiendothyra sp.
Parathurammina sp.
Spinoendothyra sp.
Age: early Viséan, Zone 11.

(GSC loc. C-155480, 321.0 m above base of section) Mount Head Formation, lower member, 25.5 m above base.
Calcisphaera sp.
Earlandia sp.
Endothyra sp.
Eoendothyranopsis hinduensis (Skipp)
Eoendothyranopsis spiroides (Zeller)
Eoforschia moelleri (Malakhova *in* Dain)
Eoparastaffella sp.
Issinella sp.
Latiendothyra sp.
Parathurammina sp.
Skippella? sp.
Spinoendothyra sp.
Age: early Viséan, Zone 11.

(GSC loc. C-155482, 324.0 m above base of section) Mount Head Formation, lower member, 28.5 m above base.
Calcisphaera sp.
Dainella sp.
Earlandia sp.
Eoendothyranopsis spiroides (Zeller)
Eoforschia sp.
Eoparastaffella sp.
Globoendothyra of the group *G. baileyi* (Hall)
Latiendothyra sp.
Parathurammina sp.
Age: early Viséan, Zone 11.

(GSC loc. C-155485, 330.5 m above base of section) Mount Head Formation, lower member, 35.0 m above base, 1.4 m below top.
Calcisphaera sp.
Dainella sp.
Earlandia sp.
Eoendothyranopsis hinduensis (Skipp)
Eoendothyranopsis spiroides (Zeller)
Eoendothyranopsis n. sp.
Eoforschia moelleri (Malakhova *in* Dain)
Eoparastaffella ovalis Vdovenko
Globoendothyra of the group *G. baileyi* (Hall)
Issinella sp.
Latiendothyra sp.
Parathurammina sp.
Proninella sp.
Pseudoammodiscus sp.
Spinoendothyra sp.
Age: early Viséan, Zone 11.

(GSC loc. C-155491, 338.6 m above base of section) Mount Head Formation, Baril Member, 6.7 m above base.
Calcisphaera sp.
Dainella sp.
Eoendothyranopsis n. sp.
Eoendothyranopsis spiroides (Zeller)
Eoparastaffella sp.
Globoendothyra sp.
Latiendothyra sp.
Age: inadequate assemblage; early to middle Viséan.

(GSC loc. C-155495, 346.0 m above base of section) Mount Head Formation, Baril Member, 14.1 m above base.
Dainella sp.
Earlandia sp.
Eoendothyranopsis spiroides (Zeller)
Eoforschia sp.
Eoparastaffella sp.
Globoendothyra of the group *G. baileyi* (Hall)
Latiendothyra sp.
Priscella sp.
Age: inadequate assemblage; probably early Viséan.

(GSC loc. C-155512, 368.5 m above base of section) Mount Head Formation, Salter Member, 21.3 m above base, 36.6 m above top lower member.
Endothyra sp.
Eoendothyranopsis n. sp.
Eoforschia sp.
Globoendothyra cf. *G. paula* (Vissarionova)
Skippella sp.
Stacheoides sp.
Age: middle? Viséan, probably Zone 12.

(GSC loc. C-155516, 374.0 m above base of section) Mount Head Formation, Salter Member, 26.8 m above base, 42.1 m above top lower member.
Calcisphaera sp.
Earlandia sp.
Endothyra sp.
Eoendothyranopsis n. sp.
Eoendothyranopsis hinduensis (Skipp)
Eoendothyranopsis spiroides (Zeller)
Eoforschia moelleri (Malakhova *in* Dain)
Globoendothyra of the group *G. baileyi* (Hall)
Globoendothyra paula (Vissarionova)
Parathurammina sp.
Plectogyranopsis? sp.
Priscella sp.
Skippella sp.
Age: early middle Viséan, Zone 12

Locality 21, Fig. 1. Becker Creek; latitude 54°32'23"N, longitude 120°40'00"W; UTM zone 10u, 6045920N, 650950E; NTS 93 I/10, Monkman Pass map area; east-central British Columbia; section 87RAH5 (GSC localities in metres above base of section).

(GSC loc. C-164012, 199.8 m above base of section) Turner Valley Formation, 55.0 m below top, 22.4 m above base.
Calcisphaera sp.
Endothyra sp.
Eoendothyranopsis of the group *E. spiroides* Zeller
Eoforschia moelleri (Malakhova *in* Dain)
Globoendothyra sp.
Age: early Viséan, Zone 11

(GSC loc. C-164022, 223.3 m above base of section) Turner Valley Formation, 31.5 m below top, 45.9 m above base
Eoendothyranopsis spiroides (Zeller)
Eoparastaffella ovalis Vdovenko
Globoendothyra of the group *G. baileyi* (Hall)
Issinella sp.
Age: early Viséan, Zone 11

(GSC loc. C-164023, 224.8 m above base of section) Turner Valley Formation, 30.0 m below top, 67.4 m above base.
Eoendothyranopsis of the group *E. spiroides* (Zeller)
Eoforschia moelleri (Malakhova *in* Dain)
Eoparastaffella ovalis Vdovenko
Globoendothyra of the group *G. baileyi* (Hall)
Issinella sp.
Kamaena sp.
Age: early Viséan, Zone 11

(GSC loc. C-164026, 233.4 m above base of section) Turner Valley Formation, 21.4 m below top, 56.0 m above base.
Dainella sp.
Eoendothyranopsis spiroides spiroides (Zeller)
Eoendothyranopsis of the group *E. spiroides* (Zeller)
Eoforschia sp.
Eoparastaffella sp.
Globoendothyra of the group *G. baileyi* (Hall)
Issinella sp.
Age: early Viséan, Zone 11

(GSC loc. C-164027, 234.4 m above base of section) Turner Valley Formation, 20.4 m below top, 57.0 m above base.
Calcisphaera sp.
Dainella sp.
Eoendothyranopsis spiroides spiroides (Zeller)
Eoendothyranopsis of the group *E. spiroides* (Zeller)
Eoforschia sp.
Issinella sp.
Latiendothyra sp. (*Laxoendothyra* sp.)
Paracalligelloides sp.
Parathurammina sp.
Priscella sp. (abundant)
Septabrunsiina? sp.
Skippella sp.
Sphaerinvia sp.
Age: early Viséan, Zone 11.

(GSC loc. C-164030, 241.8 m above base of section) Turner Valley Formation, 13.0 m below top, 64.4 m above base.
Dainella? sp.
Eoendothyranopsis spiroides spiroides (Zeller)
Eoforschia moelleri (Malakhova *in* Dain)
Eoparastaffella sp.
Eoparastaffella ovalis Vdovenko
Latiendothyra sp.
Priscella prisca (Rauzer-Chernoussova and Reitlinger)
Priscella sp.
Age: early Viséan, Zone 11.

(GSC loc. C-164045, 266.2 m above base of section) Mount Head Formation, lower member, 11.4 m above base.
Calcisphaera sp.
Earlandia sp.
Eoendothyranopsis cf. *E. hinduensis* (Skipp)
Eoendothyranopsis spiroides (Zeller)
Latiendothyra sp.
Paracalligelloides sp.
Parathurammina sp.
Skippella sp.
Spinobrunsiina sp.
Age: early Viséan, Zone 11.

(GSC loc. C-164048, 268.6 m above base of section) Mount Head Formation, lower member, 13.8 m above base.
Calcisphaera sp.
Dainella sp.
Eblanaia? or *Globendothyra*? sp.
Eoendothyranopsis spiroides (Zeller)
Eoforschia sp.
Eoparastaffella sp.
Globoendothyra cf. *G. bridgensis* (Skipp)
Paracalligelloides sp.
Parathurammina sp.
Skippella sp.
Age: early Viséan, Zone 11.

(GSC loc. C-164051, 270.9 m above base of section) Mount Head Formation, lower member, 16.1 m above base, 10.7 m below top.
Aphralysia sp.
Calcisphaera sp.
Earlandia sp.
Endothyra sp.
Eoendothyranopsis cf. *E. hinduensis* (Skipp)
Eoendothyranopsis spiroides (Zeller)
Eoendothyranopsis of the group *E. spiroides* (Zeller)
Eoforschia moelleri (Malakhova *in* Dain)
Globoendothyra bridgensis (Skipp)
Latiendothyra sp. (*Laxoendothyra* sp.)
Ortriosiphonoides sp.
Parathurammina sp.
Spinoendothyra sp.
Age: early Viséan, Zone 11.

(GSC loc. C-164061, 282.8 m above base of section) Mount Head Formation, Baril Member, 1.2 m above base.
Calcisphaera sp.
Dainella sp.
Earlandia sp.
Endothyra sp.
Eoendothyranopsis cf. *E. hinduensis* (Skipp)
Eoendothyranopsis spiroides (Zeller)
Eoforschia sp.
Eoparastaffella ovalis Vdovenko
Globoendothyra bridgensis (Skipp)
Issinella sp.
Palaeoberesella sp.
Parathurammina sp.
Priscella sp.
Skippella sp.
Age: early Viséan, Zone 11.

(GSC loc. C-164064, 285.5 m above base of section) Mount Head Formation, Baril Member, 3.9 m above base, 8.4 m below top.

- *Calcisphaera* sp.
- *Dainella* sp.
- *Eoendothyranopsis spiroides* (Zeller)
- *Eoforschia* sp.
- *Globoendothyra* of the group *G. baileyi* (Hall)
- *Latiendothyra* sp. (*Laxoendothyra* sp.)
- *Parathurammina* sp.
- *Spinoendothyra* sp.

Age: early Viséan, Zone 11.

(GSC loc. C-164074, 299.7 m above base of section) Mount Head Formation, Salter Member, 5.8 m above base, 57.9 m below top.

- *Earlandia vulgaris* (Rauzer-Chernoussova and Reitlinger)
- *Endothyra* sp.
- *Eoendothyranopsis hinduensis* (Skipp)
- *Eoendothyranopsis* of the group *E. spiroides* (Zeller)
- *Eoforschia* sp.
- *Globoendothyra paula* (Vissarionova)
- *Koninckopora* sp.
- *Priscella* sp.

Age: middle Viséan, Zone 12.

(GSC loc. C-164075, 300.9 m above base of section) Mount Head Formation, Salter Member, 7.0 m above base, 56.7 m below top.

- *Calcisphaera pachysphaerica* (Pronina)
- *Dainella* sp.
- *Earlandia vulgaris* (Rauzer-Chernoussova and Reitlinger)
- *Endothyra* sp.
- *Eoendothyranopsis hinduensis* (Skipp)
- *Eoforschia moelleri* (Malakhova *in* Dain)
- *Globoendothyra paula* (Vissarionova)
- *Kamaena* sp.
- *Kamaenella*? sp.
- *Mametella skimoensis* (Mamet and Rudloff)
- *Priscella* sp.

Age: middle Viséan, Zone 12.

APPENDIX 2
Foraminifers, calcareous algae and *incertae sedis* (P.L. Brenckle)

Data in this report are paraphrased from a report prepared in 1992 by P.L. Brenckle (formerly Amoco Production Co., Houston, Texas).

Locality 1A, Fig. 1. East side Ochak Mountain; latitude 54°20'19"N, longitude 120°30'01"W; UTM zone 10u, 6023900N, 662550E; NTS 93-I/7, Wapiti Pass map area; east-central British Columbia; section 92RAH3 of B.C. Richards (GSC localities in metres above base of section). This locality lies 1.9 km east of the summit of Ochak Mountain at an elevation of about 6,600' (2,012 m). The site, on the western headwall of a cirque that opens eastward, is above a tarn lying at the foot of the headwall. The locality is equivalent to the upper part of E.W. Bamber's section 5BR78.

(GSC loc. C-225674, 32.1 m) Mount Head Formation, lower member, 9.6 m above base of Mount Head in mound facies (lithofacies 6) shown on Figure 3.

Brazhnikovia sp.?
Calcisphaera laevis Williamson
Diplosphaerina inaequalis (Derville)
Earlandia of the group *E. clavatula* (Howchin)
Eblania sp.?
Parathurammina cushmani
Parathurammina sp.
Proninella sp.
radiosphaerid calcisphere
indet. dasyclad
kamaenids

Age: early Viséan.

Locality 1C, Fig. 1. East side Ochak Mountain; latitude 54°20'12"N, longitude 120°30'05"W; UTM zone 10u, 6023650N, 662450E; NTS 93-I/7, Wapiti Pass map area; east-central British Columbia. This locality, station 91NF of W.W. Nassichuk, lies slightly west of the rim of an eastward-facing cirque headwall, where localities 1A and 1B are situated. The site is 1.9 km east of the summit of Ochak Mountain and about 250 to 300 m southwest of locality 1A.

(GSC loc. C-178983) Mount Head Formation, lower member, about 7 m above base of Mount Head.

Brazhnikovia sp.
Calcisphaera laevis Williamson
?*Cribrokamaena* sp.
Diplosphaerina inaequalis (Derville)
Elbania sp.
Issinella sp.
Parathurammina cushmani
Parathurammina sp.
Proninella sp.
Caligellidae
radiosphaerid calcisphere

Age: early Viséan.

(GSC loc. C-178985) Mount Head Formation, lower member, about 8 m above base of Mount Head.

Calsphaera sp. A
Dainella sp.
Earlandia of the group *E. clavatula* (Howchin)
Eblania michoti (Conil and Lys)
Eoendothyranopsis hinduensis (Skipp *in* McKee and Gutschick)
Eoendothyranopsis spiroides (Zeller)
Eoparastaffella? sp.
Girvanella sp. A
Globoendothyra piasae?
Globoendothyra aff. *G. baileyi* (Hall)
Pohlia henbesti (Skipp, Holcomb and Gutschick)
Septabrunsiina sp.
indet. dasyclad A
Solenoporid A

Age: early Viséan.

Locality 20, Fig. 1. Southwest of Muinok Mountain; latitude 54°18'38"N, longitude 120°26'43"W; UTM zone 10u, 6020800N, 666200E; NTS 93-I/7, Wapiti Pass map area; east-central British Columbia. This locality is E.W. Bamber's station 1BR-71 on the north face of a northeasterly trending ridge north of upper Belcourt Creek. The site is 4.35 km southwest of summit of Muinok Mountain.

(GSC loc. C-206253) upper Turner Valley Formation, about 15 m below ammonoid-bearing unit in lower member of Mount Head Formation (GSC locality C-11489) at locality 20.

Eblania sp.
?*Eoparastaffella* sp.
Globoendothyra sp.
Septatournayella sp.

Age: early Viséan.

Appendix 3
Conodonts (H.R. Lane)

Data in this appendix are paraphrased from a report prepared by H.R. Lane (formerly Amoco Production Co., Houston, Texas) during 1979.

Locality 1B, Fig. 1. Ochak Mountain; latitude 54°20'16"N, longitude 120°30'00"W; NTS 93 I/7, Monkman Pass map area, east-central British Columbia. This locality, which is situated above tree line and above a small tarn, is on the west side of a broad cirque that opens eastward. The conodonts were extracted from a large ammonoid-bearing limestone block collected from the lower member of the Mount Head Formation.

(GSC Loc. C-80116) lower member, 7 to 12 m above base.

- *Anchignathodus* cf. *A. penescitulus* (Rexroad and Collinson)
- *Apatognathus* spp.
- *Eotaphrus burlingtonensis* Pierce and Langenheim
- *Hibbardella* sp.
- *Ligonodina* sp.
- *Neoprioniodus* sp.
- *Ozarkodina* cf. *O. laeviposticus* Rexroad and Collinson
- *Polygnathus mehli* Thompson
- *Spathognathus* cf. *S. macer* (Branson and Mehl)

The occurrence of *Polygnathus mehli* and *Eotaphrus burlingtonensis* clearly dates the assemblage as middle Osagean. In terms of the standard Mississippian section in the United States, the fauna occurs in the upper part of the Burlington Limestone in southeastern Iowa and also at other localities in the Mississippi Valley. The fauna is assignable to faunal unit 5B of Lane (1978, p. 169), which I now regard as early Viséan rather than late Tournaisian as stated in that publication.

Appendix 4
Conodonts (A.C. Higgins)

Data in this appendix are paraphrased from internal reports prepared by A.C. Higgins (StrataData Ltd., U.K.) at the Institute of Sedimentary and Petroleum Geology during 1985 and 1986. Only key taxa (mainly platform elements) are listed in Higgins' reports. Most of the samples were collected by B.C. Richards. In this appendix, the locality coordinates given are for the bases of the relevant sections.

Locality 4, Fig. 1. South of Kvass Creek; latitude 53°37'18"N, longitude 119°07'43"W; UTM zone 10, 5943350N, 359150E; NTS 83 E/11, Mount Robson map area; Willmore Wilderness Park, west-central Alberta; section 82RAH3 (GSC localities in metres above base of section). Conodont data are from GSC internal report 13-ACH-85.

(GSC loc. C-110182, 417.9 m) uppermost Livingstone Formation, 6.4 m below top, 49.8 m below lower member of Mount Head Formation.

Eotaphrus burlingtonensis Pierce and Langenheim

(GSC loc. C-110183, 425.8 m) middle Turner Valley Formation, 1.5 m above top Livingstone Formation, 41.9 m below Mount Head Formation.

Anchignathodus penescitulus (Rexroad and Collinson)
Polygnathus sp.

(GSC loc. C-110186, 465.2 m) upper Turner Valley Formation, 40.9 m above top Livingstone Formation, 2.5 m below base, Mount Head Formation.

Polygnathus mehli Thompson
Age: inadequate assemblage; early Viséan, upper *anchoralis-latus* to lowermost *texanus* zones. The presence of *Polygnathus mehli* suggests the upper *anchoralis-latus* Zone is most probable.

Locality 3, Fig. 1. Monoghan Creek; latitude 53°23'37"N, longitude 118°59'38"W; UTM zone 10u, 5934250N, 367850E; NTS 83 E/10 and 11, Mount Robson map area; Willmore Wilderness Park, west-central Alberta; section 82RAH4 (GSC localities in metres above base of section). Conodont data are from GSC internal report 17-ACH-85.

(GSC loc. C-110201, 415 m) top of lower Turner Valley Formation, 49.2 m above base, 45.8 m below base, Mount Head Formation.

Anchignathodus penescitulus (Rexroad and Collinson)
Polygnathus mehli mehli Thompson
Eotaphrus burlingtonensis Pierce and Langenheim
Age: inadequate assemblage; early Viséan, upper *anchoralis-latus* to lowermost *texanus* zones. The presence of *Polygnathus mehli mehli* and *Eotaphrus burlingtonensis* suggests the upper *anchoralis-latus* Zone is most probable [see Higgins et al., 1991, fig. 10].

Locality 10, Fig. 1. Headwaters of Belcourt Creek; latitude 54°21'54"N, longitude 120°29'58"W; UTM zone 10u, 6126840N, 663500E; NTS 93-I/8, Monkman Pass map area; east-central British Columbia; section 81RAH7 (GSC localities in metres above base of section). Conodont data are from GSC internal report 19-ACH-85.

(GSC loc. C-93785, 299.0 m) upper Turner Valley Formation, 61.7 m above base of formation, 11.0 m below base, Mount Head Formation.

Anchignathodus penescitulus (Rexroad and Collinson)
Polygnathus communis communis Branson and Mehl
Age: inadequate assemblage.

Locality 12, Fig. 1. Mount Becker; latitude 54°31'02"N, longitude 120°38'46:W; UTM zone 10u, 6043440N, 652360E; NTS 93-I/10, Monkman Pass map area; east-central British Columbia; section 81RAH4 (GSC localities in metres above base of section). Conodont data are from GSC internal report 5-ACH-86.

(GSC loc. C-93637, 213 m) Turner Valley Formation, 19.7 m above base, 46.2 m below top.

Polygnathus communis communis Branson and Mehl
Polygnathus communis carina Hass
Neoprioniodus tulensis (Pander)
Anchignathodus penescitulus (Rexroad and Collinson)
Synprioniodina sp.
Age: inadequate assemblage, early Viséan, upper *anchoralis-latus* to lowermost *texanus* zones. The presence of *Polygnathus communis carina* suggests the upper *anchoralis-latus* Zone is most probable.

(GSC loc. C-93641, 276.9 m) Mount Head Formation, lower member, 2.5 m above base.

Anchignathodus penescitulus (Rexroad and Collinson)
Age: inadequate assemblage.

(GSC loc. C-93648, 303.8 m) Mount Head Formation, Salter Member, 7.4 m above base

Anchignathodus scitulus (Hinde)
Neoprioniodus tulensis (Pander)
Age: inadequate assemblage, probably middle Viséan. The presence of *Anchignathodus scitulus* suggests the *Cavusgnathus* zone [see Higgins et al., 1991, fig. 10].

(GSC loc. C-93651, 348.8 m) Mount Head Formation, Salter Member, 52.4 m above base.

Cavusgnathus sp.
Age: middle to late Viséan, *Cavusgnathus* Zone.

Locality 14, Fig. 1. Fellers Creek; latitude 54°42'19"N, longitude 120°53'06"W; UTM zone 10u, 6063800N, 636400E; NTS 93-I/10, Monkman Pass map area; east-central British Columbia; section 81RAH5. Conodont data are from GSC internal report 6-ACH-86.

(GSC loc. C-93753, 478.8 m) Turner Valley Formation, upper bed.

Vogelgnathus campbelli (Rexroad)
Age: inadequate assemblage.

(GSC loc. C-93755, 498.2 m) Mount Head Formation, Baril Member, 1.8 m above base, 8.7 m below top.

Polygnathus mehli Thompson
Age: inadequate assemblage, early Viséan, upper *anchoralis-latus* to lowermost *texanus* zones.

(GSC loc. C-93756, 512.0 m) Mount Head Formation, Salter Member, 5.1 m above base.

Anchignathodus scitulus (Hinde)
Apatognathus sp.
Age: inadequate assemblage, probably middle Viséan, *Cavusgnathus* Zone.

Locality 17, Fig. 1. Watson Peak; latitude 55°13'58"N, longitude 122°05'07"W; UTM zone 10u, 6120850N, 558250E; NTS 93-O/1, Pine Pass map area; east-central British Columbia; section 81RAH9. Conodont data are from GSC internal report 12-ACH-85.

(GSC loc. C-91026, 263.0 m) Turner Valley Formation, 18 m below top.

Anchignathodus penescitulus (Rexroad and Collinson)
Apatognathus sp.
Ozarkodina laeviposticus Rexroad and Collinson
Polygnathus mehli Thompson

Age: early Viséan, upper *anchoralis-latus* to lowermost *texanus* zones. The presence of *Polygnathus mehli* suggests the upper *anchoralis-latus* Zone is most probable.

(GSC loc. C-91029, 318.0 m) Mount Head? Formation, lower member, 37 m above base.

Anchignathodus penescitulus (Rexroad and Collinson)

Age: inadequate assemblage.

(GSC loc. C-91031, 326.7 m) Mount Head Formation?, Baril? Member, 0.1 m below top and sub-Permian unconformity.

Anchignathodus penescitulus (Rexroad and Collinson)
Polygnathus communis communis Branson and Mehl
Vogelgnathus campbelli (Rexroad)

Age: inadequate assemblage.

PLATES 1-3

PLATE 1

Figures 1, 2, 5–7, 13. *Imitoceras tardum* Work and Nassichuk, n. sp.

1, 2. Apertural and lateral views of holotype GSC 103183, GSC loc. C-80116, x2.5.

5–7, 13. Lateral, apertural, ventral, and lateral views of paratype GSC 103184, GSC loc. C-80116, x3.5.

Figures 3, 4, 8–12. *Irinoceras bamberi* Work and Nassichuk, n. sp.

3, 4, 12. Lateral, ventral, and apertural views of paratype GSC 103175, GSC loc. C-11489, x2.5.

8, 9. Apertural and lateral views of paratype GSC 103177, GSC loc. C-80116, x2.5.

10, 11. Apertural and lateral views of holotype GSC 103174, GSC loc C-80116, x1.5.

Figures 14–16. *Merocanites rileyi* Work and Nassichuk, n. sp.

14, 15. Lateral and apertural views of holotype GSC 103171, GSC loc. C-80116, x1.5.

16. Lateral view of paratype GSC 103168, GSC loc. C-178983, x2.5.

Plate 1


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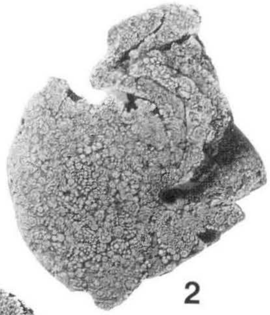
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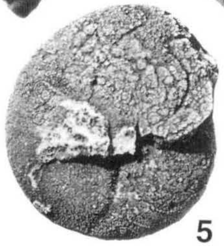
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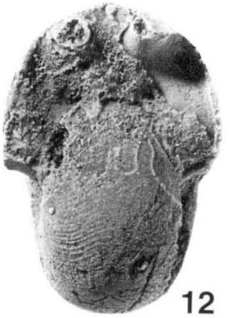
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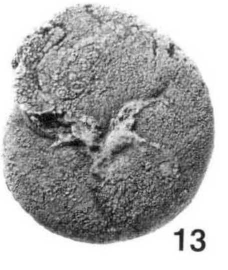
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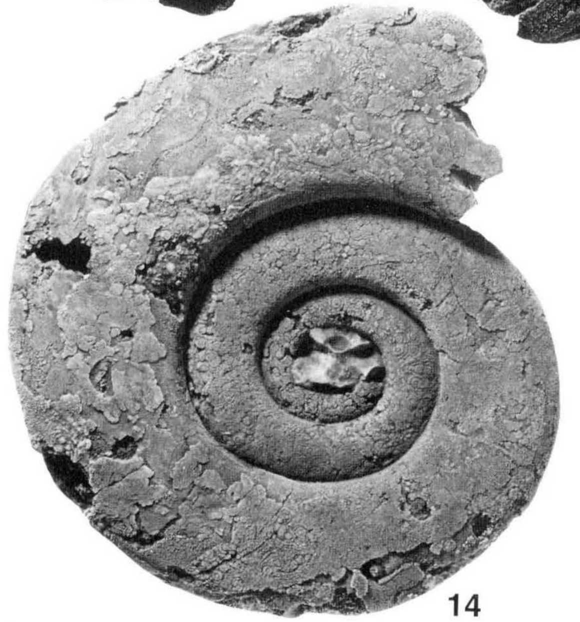
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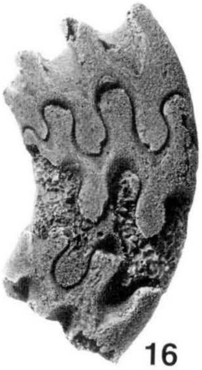
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PLATE 2

Figures 1, 2, 6–8, 17, 18. *Polaricyclus canadensis* Work and Nassichuk, n. sp.

1, 2. Ventral and lateral views of paratype GSC 103207, GSC loc. C-80116, x2.5.

6–8. Ventral, lateral, and apertural views of holotype GSC 103199, GSC loc. C-80116, x2.5.

17, 18. Apertural and lateral views of paratype GSC 103204, GSC loc. C-80116, x5.0.

Figures 3–5, 9–16. *Goniocycloides ochakensis* Work and Nassichuk, n. sp.

3–5. Apertural, lateral, and ventral views of paratype GSC 103189, GSC loc. C-80116, x2.5.

9. Lateral view of paratype GSC 103192, GSC loc. C-80116, x2.5.

10, 13. Lateral and ventral views of paratype GSC 103188, GSC loc. C-80116, x2.5.

11, 12. Apertural and lateral views of holotype GSC 103185, GSC loc. C-80116, x2.5.

14–16. Ventral, lateral, and apertural views of paratype GSC 103186, GSC loc. C-80116, x2.5.

Plate 2


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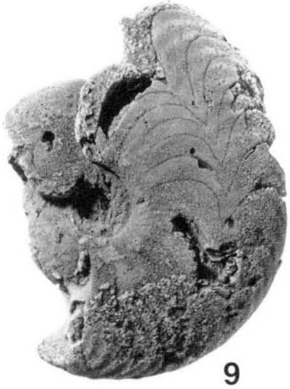
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PLATE 3

Figures 1–4. *Furnishoceras heterolobatum* Work and Nassichuk, n. sp.

Lateral, apertural, lateral, and ventral views of holotype GSC 103227, GSC loc. C-80116, x3.0.

Figures 5, 6, 13, 15. *Eurites kusinae* Work and Nassichuk, n. sp.

5, 6.	Lateral and apertural views of paratype GSC 103211, GSC loc. C-178983, x2.5.
13, 15.	Ventral and lateral views of holotype GSC 103209, GSC loc. C-80116, x2.5.

Figures 7–9. *Dzhaprakoceras belcourtense* Work and Nassichuk, n. sp.

Lateral, lateral, and apertural views of paratype GSC 103218, GSC loc. C-178983, x2.5.

Figures 10–12, 14. *Dzhaprakoceras crassum* Work and Nassichuk, n. sp.

10, 14.	Lateral and apertural views of holotype GSC 103223, GSC loc. C-178983, x2.5.
11, 12.	Apertural and lateral views of paratype GSC 103225, GSC loc. C-80116, x2.5.

Plate 3


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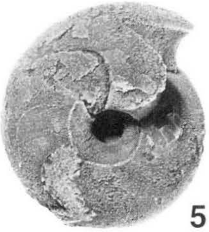
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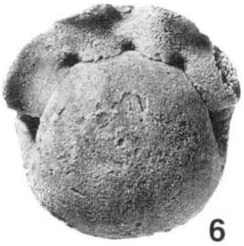
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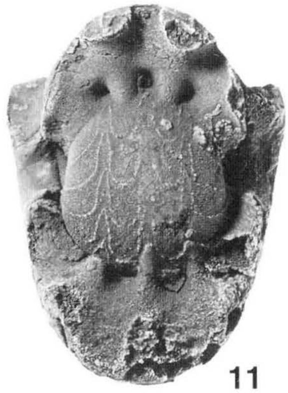
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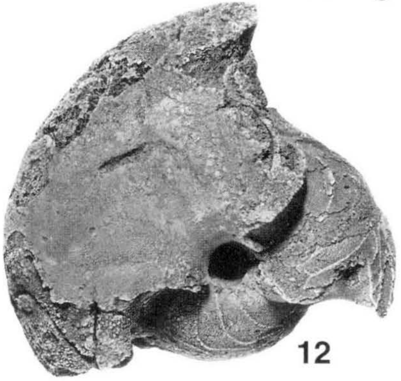
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